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Cover Photo

Women and children learn about the nutrition benefits of fish in the Stung Treng province of Cambodia, where fish are a key food system component and where AquaFish Innovation Lab has conducted research on how nutrient-dense fish can contribute to household nutrition. Photo courtesy of AquaFish Innovation Lab.

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TABLE OF CONTENTS: VOLUME 2

HUMAN NUTRITION AND HUMAN HEALTH IMPACTS OF AQUACULTURE 1

Integrated Mola Fish and Gher/Freshwater Prawn Farming with Dyke Cropping to Increase Household Nutrition and Earnings for Rural Farmers in Southwest Bangladesh 1

Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fisheries and Aquaculture in Cambodia, Part I 22

Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fisheries and Aquaculture in Cambodia, Part II 45

Assessing the Nutritional Impact of Aquaculture Policy in Fish Farming Districts in Tanzania and Ghana..........51

Establishing School Ponds for Fish Farming and Education to Improve Health and Nutrition of Women and Children in Rural Nepal 63

POLICY DEVELOPMENT 73

Policy Recommendations to Improve Food Security and Household Nutrition Through Sustainable Aquaculture and Aquatic Resource Management in Cambodia and Vietnam..73

MARKETING, ECONOMIC RISK ASSESSMENT, AND TRADE 80

Improving Nutritional Status and Livelihood for Marginalized Women Households in Southwest Bangladesh through Aquaculture..........80

Improving Nutritional Status and Livelihood for Marginalized Women Households in Southwest Bangladesh through Aquaculture, Part II..........102

Development of a Cell-Phone Based Seafood Market Information System (SMIS) in Ghana: Application to Tilapia..........132

Impacts of Climate Change on Snakehead Fish Value Chains in the Lower Mekong Basin of Cambodia and Vietnam..........136

Value Chain Analysis of Farmed Nile Tilapia (*Oreochromis niloticus*) and African Catfish (*Clarias gariepinus*) in Tanzania 156

Household Fish Ponds in Nepal: Their Impact on Fish Consumption and Health of Women and Children..........170

Household Fish Ponds in Nepal: Their Constraints Determined by Value Chain Analysis 180

Assessment of Market Opportunities for Small-Scale Fishers and Farmers in Central Uganda 186

WATERSHED AND INTEGRATED COASTAL ZONE MANAGEMENT..........198

Estimating Carrying Capacity for Aquaculture in Cambodia..........198

MITIGATING NEGATIVE ENVIRONMENTAL IMPACTS 203

Novel Approach for the Semi-Intensive Polyculture of Indigenous Air-Breathing Fish With Carps for Increasing Income and Dietary Nutrition While Reducing Negative Environmental Impacts. 203

TOPIC AREA:
HUMAN NUTRITION AND HUMAN HEALTH IMPACTS OF AQUACULTURE

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Integrated Mola Fish and Gher/Freshwater Prawn Farming with Dyke Cropping to Increase Household Nutrition and Earnings for Rural Farmers in Southwest Bangladesh

Human Nutrition and Human Health Impacts of Aquaculture/Experiment/13HHI03NC

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ABSTRACT

Although integration of freshwater prawn (*Macrobrachium rosenbergii*) farming in seasonal rice paddy fields (ghers) has been successfully implemented and serves as a significant source of income to Southwest Bangladesh coastal families, farmers typically sell the prawns for the export market to fetch higher price. Meanwhile family members (particularly women and children) remain malnourished from lack of complete protein, vitamins, and other minerals in their diet. The present investigation proposes to address this problem by incorporating Mola, a small indigenous fish species with high nutrient value, into current prawn-gher farming practices. The experiment was conducted in two studies. In the first study (July 2014 to January 2015) the stocking density of prawn, mola, and rohu were 2.0, 1.0, and 0.1/m^2, respectively. In Treatment 1 (T1), prawn were stocked with rohu only. In Treatment 2 (T2), prawn were stocked with mola only. In Treatment 3 (T3), prawn were stocked with both rohu and Mola. Individual fish growth and water quality were monitored throughout the study and found to be suitable. Production of prawn was 417.4±12.70, 446.8±11.03, and 462.6±12.74 kg/ha in T1, T2, and T3, respectively, rohu production was 569.5±25.5 and 573.5±28.12 kg/ha in T1 and T3, respectively, and mola production was 308±20.33 and 255.5±23.08 kg/ha in T2 and T3, respectively. In the second study, mola was stocked at a rate of 1.0, 2.0 and 4.0/m^2 with prawn and rohu in T1, T2, and T3, respectively. Furthermore, Treatment 4 (T4) was used as a control with no mola grown. No additional fertilizer was applied in T4. Production of prawn was 455.58±14.69, 462.77±15.60, and 456.28±13.94 kg/ha in T1, T2, and T3, respectively. Rohu production in T1, T2, and T3 was 588.11±16.47, 572.19±17.28, and 586.75±15.39 kg/ha, respectively. T4 had significantly lower prawn and rohu production when compared to the other treatments. Further, Mola production was significantly higher in T2 and T3. Based on these results it is also suggested that Mola brood be stocked 2.0/m^2 or 4.0/m^2. The experimental results clearly indicate that the addition of Mola does not adversely impact, but in fact enhances the production of prawn. Furthermore, the farmers and their families consumed additional nutrients from domestic consumption of Mola.

Pond muds excavated from Study 1 were used to determine if they could be used as natural fertilizers of pond dyke vegetables to further increase crop production, income, and nutrition of prawn farmers. The vegetables vine spinach (*Basella alba*) and snake gourd (*Trichosanthes anguina*) were grown in one of three soil types: 100% pond dyke soil (T1), 50% pond dyke soil/50% pond mud (T2), or 100% pond mud (T3). Growth and nutritional quality of vine spinach and snake gourd were recorded. Pond mud nutrient status was higher compared to the dyke soil and plant height, leaf number, number of leaves, and yields of vine spinach were found higher in T3. The concentrations of the minerals Ca, S, P, and Fe in vine spinach were higher in T3. On the other hand, vitamin C was higher in T1 and vitamin A was higher in T2. Vine spinach was grown in the summer season and snake gourd was grown in the rainy season, leading to production of vegetables year-round. The yield of snake gourd was higher in 100% pond mud compared to other treatments. The mineral contents of Ca, S, P, protein, and vitamin C in snake gourd were higher in T1, which was similar to vine spinach. Vitamin A was higher in T2.

Through a household survey, it was found that nutrient consumption from fish and vegetable cultivation was higher for the family members of farmers selected for these prawn/fish/vegetable polyculture studies. Mola fish consumption was dramatically higher in the selected households due to increased availability mola in their ponds.

The integration of mola into the current rice/prawn/carp culture systems not only contributed to increasing prawn, fish, and vegetable (through use of pond muds) production and income generation but also helped to increase valuable nutrients such as protein, vitamins, and minerals available to the farmers and their families by incorporating Mola and vegetables into their diets.

INTRODUCTION

The widespread use of integrated farming practices, including but not restricted to the production of multiple finfish, holds significant promise for increasing dietary nutrition, productivity, and profitability of farming households in rural Bangladesh (Lightfoot et al. 1990). Currently, rice and fish comprise the main diet of low-income families, particularly during the production season for these crops (Roos et al. 2007). Although integration of freshwater prawn (*Macrobrachium rosenbergii*) farming in seasonal rice/paddy fields (ghers) has been successfully implemented and serves as a significant source of income to coastal families, farmers typically sell the prawns produced to fetch higher prices in overseas markets. Meanwhile, family members (particularly women and children) remain malnourished from lack of complete protein, vitamins, and other minerals in their diet. This investigation addressed this problem by incorporating additional crops [mola fish (*Amblypharyngodon mola*) and vegetables] into current gher-prawn farming practices. As mola fish and fresh vegetables are highly nutritional crops, but have little potential for sale in cities or overseas markets, the cultivation of these foods will directly benefit local dietary needs. These studies tested novel integrated designs targeted specifically for increasing nutrition in low-income farming households of rural Bangladesh.

Successful adoption of integrated farming practices requires the designs to be tailored around existing agricultural practices. Currently, much of the land available for agriculture is restricted to rice production (10.1 million hectares), but seasonal water bodies (2.83 million hectares, flooded for 4–6 months) remain underused and play an increasing role in the production of aquaculture crops (Kunda et al. 2008). Negative social and environmental issues associated with cultivation of marine shrimp has made farming of freshwater prawns (*M. rosenbergii*) more attractive to local farmers (Johnson and Bueno 2000, New 2000). Currently, freshwater prawns are cultured in more than 50,000 hectares in and around the southern coastal regions of Bangladesh (DOF 2012). As prawn culture is mostly produced in fallow rice fields flooded after harvest, there is great potential for expansion of this practice throughout the country, if appropriate strategies are developed (Wahab et al. 2012). While the widespread cultivation of freshwater prawns has opened new opportunities for higher income earnings for local farmers, these products are not consumed directly, but rather sold to overseas markets which fetch higher prices. The objectives of this project were targeted to increase the culture of prawns in underused gher/ponds throughout Southern Bangladesh but also to promote their integration with other crops (both fish and vegetables), which are consumed directly by local households, thereby increasing both earned income (from prawn sales) and dietary nutrition (side crops-fish and vegetables) available to rural families. The inclusion of other fish species [e.g., mola and rohu (*Labeo rohita*)] could also increase prawn production yields, as combining species of different trophic levels could maximize nutrient utilization and decrease the potential for harmful phytoplankton blooms, which cause mortality by decreasing dissolved oxygen (DO) levels (Halver 1984, Wahab et al. 2008). Therefore, efforts were made to identify a suitable stocking density for mola for maximum nutrient utilization and prawn production through harnessing synergistic effects.

Child malnutrition continues to be a major public health problem in rural Bangladesh. Up to 38% of all pre-school children have vitamin A deficiency, with up to 55 percent exhibiting signs of iron-deficient anemia (Micronutrient Initiative/UNICEF 2004, West 2002). These effects may be alleviated, in part, through consumption of small indigenous fishes, such as mola, which have significantly higher concentrations of vitamin A (~1900 IU, Thilsted et al. 1996) and micronutrient content than other commonly consumed fishes (e.g., carp). The mola, a fish from 12–15 cm in length with soft bones, is particularly favored in the diets of many people; however consumption is limited to those captured in local rice fields, rivers, and canals. Early experiments suggest that mola can be successfully cultivated in the presence of other finfish cultivars (e.g., carp; Alim et al. 2004; Wahab et al. 2003). These fish are self-recruiting species, existing naturally in perennial ponds and other freshwater sources. Once stocked, mola can reproduce within the ghers or in drainage ponds and can be continuously harvested over the production cycle of carp or prawn allowing for home consumption. Mola feed primarily on phytoplankton and detritus, therefore no feed input are necessary. Moreover, their bacteria-enriched waste can be used to enhance prawn production.

Along with prawn/mola polyculture strategies, pond muds can be used to produce high nutrient rich vegetables with minimal costs. Due to its high nutrient composition, the use of pond muds in vegetable production could alleviate the need for inorganic fertilizers and pesticides which are harmful to both the health of the public and the environment. Use of pond muds can improve the pond water quality by reducing the possibility of eutrophication. There is little known on the effects of pond mud on the production and nutritional quality of pond dyke vegetation but pond muds from carp and tilapia culture systems have been used as potent fertilizers in the cultivation of seasonal vegetables in Northern Bangladesh (Wahab et al. 2001), however this method has not been developed for prawn culture.

In the present investigation, we integrated mola cultivation with prawn farming, where prawns can continue to be sold as a cash crop to increase income earnings while mola could directly meet household nutritional needs. Additionally, we used nutrient-rich mud, a byproduct of gher-prawn farming, to fertilize the unflooded spaces (dykes) between rice ponds for better vegetable cultivation. We also examined the soil nutritive value of gher-prawn mud and its utility for the cultivation of fresh produce (e.g., spinach and gourds). The consumption of mola and fresh vegetables could significantly enhance the diet of farming households and help to alleviate common nutrient deficiencies observed in preschool children and women of rural communities.

OBJECTIVES

- Evaluate production potentials of mola fish (*Amblypharyngodon mola*) integrated with existing practices of gher-prawn and gher-prawn/carp farming systems;
- Better identify mola stocking densities for gher-prawn/carp polyculture to generate increased production yields;
- Evaluate the potential use of gher/pond mud as fertilizer for growing vegetables on gher/pond dykes; and

- Assess the nutritional benefits and economic returns of the households practicing integrated aquaculture versus those not practicing integrated culture.

MATERIALS AND METHODS

Location. This investigation consisted of a series of five studies, which were carried out on participating farms located in villages near Dumuria Upazila, Khulna District, Bangladesh. Water quality and soil nutrient analyses were performed at Khulna University and BAU, Mymensingh, Bangladesh. The nutritional benefits and economic returns were analyzed by Dr. Abu Torab MA Rahim (Institute of Nutrition and Food Science, University of Dhaka) and Ms. Sadika Haque, an agricultural economist from the BAU, Mymensingh.

The average size of all the ghers/ponds used for these experiments was around 50 decimal (2,000 m^2 with a depth of 1–1.5 m.

Study 1 — Evaluate production yields of mola (*Amblypharyngodon mola*) integrated with existing practices of gher-prawn and gher-prawn/carp production in Bangladesh

Pond drying and excavation. All farmers dried their nursery and grow-out ponds just after harvesting the rice paddy. As part of the pond preparation in April to May 2014, mud from the nursery ponds was excavated and the grow-out ponds were tilled and decomposed organic matter was removed. The mud from the ponds was used in Studies 3 and 4 as nutrient-rich fertilizers for dyke vegetables.

Liming and watering. Once the ponds were completely dry and excess clay was excavated, the ponds were limed at a rate of 1 kg/dec with limestone ($CaCO_3$) during April to May 2014 for the nursery ponds. The grow-out ponds were limed in June 2014. Five to seven days after liming the ponds were filled with underground and rain water to a depth of 1–1.5 m.

Fertilization. After watering, the nursery and grow-out ponds were fertilized with molasses at the rate of 30 kg molasses/ha/month and yeast powder at the rate of 400 g/ha/month in April to May 2014 for nursery ponds and June to December 2014 for grow-out ponds. The molasses and yeast powder was mixed in water and left to ferment for 24 hours prior to fertilization.

Experimental design. Prawn post-larvae were stocked at a rate of 50/m^2 in the nursery ponds at the beginning of June 2014. Coconut or palm leaves were used to provide shelter for the prawn post-larvae. After 30 to 45 days in nursery ponds, the juvenile prawn were stocked in grow-out ponds with rohu only (T1), mola only (T2), or both mola and rohu (T3) at the beginning of July 2014. The experimental design is presented in Table 1.

Feeding of nursery and grow-out ponds. During the nursery period prawn post-larvae were fed 3–4 times each day with a commercial nursery feed at a rate of 200 g/10,000 prawn post-larvae that was increased by 50 g/day until day 45. After the nursery period, juvenile prawns were fed twice daily in the early morning and evening with a commercial feed at 10% body weight for days 46-55, decreasing to 7% body weight for days 56–65, 5% body weight for days 66–75, and 4%–2% body weight for rest of the culture period. Feeding trays were used for proper use of feed by the prawn. No supplementary feed was used to raise mola which fed on natural foods resulting from pond fertilization.

Water-quality parameters. Temperature, water transparency, DO, pH, alkalinity, ammonia, nitrates, phosphorous, and chlorophyll *a* were measured monthly. A secchi-disk was used to measure transparency. Alkalinity, ammonia, nitrates, and phosphorous were measured using a HACH kit (HACH, USA; Model FF-2).

Growth sampling. Sampling was performed monthly to assess the health and determine the growth of prawn, mola and rohu in the study.

Study 2 — Improving mola stocking densities for gher-prawn/carp polyculture to generate higher production yields. This study was designed to determine the best mola stocking density to culture along with prawns and rohu that would generate the highest production yields. The study methodology was the same as in Study 1 and occurred in 2015. For the study design, four treatments were designed using increasing stocking densities of mola. Mola were stocked with prawns at 2.0 prawns/m^2 and rohu at 0.1 rohu/m^2 at a density of 1.0 mola/m^2 (T1), 2.0 mola/m^2 (T2), or 4.0 mola/m^2 (T3). No mola were stocked with prawns and rohu as a control (T4, Table 2).

Study 3 — Evaluate the potential use of gher/pond mud for growing the nutrient rich leafy vegetable (vine spinach, *Basella alba*) on gher/pond dykes

Experimental design. A 3x3 study was designed to assess the quality of pond mud from prawn/carp/mola polyculture on growth of vine spinach (*Basella alba*), a nutrient rich leafy vegetable that has been grown on rice pond dykes. Vine spinach were grown on pond dykes used in the fish trials from Study 1 in 100% pond dyke soil (T1), 50% pond dyke soil/50% pond mud (pond mud excavated from the bottom of the ponds in Study 1) (T2), or 100% pond mud (T3) (Table 3). Pond A represents a pond from Study 1, Treatment 1, Pond B represents a pond from Study 1, Treatment 2, and Pond C represents a pond from Study 1, Treatment 3. Pond mud used in each pond group was excavated from that pond. Each plot size was 1 m x 1.5 m.

Soil characteristics. Pond dyke soils and pond mud were analyzed for quality and available nutrients. Soil or mud pH, electrical conductivity (EC), organic matter (OM), total nitrogen (total N), phosphorous, potassium, and sulphur were measured prior to sowing seeds.

Seed sowing to intercultural operation. Seeds were sown (12 February 2014) in line and followed by weeding, mulching, irrigation, and gap filling for better growth and development of the plant.

Harvesting. The first harvesting was done from all plots at 45 days after sowing. The plants were cut at a length of 10 cm from the ground level and data were recorded. The crop was allowed to grow and final harvesting was done after 15 days of the first harvest. The crop under investigation was first harvested on 27 April 2015 and last harvested on 12 May 2015 at the conclusion of the experiment.

Collection of plant growth data. Five plants were randomly selected and tagged as samples for collection of data and finally yield was converted as plot wise. The following parameters were considered for data collection:

- **Vine length (cm)**
- **Number of leaves per plant —** Leaves from 5 randomly chosen plants were counted. All leaves of each plant were counted separately. Only the smallest of young leaves at each sampling point were excluded from the counts.
- **Number of shoots per plant** — Branches from 5 randomly chosen plants were counted. Only the smallest of young branches at each sampling point were excluded from the counts. The mean number of branches from 5 plants is given in the results.
- **Length of largest leaf (cm) —** The distance from the base of petiole to the tip of leaf was considered as the length of leaf.
- **Breadth of largest leaf (cm) —** The breadth of the largest leaf of 5 plants was recorded.
- **Fresh weight of shoot/plant (g) —** Leaves from selected plants were separated and weighed.

- **Percent dry weight of shoot** ––– A 100 g sample of leaves cut into small pieces and air-dried for 7 days and then oven-dried at 70^0C for 72 hours before taking the dry weight. Weights were measured until a constant weight was reached.
- **Dry matter (%)** - $\frac{\text{Dry weight}}{\text{Fresh weight}}$ x 100
- **Yield per plot –** The yield of vine spinach per plot was calculated at following the harvest of leaves and twigs per plot at 45 and 60 days after sowing (DAS). The yield per plot was calculated.

Nutritional analysis of plant

Preparation of plant samples. Plant samples were cut into pieces and air-dried for 7 days followed by oven-drying at 70^0C for 72 hours**.** Dried sample were ground using a grinding machine. The prepared samples were kept in sealed plastic bags.

Sample digestion. One gram of each sample was weighted into a digestion tube. Ten mL of nitric acid (HNO_3) was added to the tube. The tubes were placed in a digestion chamber set at 120^0C and digested for 2 hours. When no solid material remained and the sample solution appeared light brown in color, 2 mL hydrogen peroxide (H_2O_2) was added and remained in the digestion chamber until samples appeared colorless. The extract was cooled and filtered through Whatman No. 42 filter paper. Distilled water was added to the extracted sample up to 100 mL. The extract was used for further analysis for Vitamins A and C, phosphorous, calcium, sulphur, and iron.

Vitamin C. Vitamin C was determined using the indophenols dye extraction method. This procedure is based on the quantitative discoloration of 2,6-dichlorophenol indophenols by ascorbic acid. Vitamin C content was calculated using the formula:

$$\text{Vitamin C (mg 100 g-1)} = \frac{T \times D \times V1}{V2 \times W} \text{ x } 100$$

where,
T = Titre value (mL)
D = Dye factor
V_1= Volume to be made (mL)
V_2 = Volume of extract taken for titration (mL)
W = Weight of sample

Vitamin A. Three g of the extract was taken and mixed with 80% acetone with a mortar and pestle, filtered, and the volume was brought up to 50 mL. The prepared sample was transferred to a separator funnel. The sample was collected in a 50 mL conical flask and a spectrophotometer (PG UV-VIS spectrophotometer T-60) reading was recorded at 451 nm and β carotene was calculated as follows:

$$\beta \text{ carotene} = \frac{3.984 \times OD \times \text{Volume}}{100 \times W \text{ sample volume}}$$

Phosphorus. Phosphorus content of the extract was determined by colorimetric method. Stannous chloride ($SnC1_2.2H_2O$) was used as a reducing agent to form molybdophosphoric blue complexed with sulphomolybdic acid. The intensity of the blue color was measured with a spectrophotometer (PG UV-VIS spectrophotometer T-60) at 660 nm within 15 minutes after the addition of stannous chloride reagent.

Calcium. Calcium concentration in the plant extract was determined by EDTA titrimetric method using Na_2EDTA as a complexing agent at pH 12 in the presence of calcon indicator.

Sulphur. The concentration of sulphur in the extract was determined turbidimetrically with a spectrophotometer (PG UV-VIS spectrophotometer Model: T-60). Turbidity was developed by using barium chloride ($BaC1_2 \cdot H_2O$) and measured at wave length of 425 nm.

Iron. The content of iron was measured using an atomic absorption spectrophotometer (AAS).

Study 4 — Production performance of nutrient-rich snake gourd (*Trichosanthes anguina*) in fish pond muds with improved technology. Seed of snake gourd (*Trichosanthes anguina*) was planted using a planting dibbler in a pit on the pond dykes used in Study 1 using pond dyke soil or pond mud excavated from Study 1 using the same design from Study 3 (see Table 3 for the experimental design). Two to three seeds were planted in each pit, and only one healthy plant per pit was allowed to grow. In each treatment a total 12 plants were collected and data was collected from 10 of these plants (N = 90). A pheromone trap was used to control insects which reduced the amount of insecticide application used for safe and better production of snake gourd.

The following data were collected for this study:

- **Vine length (cm) —** Vine length was measured at 45 days after seed sowing (DAS). Length was measured from the growing point to the tip of the stem.
- **Internode length of main stem (cm) —** Internode length was measured from the 10^{th} node to the 15^{th} node.
- **Length of leaf (cm) —** The length of 3 mature leaves were measured from leaf base to the tip.
- **Breadth of leaf (cm) —** The breadth of 3 mature leaves were measured at the broadest part of leaves.
- **Length of petiole (cm) —** The length of petiole was measured from three mature leaves.
- **Cavity length of fruit —** The cavity length of three randomly selected fruits from sampled plants from each treatment was measured.
- **Cavity breadth of fruit —** The cavity breadth of three randomly selected fruits from sampled plants from each treatment was measured.
- **Number of stripes per fruit —** Three randomly selected fruits of each treatment were taken and the number of stripes per fruit was recorded.
- **Yield (kg) —** The weight of edible fruit of sampled plants from each plant was weighted and used to calculate yield.

Nutritional analysis of fruit. Nutritional parameters were analyzed similar to those in Study 3 using 3 randomly selected fruits from each treatment. Protein content was measured in addition to the parameters measured in Study 3.

Protein analysis. Protein was calculated using a modified Kjeldahl method. Nitrogen is determined by digesting organic nitrogen in the sample with concentrated sulphuric acid, the nitrogen is converted into ammonium sulphate. Ammonia is liberated by creating an alkaline solution and distilling it into a known volume of standard boric acid, which is then back titrated.

The protein content of the sample was calculated by the following formula:

$$\% \text{ Nitrogen} = \frac{(\text{Ts}-\text{Tb}) \times \text{normality of acid} \times 0.014}{\text{weight of the sample}} \times 100$$

where,
T_S = Titre value of the sample
T_b = Titre value of the blank

Then the percentage crude protein was calculated by multiplying the percent nitrogen of the sample by a factor of 6.25.

Study 5 — Assess the nutritional benefits and economic return for households practicing integrated aquaculture. In order to assess the nutritional and economic benefits of adding mola and vegetables to prawn culture practices, 15 farmers were assigned one of three fish production treatments (5 farmers per treatment):

- Treatment 1: prawn and carp production along with vegetables
- Treatment 2: prawn and mola production along with vegetables
- Treatment 3: prawn, carp, and mola production along with vegetables

This design will allow for the assessment of these techniques at the farm-level and will result in data on the possible impacts of practicing integrated aquaculture on economic returns and nutritional benefits to the fish farmers. Survey questionnaires were prepared and the questionnaires were filled out by the farmers at the beginning and at the completion of the experiment. The questionnaire detailed the socioeconomic conditions as well as the economic return achieved from the study.

Statistical analysis. All differences in the parameters of this study were statistically analyzed by ANOVA (p = 0.05) using Minitab Version 16 (Minitab Inc., State College, PA, USA).

RESULTS AND DISCUSSION

Study 1 — Evaluate production yields of mola (*Amblypharyngodon mola*) integrated with existing practices of gher-prawn and gher-prawn/carp production in Bangladesh. Prawn and fish growth rates (Figure 1) as well as water quality parameters (Table 4) were measured once a month following transfer to the prawn grow-out ponds. There were no significant differences in any of the water quality parameters between any of the treatments tested. For growth parameters, the mola in both Treatments 2 and 3 gained less weight at week 2 of the grow-out period than at any other time (Figure 1a). This could have been due to a mola spawning event that occurred around this time period. During the study period, the farmers observed that in most of the grow-out ponds mature mola had bred and produced a lot of larvae and that mola larvae were seen during fine mesh net sampling; large schools of mola also were seen at the water surface of the grow-out ponds. After that, the mola gained increasing weight every month in Treatment 2 but increases in weight gain remained stagnant in Treatment 3 between months 4 and 7. In the end, mola in treatment 2 grew better than mola in Treatment 3. There was no difference in weight gain for prawn in any of the treatments (Figure 1b). A steady increase in growth rate was observed at each monthly sampling. There was also no difference in monthly weight gain of rohu between treatments 1 and 3 and weight gain increased steadily until month 7 (Figure 1c).

There was no difference in production of prawns in Treatments 2 and 3 (both treatments included mola in the grow-out period) but both of these treatments had higher production values than Treatment 1 (grown with rohu but no mola) (Table 5). Mola production was higher in treatment 2 where it was grown with prawns alone than in Treatment 3 where it was grown with both prawns and rohu but there was no difference in overall production of rohu whether grown with with or without mola. Consumption of prawn was greater by household families that grew the prawn with mola whether the prawn/mola were grown with rohu or not (Table 6). Mola consumption was higher when they were grown without rohu but rohu consumption did not depend on mola production.

These results indicate that the inclusion of mola and/or rohu polyculture into prawn cultures does not affect the overall weight gain of prawn. Also, the inclusion of mola in the prawn ponds increases both the overall production and consumption of prawn by the farmer’s household members. The addition of mola to prawn culture not only has no deleterious effects on prawn growth but mola can help increase both income from prawn/mola polyculture and the health of the farmer's families by increasing the amount of protein, vitamins, and minerals in their diets.

Study 2 — Improving mola stocking densities for gher-prawn/carp polyculture to generate higher production yields. There was no difference in water-quality parameters measured between any of the treatments (Table 7). As in Study 1, the mola growth rate decreased around month 2 (Figure 2a). This could again have been due to fish spawning during this period. After that the rate of weight gain increased monthly for Treatments 1 and 2 but plateaued in Treatment 3. This could have been due to the large amount of mola biomass in Treatment 3 versus the other two treatments. Both prawn (Figure 2b) and rohu (Figure 2c) weight gain increased linearly throughout the study and did not vary between treatments.

There was no difference in final production of prawns or rohu in ponds that were grown with mola (Treatments 1, 2, and 3) regardless of the amount of mola stocked into the ponds. I n the absence of mola production of prawns was lower (Table 8), suggesting mola may improve the overall water quality and growth of prawn and rohu. Mola production was better in ponds stocked with 2.0 mola/m^2 (Treatment 2) and 4.0 mola/m^2 (Treatment 3) and both were greater than production from ponds stocked with 1.0 mola/m^2 (Treatment 1). Consumption of prawns was higher when mola were stocked at 1.0 mola/m^2 and lowest when no mola were raised with the prawn (Treatment 4; Table 9). Consumption of mola was highest when they were stocked at 4.0 mola/m^2. The consumption rates of rohu did not vary with treatment.

Overall, no differences in weight gains of prawn were seen with varying stocking densities of mola, and presence of mola actually improved production of prawn. Production and household consumption of prawn was best when stocked with both mola and rohu. The inclusion of mola at any stocking rate up 4.0 mola/m^2 can improve both overall production of prawns and the nutritional health of the farmers' family due to higher consumption of protein, vitamins, and minerals.

Study 3 — Evaluate the potential use of gher/pond mud for growing the nutrient rich leafy vegetable (vine spinach, *Basella alba*) on gher/pond dykes. The nutrient composition due to fish species combinations from prawn/fish polyculture of both pond dyke soil and pond mud excavated from ponds in each treatment from Study 1 is important to determine its usefulness as a fertilizer for crop production. Soil samples from the respective pond dykes and pond mud were collected and analysed at the Soil Science Department, Bangladesh Agricultural University, Mymensingh. pH, EC, OM, total N, phosphorous (P), potassium (K), and sulphur (S) were different in each pond (Table 10). The pH of all soil types was lightly acidic. Organic matter (%), total N, P, and K were higher in Pond C compared to the other two ponds where stock density of fish/prawns combination was the highest.

Vine spinach plant height as well as the yield per plot, leaf number, and leaf length were found highest in the 100% pond mud soil of Pond C (Study 1, Treatment 3) where nutrient content of soil was higher compared to pond dyke soil. The lowest plant height and yield was found when vine spinach was grown in dyke soil from Pond A (Study 1, Treatment 1) and Pond B (Study1, Treatment 2). Growth and yield performance was higher when vine spinach was grown in 100% pond mud from Ponds B and C (Table 11 and Figure 3). This might be due to an abundance of nutrients available to the plant during the summer. The percentage of dry matter content in the twig (upper part of plant) was higher when grown in 50% pond mud of pond type B but the moisture content was lower. This indicated that the plant contained more solid material in treatments grown with 50% pond mud and 50% soil.

After harvesting, vine spinach samples were collected for nutritional analysis. Leaf and stem were mixed together and analysed for Vitamins A and C, calcium, iron, sulphur, and phosporous. The best growth of the plants were found when the plant contained less Vitamins A and C content (Pond C) or with higher amounts of the minerals phosphorous, sulphur, and iron (Pond A) (Table 12).

These results indicate that pond mud from prawn/rohu/mola polyculture can successfully be used as a natural fertilizer for growing vine spinach.

Study 4 — Production performance of nutrient-rich Snake gourd (*Trichosanthes anguina*) in fish pond muds with improved technology. This study was performed using the same experimental design and soil and mud samples at in Study 3. Here, we proposed to determine if snake gourd could be grown on pond dykes using pond mud from prawn/fish polyculture as a natural fertilizer (Table 13). Plant height does not significantly differ between soil type (data is not shown). The yield of snake gourd was significantly influenced by pond mud and pond types. Growth and yield were better when the snake gourd was grown in 100% pond mud (Figure 4). Also, pheromone traps were introduced in the study area to control pests and reduce the use of pesticides applied to the crops.

Vitamins and minerals of the plants are influenced by the different prawn/fish combinations grown in the ponds and their respective pond muds. Plants grown in 50% pond dyke soil/50% pond mud from Pond B had higher levels of Vitamins A and C, sulphur, and phosphorous (Table 14). Some nutrients were higher in plants grown in 100% pond dyke soil than in 100% pond mud. This might be due to heavy floods in this area of Dumuria, Khulna. This caused a stagnant condition in pond muds and reduced the activity of root growth for plant development where plants grown in 100% pond dyke soil or 50% pond dyke soil/50% pond mud had higher levels of nutrients.

Again, these results indicate that pond mud from prawn/rohu/mola polyculture can successfully be used as a natural fertilizer for growing snake gourd.

Study 5 — Assess the nutritional benefits and economic return for households practicing integrated aquaculture. The key findings of this investigation were based on different indicators of economic returns and nutritional benefits over time by the fish farmers in the selected area. Seventy-eight percent of fish farmers in the study area possess their own land, whereas 15% of those surveyed lease land to raise their crops. Six percent of the farmers own a small business and 3% of the farmers are employed by the government. In the study area, the average age of the fish farmers was 48 years, and they have 4 family members in their household on average. About 94% of the farmers were educated while only a few farmers were illiterate.

It also was found that people in the study area consume more small fish such as mola due to the increased production of mola in the area following the current studies. The study noted that 42% of families consume more than 3 kg of mola fish in 5 days during each week, and 21% families were found to consume more than 6 kg of mola each month. These consumption rates were higher than the national average of Bangladesh. The respondents of the study area mentioned that consumption of the mola fish has increased due to increased mola production in their region. This investigation revealed that 28% of families consumed more than 8 kg of carp per month and 35% of families consumed 4 times more carp on average in their food. It was also found that 64.28% of the respondents consumed vegetables every day. The consumption of the vegetable has increased compared to the consumption prior to these studies from 26.67% to 100% due to the increased vegetable production. Not only do they consume the vegetables they produce, they also sold the surplus in the local markets.

The survey indicated that the farmers earned an average net return of 225,000 Tk/ha from the combined cultivation of vegetables, fish, and rice in the same field in Treatment 1, an average net return of 108,333 Tk/ha from the combined cultivation of vegetables, fish, and rice in the same field in Treatment 2, and an average net return of 94,736 Tk/ha by following the Aquatic Agricultural System (AAS) (Treatment 3) (Table 15). The overall harvest volume, consumption, and sale price are shown in Table 16.

CONCLUSION

Nutrient-rich mola was harvested continuously from prawn gher systems. The other species (prawns and rohu) were harvested after attaining marketable size. The addition of mola in prawn ghers had no negative impact on the main crop of freshwater prawn. Furthermore, farmers obtained mola as an additional crop that was used for household consumption. Surplus mola were sold at local markets for income. The present investigation not only contributed to increasing prawn, fish, and vegetable production and income generation but also helped to increase valuable nutrients such as protein, vitamins, and minerals available to the farmers and their families by incorporating mola fish in their diets. Pond muds showed the potential to increase vegetable production in the pond dykes and the adjacent lands due to the higher content of soil nutrients in the pond mud.

QUANTIFIED ANTICIPATED BENEFITS

- Cultivation of nutrient-rich mola has been successfully demonstrated in the gher-prawn farming systems in southern Bangladesh;
- Consumption of small fish mola has been noticeably increased in the selected area after introduction of this nutrient-rich fish in the prawn gher;
- Integration of mola and rohu did not reduce the production of prawn in the gher
- The integration of vegetable farming on "prawn-mola" pond dykes offers great potential for use of rich pond muds for upscaling of this technology; and
- Introduction of AAS has enriched the nutrient intake of the women and children in the prawn farming households.

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TABLES AND FIGURES

Table 1. Experimental design for Study 1.

	Treatment 1	*Treatment 2*	*Treatment 3*
Prawns (*M. rosenbergii*)	2.0/m^2	2.0/m^2	2.0/m^2
Mola (*A. mola*)	none	1.0/m^2	1.0/m^2
Rohu (*L. rohita*)	0.1/m^2	none	0.1/m^2
Replicate gher ponds (*n*)	5	5	5

Table 2. Experimental design for Study 2

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Prawns (*M. rosenbergii*)	2.0/m^2	2.0/m^2	2.0/m^2	2.0/m^2
Rohu (*L. rohita*)	0.1/m^2	0.1/m^2	0.1/m^2	0.1/m^2
Mola (*A. mola*)	1.0/m^2	2.0/m^2	4.0/m^2	none
Replicate gher ponds (*n*)	5	5	5	5

Table 3. Experimental design for Studies 3 and 4. Vegetables were grown on pond dykes used for fish grow-out experiments in Study 1 using pond mud from the different fish treatment ponds. A = Study 1, Treatment 1; B = Study 1, Treatment 2; C = Study 1, Treatment 3.

Pond	*Parameter*	*Treatment 1*	*Treatment 2*	*Treatment 3*
A	Prawns	2.0/m^2	2.0/m^2	2.0/m^2
	Mola	none	none	none
	Rohu	0.1/m^2	0.1/m^2	0.1/m^2
	Soil type	100% pond dyke soil	50% pond mud/50% pond dyke soil	100% pond mud
B	Prawns	2.0/m^2	2.0/m^2	2.0/m^2
	Mola	2.0/m^2	2.0/m^2	2.0/m^2
	Rohu	none	none	none
	Soil type	100% pond dyke soil	50% pond mud/50% pond dyke soil	100% pond mud
C	Prawns	2.0/m^2	2.0/m^2	2.0/m^2
	Mola	2.0/m^2	2.0/m^2	2.0/m^2
	Rohu	0.1/m^2	0.1/m^2	0.1/m^2
	Soil type	100% pond dyke soil	50% pond mud/50% pond dyke soil	100% pond mud
	Replicate gher ponds (*n*)	3	3	3

Table 4. Water quality parameters from Study 1. Values are mean ± SD.

	Treatment 1	*Treatment 2*	*Treatment 3*
Temperature (ºC)	31.98±1.68	31.86±2.21	31.46±2.42
Transparency (cm)	26.2±5.45	27.2±4.66	27.0±7.63
pH	7.38±0.29	7.32±0.23	7.3±0.18
DO (mg/L)	5.68±0.51	5.22±0.36	5.76±0.84
Alkalinity (mg/L)	200±50	170±27.38	190±41.83
Ammonia (mg/L)	0.33±.03	0.34±.021	0.35±0.03
Nitrate Nitrogen (mg/L)	2.99±0.93	3.46±0.94	3.86±1.12
Phosphate phosphorus (mg/L)	0.48±0.23	0.59±0.32	0.47±0.23
Chlorophyll-a (µg/L)	73.74±4.25	61.90±6.54	55.78±2.03

Table 5. Production (kg/ha) of prawn, mola, and rohu from July 2014 to January 2015 in Study 1. Values are mean ± SD. Values with different letters are significantly different ($p < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*
Prawn	417.4±12.70^{b}	446.8±11.03^{a}	462.6±12.74^{a}
Mola	NA	308.0±20.33^{a}	255.5±23.08^{b}
Rohu	569.5±25.50	NA	573.5±28.12

Table 6. Consumption of prawn, mola, and rohu from July 2014 to January 2015 in Study 1. Values are mean ± SD. Values with different letters are significantly different ($p < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*
Prawn (kg)	12.2±1.48^{b}	17.6±2.82^{a}	20.0±4.90^{a}
Mola (kg)	NA	116.1±13.37^{a}	92.0±17.18^{b}
Rohu (kg)	137.0±23.14	NA	132.0±27.29

Table 7. Water quality parameters from Study 2. Values are mean ± SD.

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Temperature (ºC)	31.63±2.23	31.58±1.87	31.66±1.80	31.87± 1.94
Transparency (cm)	26.2±4.15	29.2±6.45	28.2±4.63	30.1±4.63
pH	7.7±0.68	7.18±0.39	7.18±0.29	7.3±0.18
DO (mg/L)	5.18±0.81	5.16±0.41	5.62±0.43	5.14±0.34
Alkalinity (mg/L)	223±33	218±33	189±29.31	210±31.73
Ammonia (mg/L)	0.31±.02	0.37±.02	0.36±.02	0.36±0.05
Nitrate Nitrogen (mg/L)	2.46±0.72	2.96±0.72	3.16±0.64	3.29±1.02
Phosphate phosphorus (mg/L)	0.51±0.41	0.46±0.31	0.53±0.12	0.49±0.2
Chlorophyll *a* (µg/L)	79.17±2.18	69.57±3.15	81.90±3.14	53.78±1.73

Table 8. Production (kg/ha) of prawn, mola, and rohu from July 2015 to December 2015 in Study 2. Values are mean ± SD. Values with different letters are significantly different ($p < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Prawn	455.58±14.69^{a}	462.77±15.60^{a}	456.28±13.94^{a}	362.25±17.84^{b}
Mola	298.55±11.55^{b}	376.21±15.34^{a}	397.66±18.41^{a}	NA
Rohu	588.11±16.47^{a}	572.19±17.28^{a}	586.75±15.39^{a}	502.92±16.84^{b}

Table 9. Consumption of prawn, mola, and rohu from July 2015 to December 2015 in Study 2. Values are mean ± SD. Values with different letters are significantly different ($p < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Prawn (kg)	18.9±1.10[a]	13.2±0.49[c]	14.9±0.60[b]	10.0±0.82[d]
Mola (kg)	109.2±2.25[c]	118.6±1.64[b]	124.4±2.03[a]	Nil
Rohu (kg)	135.3±4.01	125.7±2.89	132.4±2.78	130.7±8.89

Table 10. Nutrient quality of pond dyke soil and pond mud in Studies 3 and 4

	Pond A		*Pond B*		*Pond C*	
	Pond mud	*Dyke soil*	*Pond mud*	*Dyke soil*	*Pond mud*	*Dyke soil*
pH	5.97	6.17	6.51	6.79	6.59	6.54
EC (µ cm/cm)	842.3	1,090	396	289	682.3	258
OM (%)	1.65	1.43	1.66	1.67	1.99	2.59
Total N (%)	0.08	0.08	0.08	0.08	0.1	0.12
P (ppm)	22.6	18.09	44.29	37.33	41.9	42.7
K (ppm)	97.41	116.14	113.6	102.37	143.9	97.08
S (ppm)	351.4	328	290.32	175.33	233	98.28

Table 11. The combined effects of pond types and pond mud on growth and yield of vine spinach. PA = Study 1, Treatment 1 ponds; PB = Study 1, Treatment 2 ponds; PC = Study 1, Treatment 3 ponds; T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3

Treatment combination	*Plant height (cm)*	*leaf number*	*Leaf length (cm)*	*Fresh weight of twig (g)*	*% Dry matter of twig*
P_AT_1	26.2	18.6	12.9	91.4	8.4
P_AT_2	24.7	12.6	11.6	75.2	8.1
P_AT_3	29.3	15.1	13.1	72.2	8.2
P_BT_1	21.3	12.5	11.7	49.3	8.3
P_BT_2	21.1	14.6	10.6	72.5	14.1
P_BT_3	29.8	20.3	12	80.1	8
P_CT_1	23.8	18.3	11.2	84.2	7.8
P_CT_2	25.1	14.7	14.6	100.6	7.8
P_CT_3	29.8	21.6	17.2	82.5	8.5
$LSD_{0.05}$	9.11	7.32	2.69	0.608	0.212
$LSD_{0.01}$	12.07	9.7	3.56	0.806	0.281
Level of significance	NS	NS	*	**	**

Table 12. The combined effects of pond types and pond mud on nutritional value of vine spinach. PA = Study 1, Treatment 1 ponds; PB = Study 1, Treatment 2 ponds; PC = Study 1, Treatment 3 ponds; T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3.

Treatment combination	*Ca (%)*	*P (%)*	*S (mg/100g)*	*Fe (%)*	*Vit-A (µg/100g)*	*Vit-C (mg/100g)*
P_AT_1	0.556	0.024	2.247	0.092	66.333	106.14
P_AT_2	0.694	0.055	2.144	0.054	85	75.04
P_AT_3	1.742	0.13	2.778	0.595	71	94.43
P_BT_1	0.692	0.041	1.834	0.375	80.333	97.74
P_BT_2	0.824	0.046	1.055	0.529	81.333	95.09
P_BT_3	1.363	0.095	2.667	0.764	80	50.53
P_CT_1	1.116	0.072	1.783	0.608	78	82.72
P_CT_2	1.074	0.127	1.986	0.507	53	74.86
P_CT_3	1.401	0.147	2.347	0.645	63.333	46.49
$LSD_{0.05}$	0.083	0.018	0.066	0.03	5.84	4.57
$LSD_{0.01}$	0.11	0.024	0.088	0.04	7.74	6.05
Level of significance	**	**	**	**	**	**

Table 13. The combined effects of pond types and pond mud on growth and yield of snake gourd. PA = Study 1, Treatment 1 ponds; PB = Study 1, Treatment 2 ponds; PC = Study 1, Treatment 3 ponds; T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3.

Treatment combination	*Mean Internode Length (cm)*	*Petiole Length (cm)*	*Fruit Cavity Breadth (cm)*	*Fruit Flesh Thickness (cm)*	*Stripes Per Fruit*
P_AT_1	9.92	10.2	3.17	0.36	10.8
P_AT_2	9.56	12.1	2.99	0.39	10.7
P_AT_3	10.86	9.1	3.26	0.5	10.7
P_BT_1	9.32	10.1	3.11	0.5	10.2
P_BT_2	9.22	10.4	3.43	0.5	9.9
P_BT_3	9.14	8.9	3.31	0.49	9
P_CT_1	10.74	10.8	2.86	0.5	9.6
P_CT_2	10.5	10.2	3.05	0.5	9.9
P_CT_3	9.28	11	2.86	0.49	10.6
$LSD_{0.05}$	0.744	0.869	0.247	0.036	0.648
$LSD_{0.01}$	0.986	1.15	0.328	0.047	0.859
Level of significance	**	**	*	**	**

Table 14. The combined effects of pond types and pond mud on nutritional value of snake gourd. PA = Study 1, Treatment 1 ponds; PB = Study 1, Treatment 2 ponds; PC = Study 1, Treatment 3 ponds; T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3.

Treatment combination	*Ca (%)*	*Mg (%)*	*S (mg/100g)*	*P (%)*	*Protein (%)*	*Vit-A (µg/100g)*	*Vit-C (mg/100g)*
P_AT_1	0.483	0.876	4.726	0.629	2.867	49.057	9.613
P_AT_2	0.479	0.8245	6.679	0.86	2.3	53.287	7.86
P_AT_3	0.327	0.7778	4.485	0.596	1.433	46.878	4.823
P_BT_1	0.564	0.5355	5.661	0.86	2.3	52.764	14.47
P_BT_2	0.411	0.6788	5.356	0.604	2.2	58.596	5.397
P_BT_3	0.412	0.5825	5.196	0.502	1.9	39.408	10.35
P_CT_1	0.411	0.7241	4.931	0.803	2.433	38.088	5.203
P_CT_2	0.408	0.6816	6.433	0.68	2.4	37.318	3.26
P_CT_3	0.327	0.6763	4.894	0.796	2.2	34.9	4.207
$LSD_{0.05}$	0.011	0.005	0.421	0.007	0.187	0.83	0.292
$LSD_{0.01}$	0.015	0.007	0.558	0.009	0.248	1.1	0.388
Level of significance	**	**	**	**	**	**	**

Table 15. Costs and returns from vegetables, fish, and rice of different groups of farmers surveyed in Study 5. Values are Tk/ha.

	Treatment 1			*Treatment 2*			*Treatment 3*		
	Vegetables	*Fish*	*Rice*	*Vegetables*	*Fish*	*Rice*	*Vegetables*	*Fish*	*Rice*
Total return (Tk)	14,820	123,500	187,720	33,333	200,000	51,666	-	182,000	-
Total Cost (Tk)	7,410	93,860	59,280	20,000	116,666	40,000	-	88,400	-
Net return (Tk)	7,410	29,640	128,440	13,333	83,333	11,666	-	93,600	-
Gross return (Tk)	165,490			108,332.00			93,600		

Table 16. Harvest volume, consumption, and sale price of different groups of farmers surveyed in Study 5.

	Treatment 1		*Treatment 2*		*Treatment 3*		
	Prawn	*carp*	*Prawn*	*Mola*	*Prawn*	*Mola*	*Carp*
Harvesting (kg)	1,164	2,162	740	330	1,104	821	2,189
Fish consumption (kg)	35	393	30	200	50	229	330
Sale/buy (kg)	1,129	1,769	710	130	1,054	592	1,859

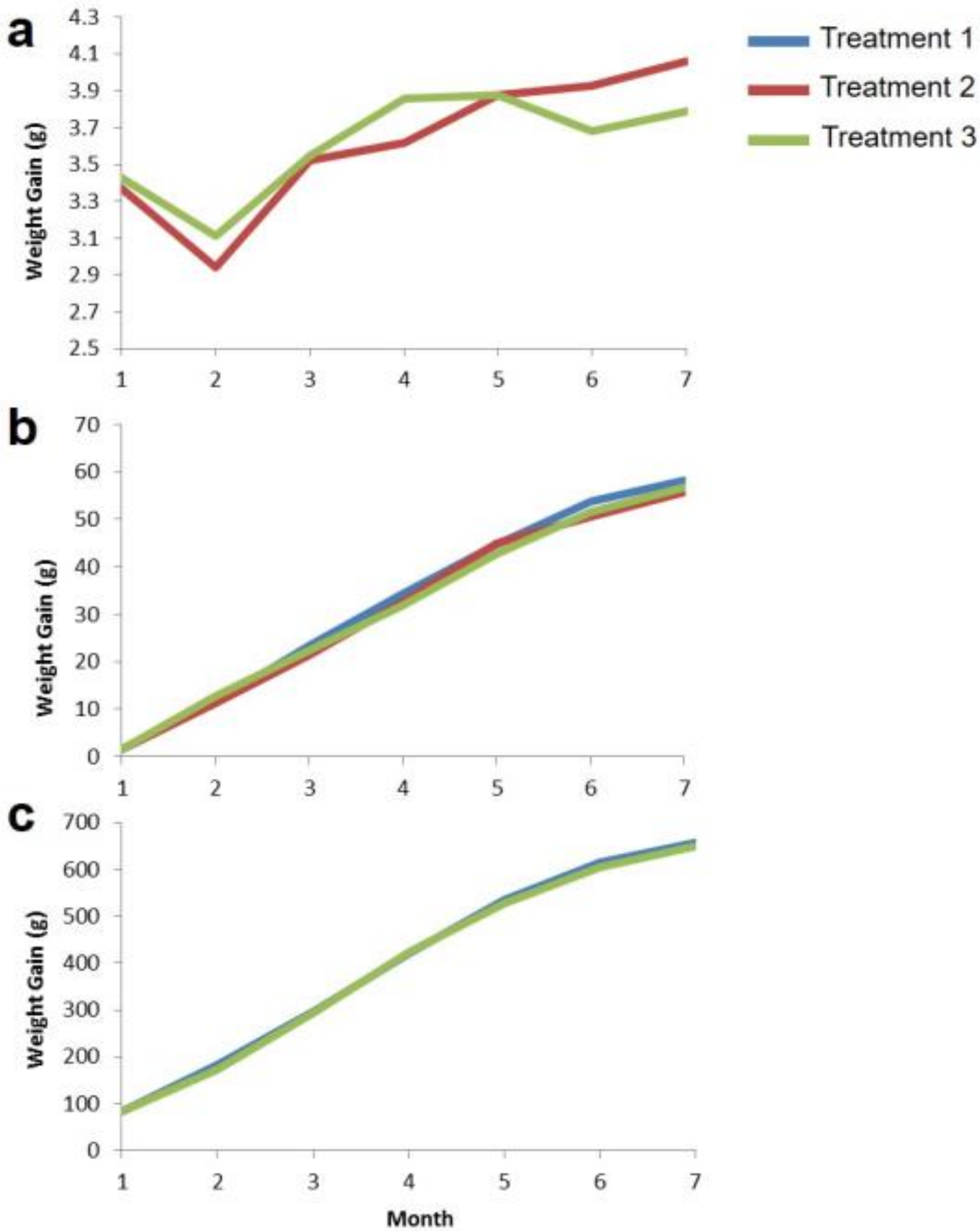

Figure 1. Monthy weight gain of (a) mola, (b) prawns, and (c) rohu in Study 1. At the end of the study, mola in treatment 2 (raised with prawns only) had a higher rate of weight gain than those in treatment 3 (raised with prawns and rohu). There was no difference in weight gain of prawns or rohu between treatments.

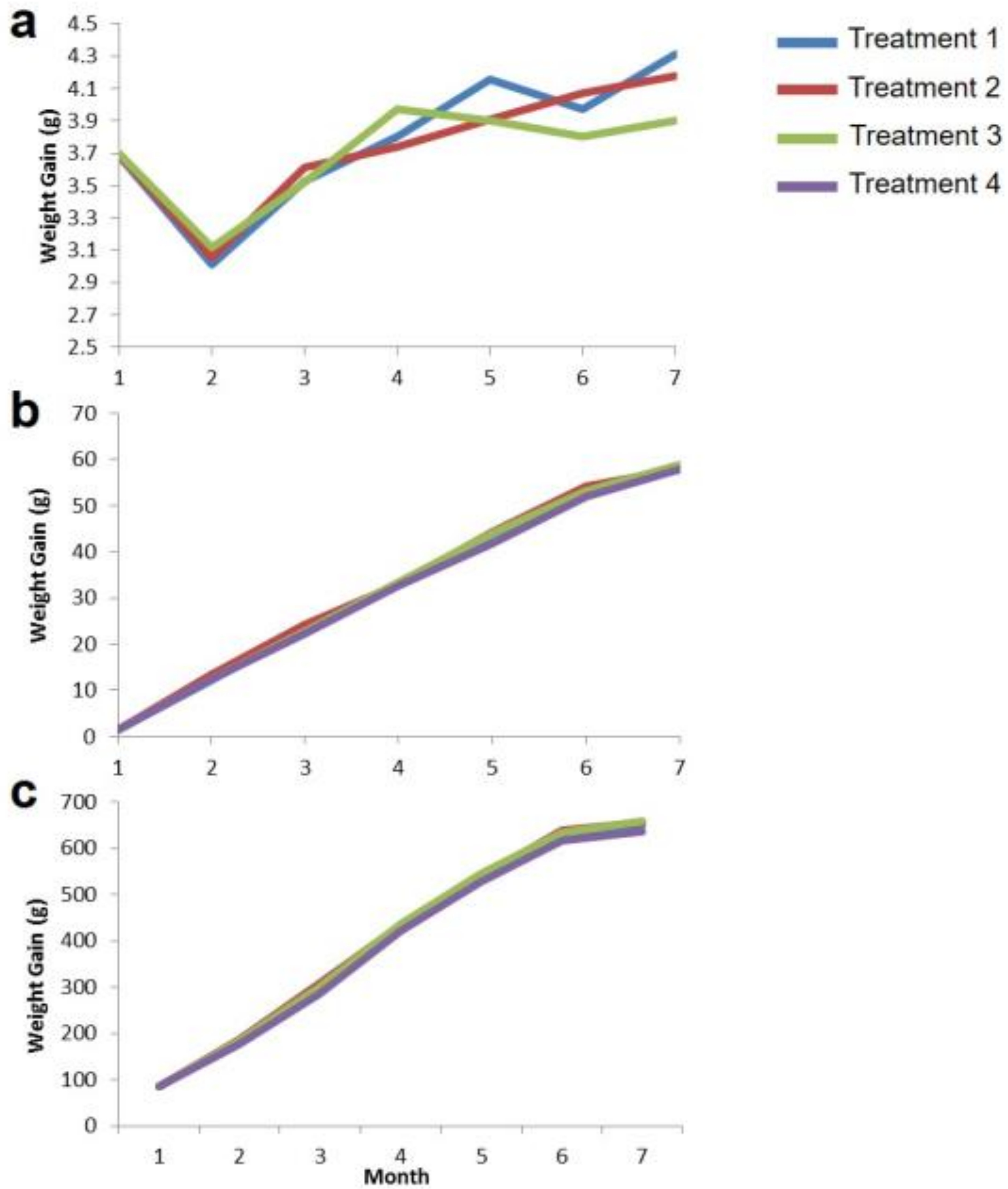

Figure 2. Monthy weight gain of (a) mola, (b) prawns, and (c) rohu in Study 1. At the end of the study, mola in treatments 1 and 2 (stocked at $1.0/m^2$ and $2.0/m^2$, respectively) had a higher rate of weight gain than those in treatment 3 (stocked at $4.0/m^2$). There was no difference in weight gain of prawns or rohu between treatments.

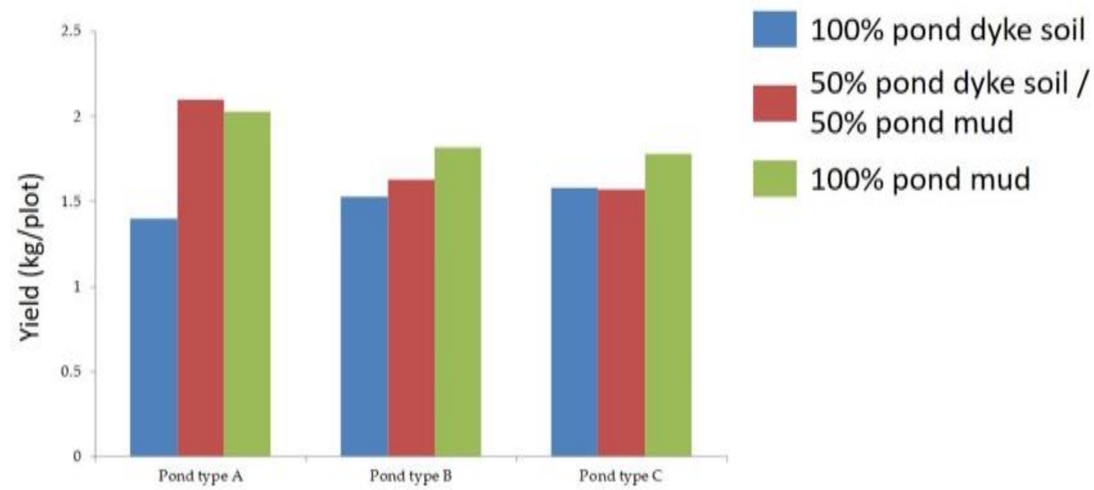

Figure 3. The effect of pond and soil type on yield of vine spinach in Study.

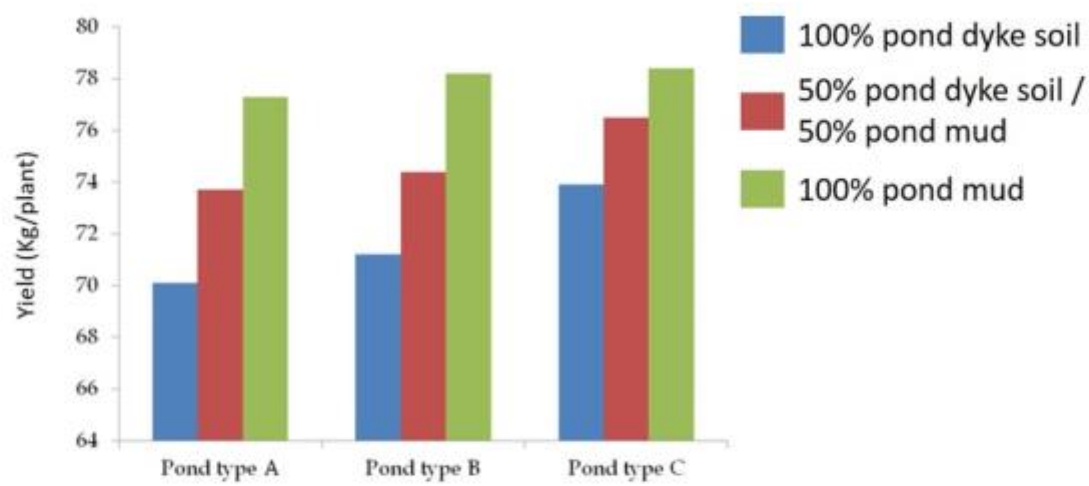

Figure 4. The effect of pond and soil type on yield of snake gourd in Study 4.

Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fisheries and Aquaculture in Cambodia, Part I

FOOD AND NUTRITIONAL CONSUMPTION SURVEY: WOMEN AND PRESCHOOL-AGE CHILDREN IN CAMBODIA

Enhanced Trade and Investment for Global Fishery Markets/Study/13HHI02UC

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ABSTRACT

Fish is an integral part of women and preschool children's staple food for their daily consumption and is a main source of protein and other key micronutrients. At the same time, the prevalence of malnutrition among women and preschool children continues to be a major problem in Cambodia. However, data and information on the commonly consumed fish species and the current dietary intake of women and preschoolers in Cambodia are lacking. This study aimed to identify the commonly consumed fish species and Other Aquatic Animals (OAAs); evaluate the food consumption; and dietary energy and nutrient intakes among women and preschool children. 300 women and 342 preschoolers (aged 6 months to 5 years) were randomly selected for study. The 24 hr-food recall questionnaire was used. Microsoft Excel 2013 and SPSS Statistics Version 20.0 were used for data entry and analysis. Forty three (43) fish species and OAAs were consumed by women and 38 fish species and OAAs were consumed by preschoolers. Fish provides 80% of the total animal protein intake. Women consumed fish at 145.3 g/day and preschoolers at 52.9g/day. Women's total average daily per capita food consumption was 861g/day, while for preschoolers it was 489 g/day. Women's total average dietary energy intake was 1976 kcal/day, while for preschoolers it was 844.9 kcal/day.

INTRODUCTION

Fish is an integral part of women and preschool children's staple food for their daily consumption and is a main source of protein and other key micronutrients. At the same time, the prevalence of malnutrition among women and preschool children continues to be a major problem in Cambodia. However, data and information on the commonly consumed fish species and the current dietary intake of women and preschoolers in Cambodia are lacking.

OBJECTIVES

The primary purpose of this activity was to identify the commonly consumed fish species and Other Aquatic Animals (OAAs) of the sample women and preschool-age children. The secondary purpose was to evaluate their current food consumption: energy, and key nutrient intakes of women and preschool children and the relative contribution made by fish and Other Aquatic Animals (OAAs) and its products to total nutrient intake of studied subjects.

METHODS

Study design and scope. Stung Treng province (Upstream Mekong River), Prey Veng province (Downstream Mekong River) and Kampong Thom province (Tonle Sap Area) were selected for study sites. The data collection was conducted in the rainy season from 2 to 26 June 2014. The target subjects of the study subjects are women and preschool children (aged six months to five years). Three hundred (300) eligible women and 343 eligible preschool-age children were selected by using simple randomized sampling from the three provinces. Dietary intake was surveyed through face-to-face interviews by using a single 24-hour food recall to estimate the amount of food that had been eaten in the past 24 hours. Food models were used to identify food items that were eaten by the subjects. All food and beverages consumed were recorded using standard household measurement and an electronic scale (precision to 0.1g). The names of local dishes consumed were also recorded. The amount of each food item consumed was estimated from the real food models. Mothers were asked to show the amount of food consumed by her child, which was then weighed. All food item consumption of women and preschoolers were converted to weight in grams and the nutrient content of the foods consumed were computed by using the ASEAN Food Composition Table (ASEANFCT 2000). Nutrients for evaluation included: energy; macronutrients (protein, carbohydrate and fats); and key micronutrients (iron, zinc, calcium, and vitamin A). The nutrient intakes of women and preschool children were then compared to the Recommended Dietary Allowances harmonization in Southeast Asia (Barba, 2008) to determine the level of nutritional adequacy of the food intake to estimate the amount of food that had been eaten.

Training and survey organization. Data were collected by four trained field enumerators. The training aimed to educate field enumerators on how to conduct dietary assessment by using the 24-hour food recall questionnaire; to educate the interviewers to be familiar with fish species; to reinforce the recall interviewers with exercise practices and pilot testing; and to educate the interviewers to be familiar with the questionnaire before data entry was employed. Pilot pretesting of questionnaires was conducted in order to identify the potential problems encountered in questionnaires, questions, and recall form. A letter of survey objectives was presented to the local authorities informing them of the conduct of the survey before the actual fieldwork was started. Questionnaires were cross-checked by the members of the team for any missing pieces of information followed by data entry. Microsoft Excel 2013 and SPSS Statistics Version 20.0 were used for data entry and analysis. Data coding, cleaning, and cross-checking were conducted. Descriptive statistics were used.

RESULTS

Socio-economic characteristics. The socio-economic survey provided a summary of the demographic and socio-economic characteristics of the women. Data collected included type of dwelling unit; household possessions; water supply and sanitation; and characteristics of the women such as age, education attainment, and occupation. The socio-economic variables were vital in the analysis of the relationships between the nutrition and health variables, and very useful in targeting and locating specific population groups who are nutritionally vulnerable to socio-economic fluctuations and environmental degradation.

Nearly one-third (30.7%) of the sample women belonged to the adult age category (25 - 29 years old), followed by 26.7% belonging to the age category (30-34 years old). Only 1% was in the age group more than 50 years old. The average age of sample women was 29.6 years old. Regarding marriage, 86.7% of women belonged to age category (20-24 years old) when first married, followed by about 5% belonging to age group (25-29 years old) with an average age of 21.7 years when first married. Women had an average of 2.1 children. More than 70% of the women had 1-2 children, whereas only 5% had more than 5 children (Table 2).

The Cambodian educational system, grade one to six is classify as primary level, grades seven to nine is classified as secondary level, while grades 10 to 12 is classified as high school. Forty-five percent (45%) of sampled women had completed secondary school and 29% more had completed the primary level. Only about 12 % and 3% reached high school and college/university, respectively. The literacy rate was 69% (Table 2). 62.8% of the respondents derived income from agriculture, followed by labor force, fishing and animal husbandry, which accounted for about 42.5%, 41.5% and 40%, respectively. Up to 21.7% generated income from 28 other different job items. Almost half of respondents had two different jobs and only 12% had one job (Table 3).

Information on ownership of durable goods and other possessions is presented in Table 3. Among the appliances that are most acquired by women, mobile telephones rank highest (77%), followed by televisions (56%) and other appliances such as CD/DVD, refrigerator, generator, fans, rice harvesting machine, water pump machine, air-condition, wood cutting machine, electric cooker owned more than 15%. More than half of all respondents own a motorcycle, followed by bicycle ownership of more than 43%. The percentage owning a boat was only 1%. The type of the material used for the house is one of indicators for the impression of the wealth at the first glance. Nearly all (95.4%), of the sample women owned wooden houses (Table 4) and the remainder owned a concrete house. More than half of the sample women (56%) owned land for agriculture.

The source of drinking water is an indicator of whether it is suitable for drinking. Nearly 79% of household of the women sampled consumed drinking water from rainwater and more than half of the women sampled utilized water from a river for drinking water. Nearly one-fourth of women sampled consumed drinking water from a pipe or running water (Table 5). Almost half of the sample women's household had no access to toilet hygiene facility and made use of fields or bush areas. Thirteen percent reported sharing their toilet facility.

Early initiation of breastfeeding is encouraged for a number of reasons. Mothers benefit from early suckling because it stimulates breast milk and facilitates the release of oxytocin, which helps the uterus contract and reduces postpartum blood loss. The first breast milk contains colostrum, which is highly nutritious and has antibodies that protect newborns from disease. UNICEF and WHO recommend that children be exclusively breastfed during the first 6 months of file and that children be given solid or semisolid complementary food in addition to continued breastfeeding from six months to 24 months. Exclusive breastfeeding is recommended because breast milk is uncontaminated and contains all of the nutrients necessary for children in the first few months of life. The proportion of sample children ever breastfed was almost all (98%) and those breastfed only 2.3% (Table 6). More than three-fourths of sample children under six months of age were exclusively breastfed. Forty-three percent of women sampled reported their children get sick a few times a month and more than one-fourth (22%) get sick once a month (Table 5).

Food consumption by women. Food consumption in different areas of the country may be influenced by topography; religious customs; cultural relationships; trades and price (food affordability); agricultural products (local food availability); family size; household food distribution. These factors influence food consumption patterns of individuals, especially women and children. The majority of foods that made up the sample women's diet comes from plants at 76%, while 23% comes from animal source, and 1% comes from food groups such as condiments and spices (Figure 1).

The overall sampled women's diet is basically a rice-vegetable-fish combination (Figure 2). In terms of weight, the total mean one day per capita food consumption is 861g/d, in as-purchased raw form. The most highly consumed food was cereal and cereal products at 369.4 g/d (43% of the total food intake). Vegetables were the second top food group commonly consumed by sample women at around 150 g/d (18 % of the total food intake). Intake of fish, OAA, and their products were the third largest consumption at 145.3 g/d (17% of the total food intake). Consumption of fruits and beverages was 54 g/d (6%). The rest of the major food groups consumed in small amounts were fats and oils; egg, sugar and syrups; legumes, nuts, seeds; and starch roots and tubers.

Among the studied provinces, the Prey Veng province, located in Cambodian Lower Mekong part, showed highest food intake at 884 g/d, followed by Kampong Thom Province, Tonle Sap area, at around 855 g/d, while Stung Treng province, located in Cambodian Upper Mekong part, was lowest at around 843 g/d (Table 7). Intake of cereals and cereal products, predominantly rice, was high Prey Veng province at around 377 g/d followed by Kampong Thom province at 365.2 g/d. Stung Treng consumed 366 g/d. Kampong Thom province consumed vegetables at around 152 g/d followed by Prey Veng province at around 151 g/d and Stung Treng was around 148.6 g/d. Fish, OAA and their products were generally eaten more than meat or poultry or eggs in all sample provinces. Higher consumption of fish was observed in Prey Veng province at around 155g/d, followed by Stung Treng province at around 141g/d and Kampong Thom province at 140g/d. The other different food groups: fats and oils; egg, sugar and syrups; legumes, nuts, seeds; and starch roots and tubers were also consumed, by sample women, across the studied provinces.

Food consumption by preschool children. Diets of sampled pre-school children came from plant sources (75%), animal sources (24%), and condiments and spices (1%) (Figure 3). The mean one-day total food intake of children aged six months to five years old weighed 499 g, in as- purchased form (Figure 4), consisting largely of 256 g (51%) of cereal and cereal products of which rice and rice products were the predominant forms, of 55g (11%) of milk and milk products, of 53g (11%) of fish and Other Aquatic Animals, and a combination of vegetables and fruits around 50g (10%). Energy-giving foods such as rice and body building foods such as milk, fish, meat, poultry, and egg are food items that are needed most importantly in preschool children's diet to support the fast rate of growth and development. Rice contributed more than half of the total food intake. This age group's intake of fish and fish products was about 11% while meat and meat products were 2.4%, and poultry and eggs was 1.5%. Milk and milk products were at 11% of the total food intake. Fruits and vegetables amounted to 29.3 and 20.5 g, respectively, which shared about 5.9% and 4% of total food intake, respectively. The intake of fats and oils, at 0.8 g or 0.17% of the total food intake, although low, is important for the transport of fat-soluble vitamins, especially vitamin A found in animal tissues or beta-carotene, the precursor of vitamin A from the plant tissues.

Table 8 shows that The mean one-day food intake of children aged six months to five years by province was: Prey Veng province highest at 547 g, followed by Stung Treng province at 467 g, whereas lowest food intake was observed in Kampong Thom at 458 g per day. Intake of cereals and cereal products, predominantly rice, was high in Prey Veng province at 300 g followed by mountainous Stung Treng province around 250.5 g per day, while lowest intake was observed in Kampong Thom at around 221 g/d. Fish and beverages were the second largest items consumed across the studied provinces with the combination of both items accounting for nearly one-fourth of total food intake by pre-school children. Milk and milk products ranked third across the studied provinces, with Prey Veng at 49.5 g (9%), followed by Kampong Thom province at 46.5 g (10%) and Stung Treng the lowest consumption at 38 g (8%). Food groups such as fruits, vegetables, eggs, sugar and syrup, starchy roots and tubers, legumes, nuts and seed, and beverages were also consumed by this age group.

Women consume 43 fish and OAA species with an average consumption of 145.3 g/d. The 10 most consumed fish species in terms of weight and percent contribution to women consuming fish species per day were: Trey Riel (*Cirrhinus sp.*), 31g (21%) of total fish intake per day; Trey Ros (*Channa striata)*, 19 g (13%); and Trey Chhpin (*Hypsibarbus pierrei*), 15 g (10.1%) (Table 8). Other fish species, aquaculture fish, and OAA are listed in Table 9.

Preschoolers consumed 38 fish and OAA species with an average consumption of 53 g/d. The most consumed fish species in term of weight and percentage contribution to children were: Trey Riel (*Cirrhinus sp.*), 12.9 g/d (24.3%); Trey Ros (*Channa striata*), 9.6 g/d (17.8%) and Trey Kanhchus (*Mystus sp.*), 5.09 g (9.6%) (Table 10). Other fish species, aquaculture fish, and OAAs are also listed in Table 10.

Nutrient intake by women. All major food groups contribute to the caloric intake of individuals, especially women and children; therefore, adequacy in the caloric and protein intakes measured against the recommended daily allowance is a good indicator of food adequacy. An intake of one g of carbohydrate-rich foods such as cereal and its products, starchy tubers and roots, sugar and syrups, fruits and vegetables will generate four Kcal. An intake of one g of protein-rich foods such as fish, meat, milk, poultry, eggs, dried beans, nuts and seeds and their products will also generate four Kcal. An intake of one g of fats and oils, including butter or margarine will give nine Kcal. The sources of calories in a diet, namely carbohydrates, proteins and fats are an indicator of the quality of the diet. The diet of women sampled in this study has a total energy of 1976 Kcal, the largest amount of which comes from carbohydrates at 71%, with desirable contribution from proteins at 13% and very low from fats and oils (16%) (Figure 5).

The total energy and nutrient intake among three provinces ranked from 1813.3 Kcal (Kampong Thom) to 2082.6 Kcal (Prey Veng) (Table 11). The sampled women's daily protein intake ranged from 61.9 to 67.8 g, carbohydrate intake from 346.7 to 271.4 g, while lipid intake ranged from 28.9 to 44 g. Iron intake ranged from 11.7 to 13.9 mg, zinc from 3.1 to 4.1 mg, calcium intake from 478.4 to 619.4 g and vitamin A from 404.9 to 531.4 mcg RE. In terms of energy and nutrient adequacy, half of the sampled women met at least 100 % of their recommended intake for energy. About 71% of the sample women met at least 80% of the recommended intake of protein. Less than one-fifth of the sample women met at least 80% of the recommended intake for iron. More than 1/3 of sampled women met at least 80% of the recommended intake for zinc. Close to one-fourth of sampled women met the recommended intake for calcium and more than one-fourth of sampled women met the recommended intakes for vitamin A.

Nutrient intake by preschoolers. The total energy intake of sampled pre-school children among three provinces ranked from a low of 775.9 Kcal (Kampong Thom) to a high of 922.9 Kcal (Prey Veng) (Table 12). The sampled preschool children's daily protein intake ranged from 26.7 g to 32.9 g, carbohydrate intake from 119.5 g to 152.9 g, and lipid intake from 13.08 g to18.9 g. Iron intake ranged from 4.75 to 5.56 mg, zinc intake from 1.26 to 2.14 mg, calcium intake from 207.5 to 332.7 g and vitamin A intake from 221.5 to 268 mcg RE. Among the preschool children, only about 30% met the recommended dietary intake for energy; more than half met at least 80% of protein requirements; and close to one-fourth of the preschool children met at least 80% of recommended intake for iron. Less than1/10 of the preschool children met at least 80% of recommended intake for zinc; about 24% met the recommended intake for calcium and more than 18% met the recommended intake for Vitamin A.

The contribution of particular food groups to total energy and nutrients intake (Table 13) indicates that cereal and cereal products are top energy contributors in the sampled women diet contributing 60.9 %. Because of the large bulk of this food group, it is also the major contributor of carbohydrates at more than 77%. It is also the second contributor of protein at 31%, fats at 14.8%, iron at 43%, calcium at 22% and vitamin A at 7.8%. Fish and fish products are the major contributors of protein at 48.9%, fats at 28.4 %, iron at 25.8 %. Meat and meat products follow fish and fish products in their contribution to the total nutrient intake. Vegetables, on the other hand, are the second largest contributor of carbohydrate at 12.5%, and the major contributors of iron, zinc, calcium, and vitamin A. Fruits were the top contributor to total vitamin A intake, while beverage was the second largest contributor to total energy intake by the sample women.

The contribution of different food groups to total energy and nutrients intake (Table 14) indicates that cereal and cereal products are the largest contributors in the sampled pre-school children's diet to energy, carbohydrates, iron at about 57.4%, 73.4%, and 44.4%, respectively. It is also the second contributor to protein and fats at about 34.5% and 21.5%, respectively. Fish and fish products are top contributors to protein and fats with 40.8% and 28.4%, respectively. Milk and milk products were the largest contributors to zinc and calcium at around 39.7% and 36.3%, respectively. Fruits and vegetables, on the other hand, were the major contributor to vitamin A, while the other food groups such as starchy roots and tubers; legumes, nuts and seed; sugars and syrup; beverages; condiments; and spices were lesser contributors to energy and nutrient intake by preschool children.

Role of fish in nutrition security in women and preschool children. Fish plays a great role in meeting dietary energy needs. When energy needs of the body cannot be supplied by rice and other carbohydrate-rich foods, the body metabolizes the protein from fish to sustain the caloric need of the body for the proper functioning of various physiological and biochemical processes such as digestion and metabolism of foods to sustain life. Fish is also a source of fats. The fats and the protein contributed by fish significantly mitigate caloric deficiency in women's and preschool childrens diets and perhaps the protein-energy malnutrition which is the form of malnutrition that exists in developing countries like Cambodia.

Fish contribute some fat but overall intake of fat was low; it is far lower than the desirable contribution of fats to total dietary energy recommended at 30%–40% for infants and 20%–30% for all others. The low fat intake is one reason for low calorie intake. Fish provides protein, which the body uses for optimal growth, but in the context of low calorie intake the body must turn to protein to satisfy energy needs. This is the form of protein-calories malnutrition (Marasmus) and the major reason for stunted growth and development in Cambodia. Another form of protein-calorie malnutrition (Kwashiorkor) is simple protein deficiency. This type is not common in Cambodia and rarity can be attributed to availability of protein from fish. It can be noted that the contribution of dietary energy from fish at 13% (Figure 5) and 15% (Figure 6) to total dietary energy per capita is the level of protein recommended at 10%–15%.

Fish, OAAs and their products were the major contributors of energy and nutrients of animal origin to women, providing 80% of the total animal protein intake (Table 15). Meat/poultry and eggs contributed less than one-fourth to the total animal protein intake accounting for about 18 % and 2 %, respectively. Fish, OAAs and their products were also the major contributors of energy, fats, carbohydrate, iron, zinc, calcium, and vitamin A at 69.7%, 54%, 99%, 74.5%, 44.6%, 83% and 87.4%, respectively.

Again fish, OAAs and their products were the largest contributors to the total daily energy and nutrient intake from animal sources for preschool children, around 80% of the total animal protein intake (Table 16). Meat/poultry and eggs contributed to the total animal protein intake at about 14.5 and 7.3%, respectively. Fish, OAAs and their products were also the major contributor to energy, fats, carbohydrates, iron, zinc, calcium, and vitamin A at 72.1%, 60%, 93%, 57.2%, 44.1%, 92.8% and 56.4%, respectively.

DISCUSSION

Cambodian women's and preschool children's diets are basically a rice-vegetable-fish combination and have similar proportions: 76% from plant sources, 23% from animal sources, and 1% from food groups such as condiments and spices. The Philippine Food Consumption Survey in 2008 indicated that the Filipino diet comes 70% from plant sources, 29% from animal sources and 1% from condiments and prices. Our study shows that Cambodian women's and preschool children's consumption of plant-source foods was higher than that of Filipinos, whereas consumption of animal-source foods was lower. Animal- source food in Cambodia is mainly from fish. Other animal sources like beef, chicken, and pork are relatively expensive in Cambodia compared to fish which is available and affordable for rural households.

The overall mean daily per capita food consumption of women and preschool children are 861 g and 499 g in raw as-purchased form, respectively. By comparison, Filipino adult women from 13-19 years old consumed 709 g and Filipino preschool children consumed 492g, of which milk and milk product contributed the largest amount at 188g; cereal and cereal products, accounting for 148g; fish and fish products at 36g; and vegetables 16g. Fish and OAAs were the largest consumption by women and preschool children, estimated at 145.3 g and 52.9 g, respectively. Our findings are less than those in the study by Touch Bunthnag et al. (2011) at 172.7 g, perhaps because the surveys were conducted in different seasons. Cambodian women's diet has a total energy of 1976 Kcal, the largest amount of energy (up to 71%) coming from carbohydrates, with a good contribution from proteins at 13%, but low contribution from fats and oils at 16%. Cambodian preschool children's diet has a total energy of 844.9 Kcal, of which carbohydrate generates the largest amount (68%), protein 15% and fats and oils 17%. The study conducted in Cambodia by FAO (2012) found that the contribution of total energy from carbohydrate was 76%, whereas the shares of protein and fat to the overall energy supply were 10% and 14%, respectively. A study by Phuong H Nguyen et al. (2013) in Vietnam showed that energy intake of Vietnamese women was 2196 kcal/day with 65.5%, 14.8%, and 19.5% coming from carbohydrate, protein and fat, respectively.

Our study found that fish and OAAs contributed to energy intake of Cambodian women at 69.7% (Table 14) and of preschool children at 72.1% (Table 15) to the total animal energy intake. Fish is also the source of fats in contributing to the total animal fat intake at 54% (Table 14) and 60% (Table 15) of women and preschool children, respectively. More importantly, fish is a main source of protein, providing up to 80% and 78% of the total animal protein intake and 78% for women and preschool children, respectively.

Another study by United Nation Children's Emergency Fund (UNICEF)/World Food Program (WFP) showed that fish is part of the daily diet of 74%–80% of all children of over 11 months old. Fats and protein contributed from fish significantly mitigated caloric deficiency in women's and preschool children's diets and perhaps the protein-energy that exists in developing countries like Cambodia. Fish contribute some fat but overall intake of fat was low, far lower than the level of fats to total dietary energy recommended at 30%–40% for infants and 20%–30% for adults (RENI 2002). The low fat intake is the reason for low calorie intake. Fish provides protein, which the body uses for optimal growth, but in the context of low calorie intake the body must turn to protein to satisfy energy needs. This form of protein-calorie malnutrition (Marasmus) is the major reason for stunted growth and development in Cambodia. Another form of protein-calorie malnutrition (Kwashiorkor) is simple protein deficiency. This type is not common in Cambodia and its rarity can be attributed to the availability of protein from fish. The contribution of dietary energy from protein, 13% for women and 15% for preschoolers, to total dietary energy per capita is in the recommended range of 10%–15% of total protein intake per individual.

Aside from contributing to the total energy intake, fat of fish contains essential fatty acids namely, linoleic acid (omega 6), the precursor of arachidonic acid (ARA) and linolenic acid (omega 3), the precursor of DHA. These nutrients are not synthesized by the body, but must be obtained from food and are known to benefit health. DHA is a key component of the phospholipids in membranes of the eyes and brain, essential for brain and eye development infants and children. It reduce the risks of heart disease and stroke, prevents blood clots, lowers blood pressure, protects against irregular heartbeats, reduces inflammation, strengthens the immune system, and is essential for normal growth and development for healthy skin, normal growth, and reproduction. A diet that is deficient in DHA is associated with poor growth, skin lesions, reproductive failure, and fatty liver.

Beside its key contribution in meeting primarily protein and energy requirements, fish plays a significant role in meeting iron, zinc, and vitamin A requirements in women and preschool children. Iron functions as part of hemoglobin, which transports oxygen in blood to cells and part of myoglobin in muscles, which makes oxygen available for muscle contraction. Iron is part of an enzyme in the immune system to help protect against infections and is involved in making amino acids, collagen, hormones, or normal brain functions, for synthesis of neurotransmitters and brain growth in humans.

Overall, half of the Cambodian women surveyed met the recommended intake for energy. More than two-thirds (65.7%) of women met at least 80% of the recommended intake for protein, 1/10 of women met at least 80% of the recommended intake of iron intake, nearly one-fourth of women met at least 80% of the recommended intake of calcium, and 28% of women met at least 80% of the recommended intake of vitamin A.

In comparison, the Philippines Food Consumption Survey (2008) of adult Filipino women showed that only 17.9% met the recommended dietary energy requirement; 50.1% met the protein RDA; 12.3% met the iron RDA; and was 16% lower at meeting Vitamin A RDA. On the other hand, 29.5% of Cambodian preschool children met the recommended intake for energy, 53.3% met at least 80% of the recommended intake for protein, 24.1% met at least 80% of the recommended iron intake, 8% met at least 80% of the recommended intake of zinc, and less than 20% of preschool children met at least 80% of the recommended intake of vitamin A. The Philippines Food Consumption Survey (2008) showed that only 17.8% of Filipino preschoolers met the recommended dietary energy intake, 48.3% met the protein RDA, 25.2% met the iron RDA, and 26% met the vitamin A RDA.

CONCLUSION

Cambodia's natural resources provide a foundation for food security, income, and employment for their livelihood. Most of the rural people rely on rice cultivation, harvesting of fish, and OAAs. Rice and fish are the traditional staple foods playing an important role in the diets of women and children. Rice is the main source of energy and fish is the main source of animal protein. Fish is the major contributor of key micronutrients such as iron, zinc, calcium, and vitamin A in women and children. Nutritional status of the rural poor women and children was low. The low intake of micronutrients in comparison to the recommended daily intake put them in the risk of micronutrient deficiencies. Fish is a nutritionally important animal food source contributing to the daily diets of the women and children in poor rural households.

QUANTIFIED ANTICIPATED BENEFITS

This investigation has provided recommendations for better nutrition in women and children in Cambodia. Two Master's students were involved in this investigation (one female and one male). Four undergraduate students were also supported for their dissertations (two females and two males). Three IFReDI staff were involved (one female and two males). Two hundred and twelve participants (155 women) attended the series of consultation and dissemination meetings and workshops on results of the investigation, and formulating recommendations for better nutrition in women and children. Three hundred fact sheets and policy briefs were directly provided to the women sampled in the study. One thousand and two hundred (1200) fact sheets and policy briefs were delivered to IFReDI/FiA staff, scientists, researchers, government officers, NGOs, and women which are direct and indirect benefits from the projects.

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TABLES AND FIGURES

Table 1. The recommended dietary allowances per day by age group.

Population Group	Weight (kg)	Energy (Kcal)	Protein (g)	Iron (mg)
		Infants, months		
Birth-< 6	6	560	9	0.38
6-<12	9	720	14	10
		Children, years		
1-3	13	1070	28	8
4-6	19	1410	38	9
7-9	24	1600	43	11
		Males, years		
10-12	34	2140	54	13
13-15	50	2800	71	20
16-18	58	2840	73	14
19-29	59	2490	67	12
30-49	59	2442	67	12
50-64	59	2170	67	12
65+	59	1890	67	12
		Females, year		
10-12	35	1920	49	19
13-15	49	2250	63	21
16-18	50	2050	59	27
19-29	51	1860	58	27
30-49	51	1810	58	27
50-64	51	1820	58	27
65+	51	1410	58	10
		Pregnant women		
Trimester				
First		66		27
Second	+300	66		34
Third	+300	66		38
		Lactating Women		
1st 6 months	+500	105		27
2nd 6 months	+500	105		30

Table 2. Percentage distribution of the Cambodian women in this survey by age group and number of children.

Characteristic	Percent (%)
Age Group (Year) (n=300)	
15-19	1.7
20-24	22.7
25-29	30.7
30-34	26.3
35-39	9.0
40-44	6.0
45-49	2.7
50+	1.0
Minimum	17
Maximum	53
Mean	29.6
Std. Deviation	6.6
Marriage Age Group (Year) (n=300)	
15-19	8.3
20-24	86.7
25-29	5.0
Minimum	13
Maximum	46
Mean	21.7
Std. Deviation	4.06
Number of Living Children(n=343)	
1-2 children	70.7
3-4 children	23.7
5+ children	5.7
Minimum	1
Maximum	8
Mean	2.1
Std. Deviation	1.4

Table 3. Percentage distribution of Cambodian women sampled in this survey by educational attainment and employment.

Characteristic	Percent (%)
Educational Attainment(n=300)	
No Schooling	10.3
1-6 grade	29.3
7-9 grade	45.0
10-12 grade	12.3
University	3.0
Ability to read(n=300)	
Yes	69.0
No	31.0
Employment (n=300)	
Fishing	41.5
Agricultural Farmer	62.8
Animal Husbandry	40.0
Employment has wage	13.6
Small business at home	16.3
Labor	42.5
House Wife	3.3
Other Works (28 different kinds of job items)	21.7
Number of Jobs (n=300)	
One Job	12.0
Two Jobs	49.2
Three Jobs	30.2
Four Jobs	8.6

Table 4. Percentage of households (of Cambodian women sampled in this survey) possessing durable goods, using means of transportation, owning types of houses, and owning agricultural land.

Possession	Percent (%)
Household effects (n=300)	
TV	55.8
Radio	29.9
Mobile Telephone	77.4
Others (CD/DVD, refrigerator, generator, fans, thresher, water pump machine, air-condition, wood cutting machine, electric eooker)	15.6
Means of Transport (n=300)	
Bicycle	43.5
Motorcycle	64.1
Car	2.7
Kour Yorn	6.0
Boat	1.0
Housing Type (n=300)	
Wooden House	94.0
Concrete House	6
Ownership of agricultural land (n=300)	
Family has agricultural land (other than the piece of house land lot)	56.0
Family does not have agricultural land (other than the piece of house land lot)	44.0

Table 5. Percentage distribution of drinking water and type of toilet sanitation facilities by Cambodian women sampled in this survey.

Characteristic	Percent (%)
Household drinking water (n=300)	
Rainwater	78.7
River	51.2
Mechanical/Hand Pump	31.6
Pipe/running water	23.9
Electric Pump	1.3
Type of toilet sanitation facilities (n=300)	
Open Air toilet	43.5
Own Toilet	43.2
Shared Toilet	13.0

Table 6. Percentage distribution of breastfeeding status, exclusive breastfeeding, and child health care for preschool children sampled in this survey.

Characteristic	Percent (%)
Breastfeeding Status (n=343)	
Child has ever been breastfed	97.7
Child has not ever been breastfed	2.3
Frequency of Exclusive Breastfeeding (month) among under 6 month child (n=343)	
<=6	84.2
5-4	7.5
3-2	3.4
1-0	3.4
Child Care (n=290)	
Once in a week or more	3.0
Few times in a month	43
Once in a month	22.2
Few times in a year	22.9
Once in a year or less	5.3

Table 7. Percent distribution of the women's mean daily per capita food consumption across the provinces.

Food Group	All Sample Women		Stung Treng Province		Kampong Thom Province		Prey Veng Province	
	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total
Energy-Giving Foods								
Cereals and products	369.38	42.91	366.05	43.42	365.23	42.71	376.86	42.65
Sugars and syrup	5.08	0.59	2.77	0.33	5.93	0.69	6.32	0.72
Starchy roots and tubers	3.99	0.46	4.55	0.54	3.75	0.44	3.67	0.41
Fats and oils	4.76	0.55	3.14	0.37	4.67	0.55	6.46	0.73
Body-Building Foods								
Fish and OAAs	145.34	16.89	141.14	16.74	140.28	16.40	154.61	17.50
Meat and poultry	42.76	4.97	53.20	6.31	26.69	3.12	48.41	5.48
Eggs	9.53	1.11	4.86	0.58	9.42	1.10	14.33	1.62
Milk and products	4.37	0.51	2.00	0.24	6.08	0.71	5.04	0.57
Legumes, nuts and seed	4.15	0.48	3.64	0.43	4.98	0.58	3.83	0.43
Regulating Foods								
Vegetables	150.60	17.50	148.67	17.63	152.21	17.80	150.94	17.08
Fruits	54.54	6.34	51.48	6.11	70.31	8.22	41.83	4.73
Miscellaneous								
Beverages	54.68	6.35	50.78	6.02	53.43	6.25	59.83	6.77
Condiments and spices	11.54	1.34	10.86	1.29	12.16	1.42	11.59	1.31
All Foods	**861**	**100**	**843**	**100**	**855**	**100**	**884**	**100**

Table 8. Percent Distribution of the preschool-age children's mean daily per capita food consumption across the provinces.

Food Group	All Sample Children		Stung Treng Province		Kampong Thom Province		Prey Veng Province	
	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total	Consumption Raw AP (g/day)	% of Total
Energy-Giving Foods								
Cereals and products	256.54	52.46	250.56	53.63	220.96	48.29	300.52	54.95
Sugars and syrup	6.89	1.41	5.23	1.12	7.47	1.63	8.02	1.47
Starchy roots and tubers	1.78	0.36	0.05	0.01	0.03	0.01	5.32	0.97
Fats and oils	0.85	0.17	0.87	0.19	0.57	0.13	1.13	0.21
Body-Building Foods								
Fish and OAAs	52.99	10.84	51.05	10.93	50.42	11.02	57.99	10.60
Meat and poultry	10.93	2.24	11.81	2.53	7.99	1.75	13.10	2.40
Eggs	7.72	1.58	7.66	1.64	5.96	1.30	9.61	1.76
Milk and products	44.57	9.11	38.07	8.15	46.53	10.17	49.53	9.06
Legumes, nuts and seed	0.21	0.04	0.07	0.02	0.47	0.10	0.08	0.02
Regulating Foods								
Vegetables	20.57	4.21	17.18	3.68	21.37	4.67	23.33	4.27
Fruits	29.43	6.02	29.61	6.34	27.03	5.91	31.92	5.84
Miscellaneous								
Beverages	53.42	10.92	52.29	11.19	64.55	14.11	43.93	8.03
Condiments and spices	3.12	0.64	2.78	0.59	4.23	0.92	2.38	0.44
All Foods	489	100	467	100	458	100	547	100

Table 9. Ten commonly consumed fish species and percent distribution of the women's mean daily per capita fish consumption.

No.		Khmer Name	Common Name	Scientific Name	Mean	%
1	Trye Riel	ត្រីរៀល		***Cirrhinus* sp.**	31.05	21.04
2	Trye Ros	ត្រីរ៉ស់	Striped snakehead	***Channa striata***	19.14	12.97
3	Trye Chhpin	ត្រីឆ្ពិន	Mekong silver barb	***Hypsibarbus pierrei***	15.04	10.19
4	Trye Kanhchus	ត្រីកញ្ចុះ		***Mystus* sp.**	12.64	8.56
5	Trey Chhlang	ត្រីឆ្លាំង	Asian redtail catfish	***Hemibagrus* sp.(cf. *nemarus*)**	9.6	6.5
6	Trey Andeng	ត្រីអណ្តែងរឹង	Walking catfish	***Clarias batrachus***	9.17	6.21
7	Trey Deab	ត្រីដៀប	Giant snakehead	***Channa micropeltes***	7.48	5.07
8	Trey Chab	ត្រីចាប	Pirapatingga	***Piaractus brachypomus***	5.41	3.66
9	Trey Kranh	ត្រីក្រាញ់	Climbing perch	***Anabas tastudineus***	4.38	2.96
10	Trey Pou	ត្រីពោ	Spotted-ear catfish	***Pangasius larnaudii***	4.34	2.94
11	Other species				27.05	19.9

Table 10. Ten commonly consumed fish and percent distribution of the preschool-age children’s mean daily per capita fish consumption.

No.		Khmer Name	Common Name	Scientific Name	Mean (g)	%
1	Trey Riel	ត្រីរៀល		***Cirrhinus* sp.**	12.9	24.3
2	Trey Ros	ត្រីរ៉ស់	Striped snakehead	***Channa striata***	9.6	17.8
3	Trey Kanhchus	ត្រីកញ្ចុះ		***Mystus* sp.**	5.1	9.6
4	Trey Chhpin	ត្រីឆ្ពិន	Mekong silver barb	***Hypsibarbus pierrei***	4.2	8.0
5	Trey Andeng	ត្រីអណ្ដែងរឹង	Walking catfish	***Clarias batrachus***	2.8	5.2
6	Trey Chhlang	ត្រីឆ្លាំង	Asian redtail catfish	***Hemibagrus* sp.(cf. *nemarus*)**	2.6	4.8
7	Trey Chab	ត្រីចាប	Pirapatingga	***Piaractus brachypomus***	1.4	2.7
8	Trey Chongva	ត្រីចង្វា		***Rasbora* sp.**	1.4	2.6
9	Trey Deab	ត្រីដៀប	Giant snakehead	***Channa micropeltes***	1.3	2.5
10	Trey Tuke	ត្រីតុកកែ		***Cephalophlis* sp.**	1.0	2.0
11	Other species				10.8	20.5

Table 11. Mean daily intake and percent adequacy of energy and nutrient intake of Cambodian women surveyed in this study.

Energy and Nutrient	All Women	Stung Treng	Kampong Thom	Prey Veng
Energy(Kcal)	1976.0	2032.1	1813.3	2082.6
Meeting 100% of Energy Intake (%)	50.0	52.0	42.0	56.0
Protein(g)	65.7	67.4	61.9	67.8
Meeting 80% of Protein Intake (%)	71.0	75.0	66.0	72.0
Iron(mg)	13.0	11.7	13.9	13.2
Meeting 80% of Iron Intake (%)	10.7	13.0	5.0	14.0
Zinc(mg)	3.8	3.1	4.2	4.1
Meeting 80% of Zinc Intake (%)	36.3	28.0	46.0	35.0
Calcium(g)	545.2	478.4	537.7	619.3
Meeting 80% of Calcium Intake (%)	24	21.0	26.0	24.0
Vitamin A(mcg RE)	458.4	531.4	438.8	404.9
Meeting 80% of Vitim A Intake (%)	28	24.0	29.0	31.0
Carbohydrate(g)	355.7	346.7	349.0	371.4
Fats(g)	35.5	33.5	28.9	44.0

Table 12. Mean daily consumption and percent adequacy of energy and nutrient intake of the Cambodian preschool-children surveyed in this study.

Energy and Nutrient	All Children	Stung Treng	Kampong Thom	Prey Veng
Energy(Kcal)	844.94	775.94	830.54	922.90
Meeting 100% of Energy Intake (%)	29.58	22.22	28.57	37.38
Protein(g)	28.72	26.72	26.36	32.90
Meeting 80% of Protein Intake (%)	53.37	46.66	48.57	61.68
Iron(mg)	5.09	4.83	4.75	5.67
Meeting 80% of Iron Intake (%)	24.11	15.28	22.85	32.71
Zinc(mg)	1.68	1.26	1.60	2.14
Meeting 80% of Zinc Intake (%)	8.03	2.85	5.71	14.95
Calcium(g)	277.77	207.56	287.95	332.73
Meeting 80% of Calcium Intake (%)	23.79	15.23	18.09	27.10
Vitamin A(mcg RE)	241.03	233.41	268.03	221.59
Meeting 80% of Vitim A Intake (%)	18.64	13.33	22.85	18.69
Carbohydrate(g)	133.72	119.51	127.52	152.95
Fats(g)	15.10	13.08	13.13	18.90

Table 13. Percentage contribution of particular food groups to total energy and nutrient intakes of Cambodian women surveyed in this study.

Food Group (%)	Energy	Protein	Fats	Cars	Iron	Zinc	Calcium	Vit A
Cereals and products	60.93	30.91	14.84	77.14	43.08	17.35	22.08	7.83
Starchy roots and tubers	0.09	0.03	0.01	0.13	0.11	0.02	0.08	0.00
Legumes, nutsand seed	0.13	0.18	0.51	0.03	0.32	0.27	0.05	0.00
Vegetables	2.05	4.15	1.22	6.38	14.11	15.60	16.12	26.63
Fruits	1.45	0.82	0.43	1.76	3.06	2.54	1.45	29.96
Meat and poultry	3.57	11.04	17.01	0.04	7.17	33.37	3.85	0.26
Fish and OAAs	9.73	48.91	28.47	12.51	25.82	27.83	39.65	24.93
Eggs	0.64	1.43	7.20	0.03	1.65	1.14	4.29	3.31
Milk and products	0.14	0.11	4.77	0.13	0.08	0.16	3.71	0.15
Fats and oils	1.15	0.00	13.78	0.00	0.00	0.06	0.10	0.10
Sugars and syrup	0.18	0.08	0.31	0.16	0.03	0.00	0.42	0.10
Condiments and spices	0.33	1.09	0.55	0.12	4.29	1.03	6.88	2.87
Beverages	19.60	1.25	10.89	1.56	0.27	0.60	1.32	0.86

Table 14. Percentage contribution of particular food groups to total energy and nutrient intakes for Cambodian preschool children surveyed in this study.

Food Group (%)	Energy	Protein	Fats	Cars	Iron	Zinc	Calcium	Vit A
Cereals	57.47	34.57	21.50	73.46	44.46	4.44	12.10	2.07
Starchy roots and tubers	0.32	0.06	0.08	0.48	0.40	0.29	0.21	0.00
Legumes, nuts and seed	0.15	0.16	0.71	0.04	0.37	0.38	0.04	0.00
Vegetables	0.82	1.46	0.48	5.70	6.60	6.92	5.44	11.73
Fruits	3.79	1.34	1.25	4.82	7.25	5.91	2.05	38.06
Meat and poultry	2.60	7.63	9.32	0.10	5.32	19.47	0.41	0.71
Fish and OAAs	12.12	40.86	28.41	0.90	14.55	18.21	34.93	16.61
Eggs	2.08	3.84	9.55	0.15	5.58	3.62	2.29	12.12
Milk and products	7.77	7.42	11.99	7.38	11.53	39.71	36.32	16.67
Fats and oils	1.14	0.00	7.89	0.00	0.00	0.00	0.00	0.00
Sugars and syrup	2.19	0.64	3.18	2.12	0.24	0.00	1.82	0.00
Condiments and spices	0.28	0.84	0.40	0.13	3.11	1.01	2.94	1.20
Beverages	9.27	1.16	5.24	4.72	0.60	0.05	1.45	0.82

Table 15. Percentage contribution of fish to total animal energy and nutrient intakes for Cambodian women surveyed in this study.

Animal Food Source (%)	Energy	Protein	Fat	Cars	Iron	Zinc	Calcium	Vit A
Meat and poultry	25.60	17.99	32.29	0.34	20.70	53.53	8.06	0.90
Fish and OAAs	69.78	79.68	54.04	99.39	74.54	44.64	82.97	87.48
Eggs	4.62	2.33	13.67	0.27	4.76	1.83	8.97	11.62

Table 16. Percentage contribution of fish to total animal energy and nutrient intakes for Cambodian preschool children surveyed in this study.

Animal Food Source (%)	Energy	Protein	Fat	Cars	Iron	Zinc	Calcium	Vit A
Meat and poultry	15.49	14.59	19.72	11.46	20.89	47.14	1.08	2.42
Fish and OAAs	72.14	78.08	60.08	93.75	57.19	44.10	92.83	56.41
Eggs	12.37	7.33	20.20	4.49	21.92	8.77	6.09	41.17

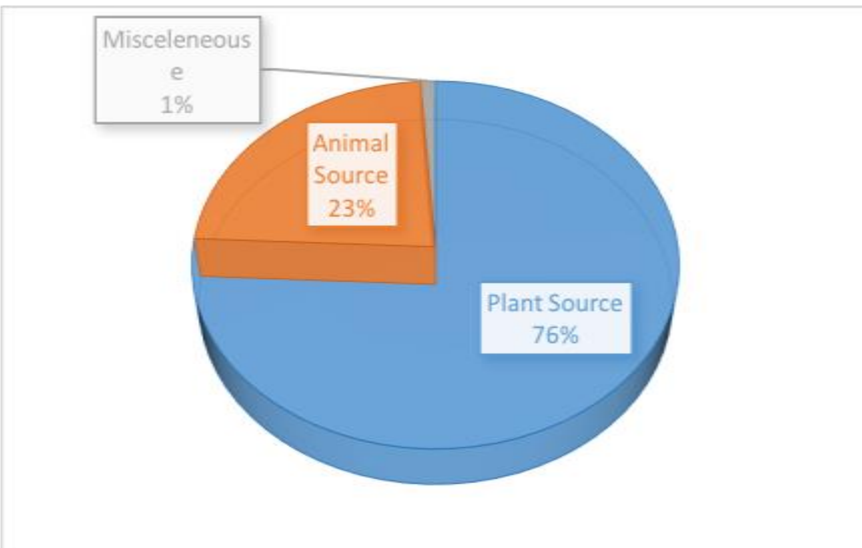

Figure 1. Percent contribution of food sources of mean daily per capita food consumption for Cambodian women surveyed in this study.

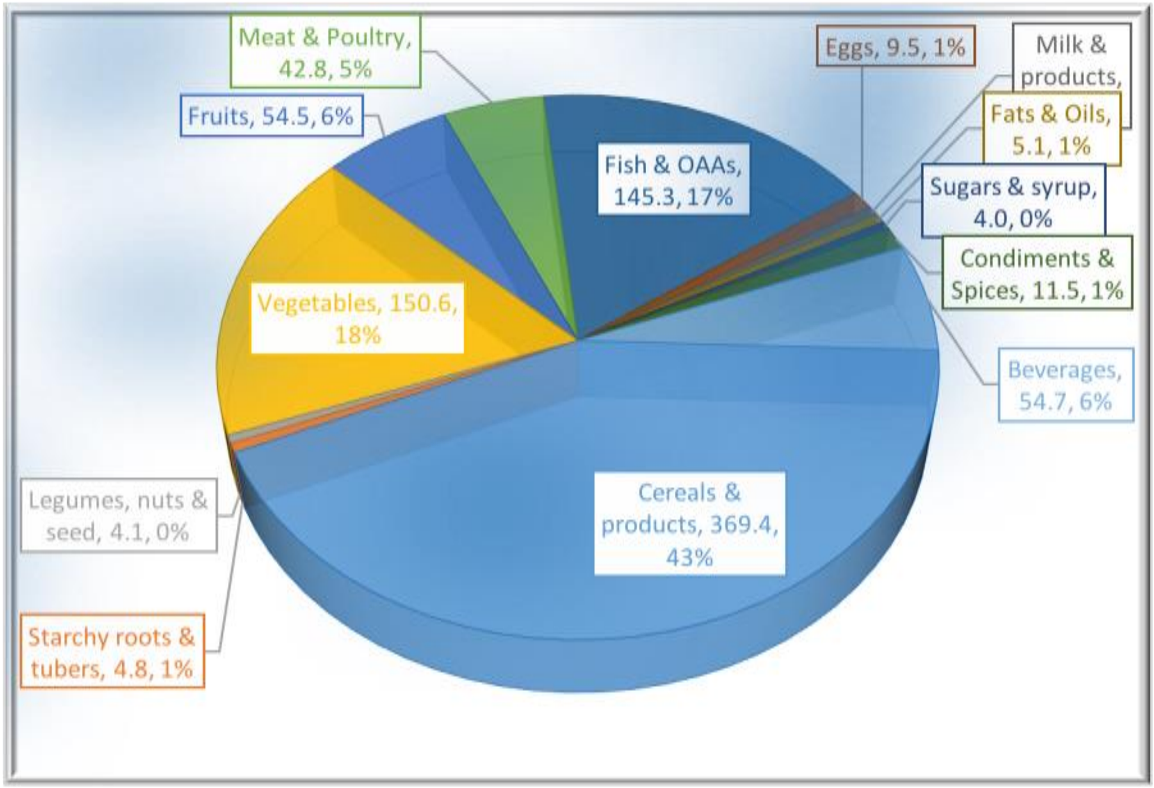

Figure 2. Percent distribution of mean daily per capita food consumption by particular food group for Cambodian women surveyed in this study.

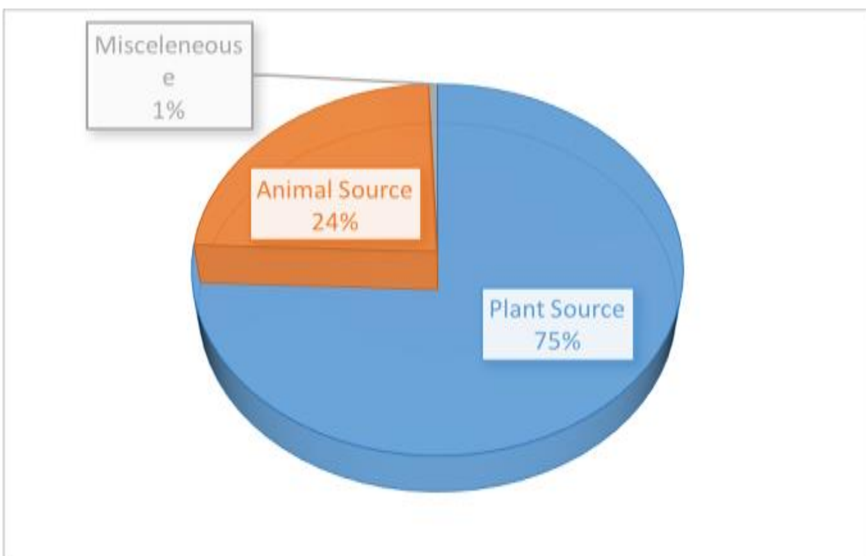

Figure 3. Percent contribution of food sources to mean daily per capita food consumption by Cambodian preschool children surveyed in this study.

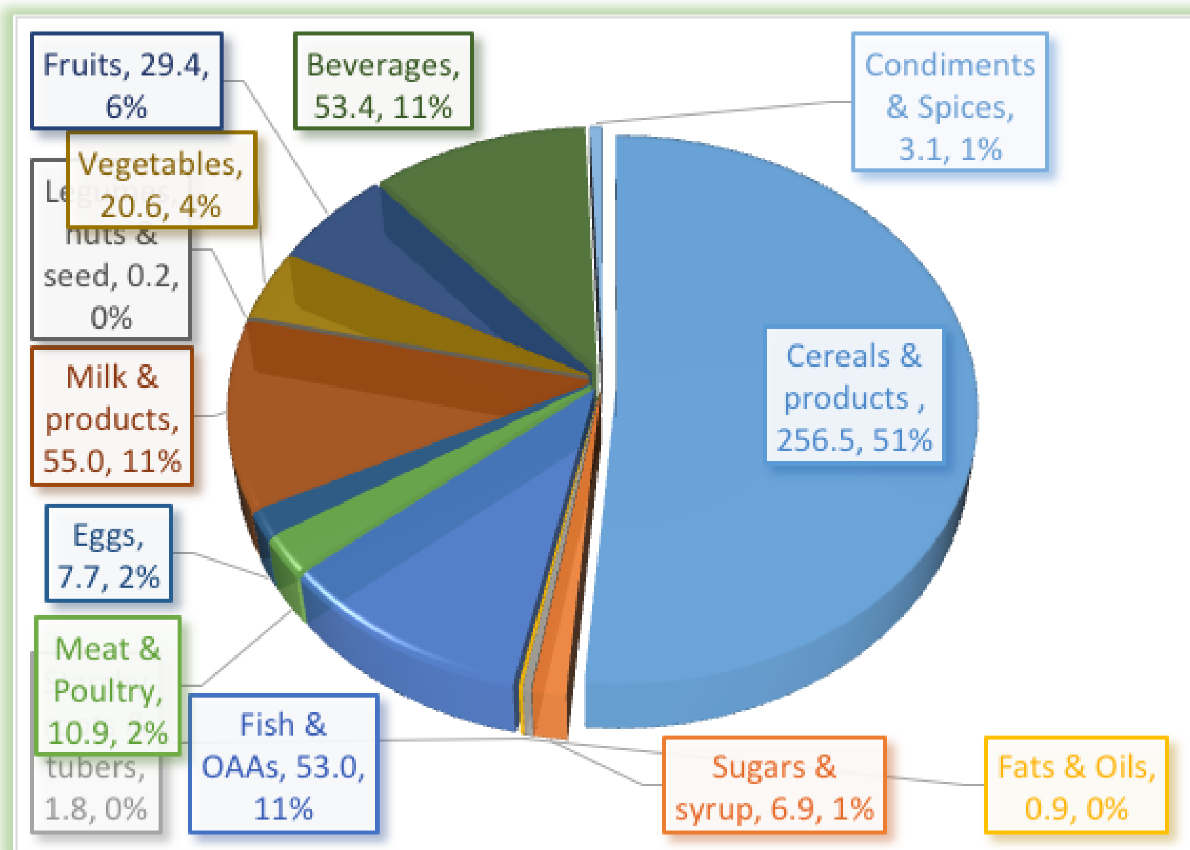

Figure 4. Percent distribution of the mean daily per capita food consumption by particular food group for Cambodian preschool children surveyed in this study.

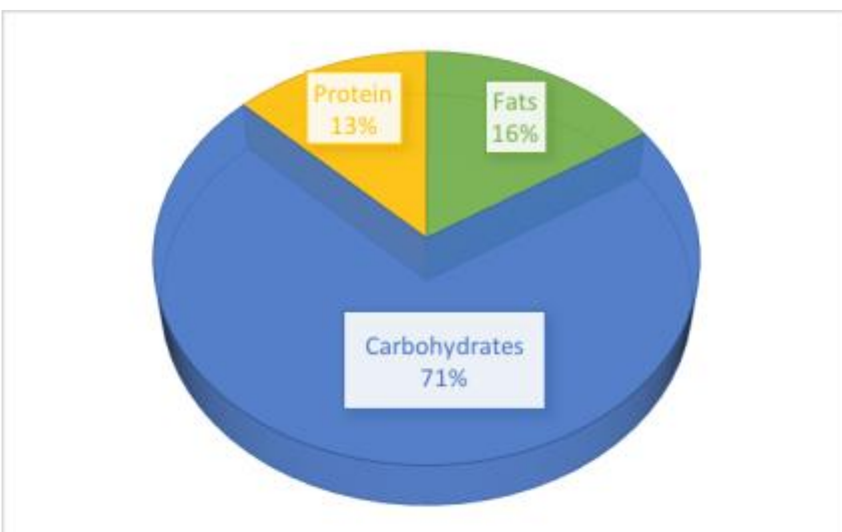

Figure 5. Percent contribution of carbohydrate, fats and protein to total dietary energy for Cambodian women surveyed in this study.

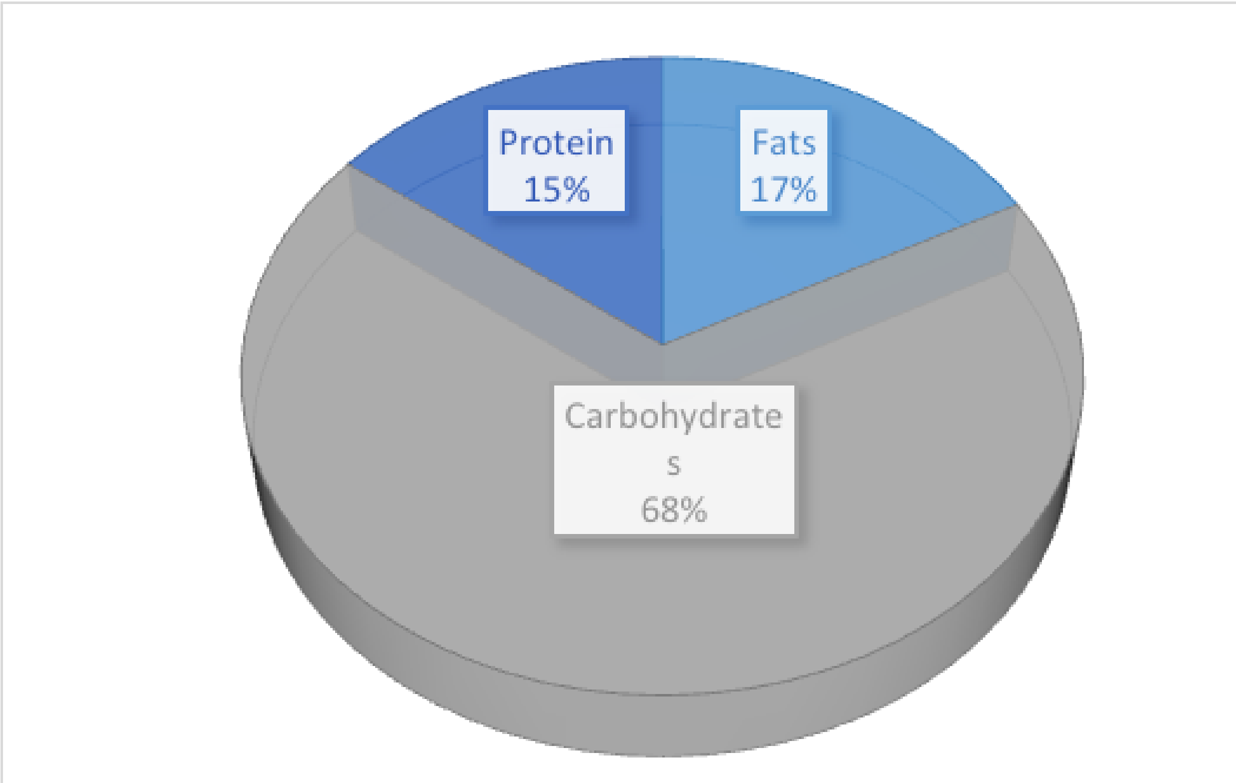

Figure 6. Percent contribution of carbohydrate, fats and protein to total dietary energy for Cambodian preschool children surveyed in this study.

Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fisheries and Aquaculture in Cambodia, Part II

NUTRITIONAL COMPOSITION OF NUTRIENT DENSITY OF COMMONLYCONSUMED FISH, OTHER AQUATIC ANIMALS, AND PROCESSED FISH CONSUMED BY WOMEN AND CHILDREN IN CAMBODIA

Enhanced Trade and Investment for Global Fishery Markets/Study/13HHI02UC

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ABSTRACT

The results from our food and nutrient consumption survey found that women commonly consume 43 species of fish and Other Aquatic Animal (OAA) species and preschoolers commonly eat 38 species of fish and OAAs. Thirteen commonly consumed fish species; three OAAs species; and two processed fish species were selected for nutrient evaluation. The primary purpose of this activity was to determine the nutritional composition of the selected commonly consumed fish species; OAAs; and processed fish that are consumed by women and preschool children with a focus on the key micronutrients iron, calcium, and phosphorus and the key macronutrients protein and fat. Protein content varied from 10.11% to 16.81% in fresh fish and from 37.38% to 38.52% in processed fish. Fat content ranged from 0.99% to 4.25% in fresh fish and from 6.01% to 24.65% in processed fish. Calcium content ranged from 15.0 to 123.9 mg/100 g in fresh fish and from 19.1 to 83.3 mg/100 g in processed fish. Phosphorus content ranged from 0.57 to 3.89 mg/100g in fresh fish and from 1.15 to 2.06 in processed fish. Iron content ranged from 0.21 to 0.83 gm/100g in fresh fish and from 0.30 to 0.38 mg/100g in processed fish.

INTRODUCTION

The food and nutritional consumption survey in women and preschool children within Investigation 5 found that women commonly consume 43 species of fish and OAA and preschoolers commonly eat 38 species of fish and OAAs (first FIR for Investigation 5). Thirteen commonly consumed fish species, specifically Trey Riel (*Cirrhinus caudimaculatus*), Trey Ros (*Chitala chitala),*Trey Kanhchos (*Mystus spp.),* Trey Chhpin (*Barbonymus gonionotus),* Trey Changwamoul (*Rasbora tornieri),* Trey Slat (*Notopterus notopterus*), Trey Andaing Toun (*Clarias microcephalus*), Trey Andaing Roueng (*Clarias batrachus*), Trey Chhlounh (*Macrognathus siammensis*), Trey Po (*Pangasius larnaudii*), Trey Chhlang (*Hemibagrus nemurus*), Trey Changvasrei (*Esomus longimanus),* and Trey Kranh (*Anabas testudineus*); three OAAs, specifically fresh snail (*Pila ampullaceal*), fresh rice field shrimp (*Macrobrachium lancasteri*), and fresh rice field crab (*Potamon sp.*); and two processed fish species smoked Trey Riel (*Cirrhinus caudimaculatus*), and sun-dried-salt Tre Ros (*Chitala chitalaI*) were selected for nutrient evaluation.

OBJECTIVE

The primary purpose of this activity was to determine the nutritional composition of the selected commonly consumed fish species, OAAs, and processed fish that are consumed by women and preschool children with a focus on key micronutrients (iron, calcium, and phosphorus) and macronutrient (protein and fat).

METHODS

Collection of samples. Samples of fish were purchased or collected from public markets in Kompong Chhnang, Kandal, and Takeo provinces and Phnom Penh city; and from Dai fisheries in Tonle Sap River in Cambodia. The samples of fish were randomly selected and physicochemical properties were analyzed in the Industrial Laboratory Centre of Cambodia (ILCC), Ministry of industry in Cambodia.

Proximate analyses. Fresh and processed samples were analyzed for proximate composition using standard methods (AOAC 1990). Proximate analysis is a quantitative method of determining the macronutrients in food. This includes moisture, total ash content, crude fat, and protein. Moisture was determined using a drying oven, ash in a muffle furnace, protein was by the Kjeldahl method and fat was by Soxhlet extraction.

Micronutrient analyses. Phosphorus, iron, and calcium were also analyzed by AOAC (1990) methods, specifically the molybdovannate method for phosphorus, the hydroxylammonium method for iron, and the muricide method for calcium.

RESULTS

Table 1 and 2 show the nutrient density value of 13 fresh water fish species, three OAAs (rice-field snail, rice-field shrimp, and rice-field crab); and two processed fish (smoked *Henicorhynchus sp*., and sun-dried-salt *Channa sp*.). The protein content in fresh and processed fish varied from 10.11% to 16.81% for fresh fish and 37.38% to 38.52% for processed fish (Table 1). Fat content ranged from 0.99% to 4.25% in fresh fish and 6.01% to 24.65% in processed fish (Table 1). Ash contents were crab (13.34 %), *Channa sp*. dried fish (22.78%), Trey Chhlounh (*Macrognathus siammensis*) (25.33%), and Trey Slat (*Notopterus notopterus)* (25.66%). Fresh fish had low ash content (2.17% to 4.26%) (Table 2). The moisture content of Trey Andeng Reung ranged from 63.42% to 84.48% in fresh fish and from 20.86% to 27.59% in processed fish (Table 2). The calcium content in fresh fish ranged from 15.0 to 123.9 mg/ 100 g (Table 1). The phosphorus content ranged from 0.57 to 3.89 mg/100g in fresh fish and 1.15 to 2.06 in processed fish (Table 1). Iron content ranged from 0.21 to 0.83 gm/100 g in fresh fish and 0.30 t0 0.38 mg/100g in processed fish (Table 1).

DISCUSSION

Fish are an excellent source of protein, a macronutrient that provides all the essential amino acids that humans need. Proteins are made up of amino acids that are the body's building blocks. These proteins tend to break down and need to be replaced on a daily basis by eating foods that are rich in protein. Protein can be found in both animal and plant foods, however, the concentration of protein is higher in animal foods. For example, 100 g of raw fish has 14-20 g of protein depending on the species compared with only 2.7 g in cooked rice or 8.7 g in cooked beans.

Fish and meat are also more efficient sources of protein. This means that humans are better able to absorb the protein contained in these animal foods compared with plant foods. For many households, fish is more accessible and affordable than meat. People can raise fish in small ponds and rice fields or catch wild fish even if they do not have money to buy fish.

Protein content varied from 10.11% to 16.81% for fresh fish and 37.38% to 38.52% for processed fish. It can be concluded that the protein content was not lost during processing. The slight increase in protein contents after drying may be due to product dehydration which concentrated proteins, thus increasing the nutritional value of fish. According to Ahmed et al. (2011), fresh fish had lower protein content (between 18.81 and 21.23 g/100g) compared to smoked-dried (69.10 and 75.72g).

Fat content ranged from 0.99% to 4.25% in fresh fish and 6.01% to 24.65% in processed fish. Fresh fish flesh appeared to be relatively low in fats and this is also due to the concentration of other components of fish after drying. According to Ahmed et al. (2011) fat content is slightly raised after sun-drying and smoke-drying.

Ash content was high in crab (13.34%), Treyros dried (*Channa* sp.) (22.78%), Trey Chhlounh (*Macrognathus siammensis*) (25.33%), and Trey Slat (*Notopterus notopterus)* (25.66%). Fresh fish was low in ash content (2.17% to 4.26%) (Table 2). Ahmed et al. (2011) found that ash content of smoked-dried fish were high, 8.13-9.86 g/100 g, while much lower values were obtained for fresh fish. Probably the high ash values of sun-dried or smoke-dried fish flesh were due to water loss during drying that concentrated other components of fish like its mineral contents.

The moisture content of Trey Andeng Reung ranged from 63.42% to 84.48% in fresh fish and from 20.86% to 27.59% in processed fish. The moisture content of the fresh fish is comparable to that in the study conducted by Ahmed et al. (2011); however, dried samples (around 79-80% moisture content) in this study contained considerably high values. Ahmed et al. (2011) reported that moisture content varied between 81.49 and 84.33 g/100 g for fresh fish; between 7.58 and 8.95 g/100 g for smoked-dried fish and between 11.5 and 14.06 g/100 g for sun-dried fish. This could be explained by the fact that during smoke-drying the flesh loses water in the initial phase. Contrary to sun-dried fish, which tends to absorb moisture from high ambient air humidity, the protective coating of smoked-dried fish minimizes rehydration.

The effect of traditional drying processes on the nutritional values of fish was studied by Eves and Brown (1993). They observed that different processing and drying methods have different effects on nutritional compositions of fish. This is because heating, freezing, and exposure to high concentrations of salt lead to chemical and physical changes and therefore digestibility is increased, due to protein denaturation, but the content of thermolabile compounds and polyunsaturated fatty acids is often reduced (George, 2012).

Fish bones are very rich in calcium which humans need to develop and maintain strong bones and teeth. The popular Cambodian meal of small fish species that are fried and eaten whole including the head and bones is an important dietary source of calcium. Teenage boys and girls need calcium because they are growing rapidly at this age. A serving of 100 g of small fish species such as *chanwa phlieng* or *chanwa mool* will provide 50% of their daily requirement. The same serving will provide 70% of the daily requirement for adult men and women.

The calcium content in fresh fish ranged from 15.0 to 123.9 mg/100g. Kotchanipha et al. (2012) similarly reported that fresh fish had a calcium content of 111.92 mg/100 g. On the other hand, processed fish contained between 19.1 and 83.1 mg/100g. Kotchanipha et al. (2012) reported that processed fish had 60 mg/100 g. According to the ASEAN Food Consumption Table (2000), calcium levels are 44 mg/100 g for fresh fish and 274 mg/100 g for processed fish. However, Dipak et al. (2013) reported that calcium content was 52.79 mg/100 g in fresh fish.

Small fish are eaten whole, including the bones, and are, therefore, a rich calcium source. Large fish do not contribute to calcium intake because their bones are discarded (Roos, 2001). In Cambodia, the majority (80%) of households cook the commonly consumed fish, *Trey Changwa Plieng*, with the head intact. The contents of calcium and iron were considerably higher (58, and 25%, respectively) in raw, cleaned samples with the head than in samples in which the head was discarded during cleaning (Thorseng and Gondolf, 2005). The calcium in small fish has been shown to have the same high bioavailability as that from milk in both humans and rats (Hansen et al. 1998; Larsen et al. 2000).

The phosphorus content ranged from 0.57 to 3.89 mg/100g in fresh fish and 1.15 to 2.06 in processed fish. Kotchanipha et al. (2012) reported that fresh fish had a calcium content of 50.54 mg/100 g compared to processed fish at 23.48 mg/100 g. However, the ASEAN Consumption Table (2000) indicated phosphorus content of 0.15 % for fresh fish and 0.53 % for processed fish.

The iron content ranged from 0.21 to 0.83 gm/100 g in fresh fish and 0.30 to 0.38 mg/100g in processed fish. The ASEAN Food Consumption Table (2000) indicated that iron content was 0.12 mg/100g in fresh fish and 0.2 mg/100g in processed fish. Iron in fish is present in the forms of heme iron, a high-molecular subpool of complex-bound nonheme iron, and inorganic iron, the proportions varying with fish species (Roos et al. 2007). Analysis of 16 common Cambodian fish species showed that, on average, 30 % of the iron in these fish was present as inorganic iron, the remainder being heme iron and complex-bound nonheme iron. The bioavailability of heme iron is estimated as 25 % for complex-bound nonheme iron and 10% for inorganic iron (Roos et al. 2007).

CONCLUSION

Fish have high protein, calcium, phosphorus, and iron content. Protein content varied from 10.11% to 16.81% in fresh fish and from 37.38% to 38.52% in processed fish. Calcium content ranged from 15.0 to 123.9 mg/100 g in fresh fish and from 19.1 to 83.3 mg/100 g in processed fish. Phosphorus content ranged from 0.57 to 3.89 mg/100g in fresh fish and from 1.15 to 2.06 in processed fish. Iron content ranged from 0.21 to 0.83 gm/100g in fresh fish and from 0.30 to 0.38 mg/100g in processed fish.

The study of food and nutritional survey on women and preschool-children founded that low intakes of iron, zinc, calcium, and vitamin A put Cambodian women and children at risk of micronutrient deficiencies. The recommendations for better nutrition in women and children in Cambodia are below:

- More research should be done to identify nutrient contents of commonly consumed fish species and processed fish products, especially micronutrients consumed by women and children. Since rice-field fisheries are the major source of micronutrients for the rural poor women and children in Cambodia, micronutrient-dense fish species should be incorporated in the cultural practices;
- A program using fish to combat micronutrient deficiencies in women and children in rural areas, focusing on iron, zinc, calcium, and vitamin A;
- Research into improved processing of fish and other aquatic animals caught in open water, lakes, and rice fields, including methods of handing and preservation;
- Research into species, parts of fish and other aquatic animals (such as eyes, head, skin, and meat) and processed fish products that are rich in micronutrients such as iron, zinc calcium, vitamin B complex and Vitamin A with the aim of incorporating these species into cultural practices;
- A nutritional education program at in partnership with partners such as the Cambodian Red Cross in consultation with the National Maternal and Child Health Center and the National Nutrition Program on commonly consumed nutrient-dense species for women (mothers) and young children with additional focus on hygiene and sanitation.

QUANTIFIED ANTICIPATED BENEFITS

This investigation has provided recommendations for better nutrition in women and children in Cambodia. Two Master's students were involved in this investigation (one female and one male). Four undergraduate students were also supported for their dissertations (two females and two males). Three IFReDI staff were involved (one female and two males). Two hundred and twelve participants (155 women) attended the series of consultation and dissemination meetings and workshops on results of the investigation, and formulating recommendations for better nutrition in women and children. Three hundred fact sheets and policy briefs were directly provided to the women sampled in the study. One thousand and two hundred (1200) fact sheets and policy briefs were delivered to IFReDI/FiA staff, scientists, researchers, government officers, NGOs, and women which are direct and indirect benefits from the projects.

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TABLES AND FIGURES

Table 1. Summary of macronutrient and micronutrient composition of fresh and processed fish species in this study.

Nutrients	Fresh		Processed	
Macronutrients	Min (%)	Max (%)	Min (%)	Max (%)
Protein	10.11	16.81	37.38	38.52
Fat	0.99	4.25	6.01	24.65
Micronutrients	Min (mg/100g)	Max (mg/100g)	Min (mg/100g)	Max (mg/100g)
Calcium	15	123.9	19.1	83.3
Phosphorous	0.57	3.98	1.15	2.06
Iron	0.26	0.83	0.3	0.38

Table 2. Nutritional composition of the selected commonly consumed fresh and processed fish species eaten by women and preschoolers in Cambodia.

Loca/Common Name	Scientific Name	Protein (%)	Fat (%)	Ash (%)	MC (%)	Ca (mg/100g)	P (%)	Fe (mg/100g)
Fish Species								
Trey Kanhchos	*Mystus* spp.	13.09	3.70	3.48	76.38	66.1	3.60	0.33
Trey Chhpin	*Barbonymus gonionotus*	16.05	3.46	3.69	67.43	46.9	0.57	0.34
Trey Changwamoul	*Rasbora tornieri*	16.40	1.74	3.48	68.29	62.1	3.89	0.35
Trey Riel	*Cirrhinus caudimaculatus*	13.22	4.25	3.16	70.95	58.2	1.05	0.21
Trey Ros	*Chitala chitala*	15.36	1.61	4.26	76.40	15.0	1.15	0.27
Trey Slat	*Notopterus notopterus*	13.64	1.00	25.66	74.34	102.4	3.97	0.26
Trey Andaing Toun	*Clarias macrocephalus*	14.81	1.00	2.45	73.62	45.3	3.01	0.26
Trey Andaing Roueng	*Clarias batrachus*	14.22	1.00	2.20	63.42	87.3	3.06	0.28
Trey Chhlounh	*Macrognathus siammensis*	14.07	1.00	25.33	74.67	91.1	3.85	0.30
Trey Po	*Pangasius larnaudii*	10.11	1.00	3.54	68.34	72.5	3.20	0.24
Trey Chhlang	*Hemibagrus nemurus*	15.30	0.99	2.17	73.82	123.9	3.48	0.30
Trey Changvasrei	*Esomus longimanus*	16.81	1.00	2.21	73.51	97.9	3.98	0.35
Trey Kranh	*Anabas testudineus*	15.99	1.00	3.37	69.51	82.3	3.70	0.27
Other Aquatic Animals								
Fresh Rice-Field Snail	*Pila ampullacea*	11.63	1.44	2.4	84.48	66.1	1.04	0.83
Fresh Rice-Field Shrimp	*Macrobrachium lanchsteri*	12.01	1.64	2.92	82.16	60.5	0.65	0.34
Fresh Rice-Field Crab	*Potamon sp.*	13.82	2.65	13.34	67.03	56.0	0.75	0.50
Processed Fish								
Smoked Trey Riel	*Cirrhinus caudimaculatus*	38.52	24.65	10.20	20.86	83.3	2.06	0.38
Sun-dried-salt Trey Ros	*Chitala chitala*	37.38	6.01	22.78	27.59	19.1	1.15	0.30

Assessing the Nutritional Impact of Aquaculture Policy in Fish Farming Districts in Tanzania and Ghana

Human Nutrition and Human Health Impacts of Aquaculture/Study/13HHI01PU

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ABSTRACTS

The study assessed the benefits that manifest themselves in nutritional outcomes from households engaged in fish farming in Ghana (Ashanti and Brong Ahafo regions) and Tanzania (Morogoro and Mbeya regions). Fish is an important source of protein and essential micronutrients for many African households and participation in fish farming could have both direct effect through fish consumption, and indirect pathway through an income effect for nutritional impact. The study used the World Food Program's (WFP) Food Consumption Score (FCS) measures to assess nutritional quality with a target on fish. The average FCS value for fish-farming households in Ghana was 72 while that of nonfish-farming households (control group) was 68. In Tanzania, it was 56 for fish-farming households and 58 for the control group respectively. The results suggest that in Ghana, fish-farming households have higher diet diversity and food security than the nonfish-farming households, while in Tanzania, the opposite is the case. A two-stage least squares (2SLS) approach used to analyze the data for Ghana showed that household income, mother's education and residing in an urban area positively affect FCS and consequently dietary diversity and nutritional quality. In Tanzania however, an ordinary least squares (OLS) analysis of the data showed household income, residing in an urban area and the index for wealth positively affect dietary diversity and nutritional quality. The mother's education appears to be a very strong predictor of the household FCS because of her being the main caregiver, and her influence on the household's nutrition can be substantial. Moreover, an educated person is assumed to know the right kinds of foods to buy in terms of nutritional quality as well as the dietary diversity to boost household health. The index for wealth is a good indicator of the household's socioeconomic status and is assumed to influence the purchase and consumption of high-quality and nutritionally balanced foods.

INTRODUCTION

The Millennium Development Goals (MDGs) adopted by the world's leaders at the Millennium Summit of the United Nations in 2000 sought to achieve peace and decent standards of living for every man, woman and child. The MDGs aim to eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality improve maternal health, combat HIV/AIDS, malaria and other diseases, ensure environmental sustainability, and develop global partnerships for development. Tanzania and Ghana committed to the time-bound MDGs and the associated indicators.

Aquaculture is one of the world's fastest growing food production sectors with great potential for food supply and poverty alleviation and is responsible for at least 50% of the fish consumed by humans (Diana 2009). Fish farming has contributed toward poverty alleviation in poor societies in various parts of the world where it is traditionally practiced, e.g., Bangladesh (Jahan et al. 2010) and Nepal (Bhujel et al. 2008). Aquaculture expansion in Asian countries such as Bangladesh and Thailand has led to enhanced food security among adopters and the population at large (De Silva and Davy 2010, Jahan et al. 2010, Lazard et al. 2010). In Bangladesh, Thilsted et al. (2014) reported that even though fish is quite expensive, consumption in small quantities makes a significant difference in contributing to the nutritional quality of the diets of poor people. In Asia, fish was found to be the major source of protein for low income households even though they consumed less compared to rich households (Dey et al. 2005).

Helen Keller International (HKI) established a direct linkage between agriculture and nutrition particularly for farmers and agricultural laborers from homestead food production in Bangladesh, Cambodia, Nepal, and the Philippines (HKI/Asia-Pacific 2001). The HKI program promoted small-scale production and consumption of micronutrient-rich crops and small animals, which resulted in vulnerable members of low-income households producing and consuming more micronutrient-rich foods and earning increased incomes from the sale of high-value products. Thus, improving food and nutritional security requires adequate food supply, and access to food by households from own production, the market or other sources, and the appropriate utilization of those foods to meet the dietary needs of the households. Effective agricultural interventions on household nutrition involve diverse and complementary processes and strategies that focus on agricultural production for food as well as a focus on women empowerment, livelihoods and optimal use of intra-household resources (World Bank 2007).

In sub-Saharan Africa, aquaculture development aims to improve food security and human nutrition; increase domestic fish production; create employment; promote diversification and reduce risk; promote economic development; and improve efficiency in the use of resources, especially water (Béné and Heck 2005, Satia 2011). Households along Lake Chad that were plagued by chronic food shortages were reported to have sold part of their fish harvests from ponds to improve incomes compared to well-off farming households (Karim 2006). Bueno (2009) suggests that the fish farmer’s goal is often to produce the family animal protein food supply and sell part of the harvest for additional family income. Aquaculture is considered an option for rural development because it provides an important opportunity to help solve problems of poverty, and protein malnutrition of the rural poor. Consequently, small scale aquaculture has been identified as an occupation for income generation, women empowerment and increase in food availability in developing countries (Stepan 2013).

As the Tanzania and Ghana governments continue to implement their fisheries and aquaculture strategic plan, it is important to highlight nutritional impacts to ensure that the nutritional outcomes of aquaculture development or, for that matter, any new agricultural policy are accounted for in the implementation or intervention plans. Accounting for changes in nutritional outcomes is particularly relevant in Tanzania and Ghana given the efforts of the various governments to improve nutritional security.

OBJECTIVES

The focus of this study is to look beyond the direct production measures from fish farming in rural communities and consider the additional benefits that manifest themselves in nutritional outcomes. Given that fish is an important source of protein and essential micronutrients for almost all African households, this study evaluated the impact of participating in fish farming on household nutrition. Some empirical questions that were addressed were: (1) How much better off is a fish-farming household compared to a nonfish-farming household in terms of dietary diversity and nutritional adequacy? (2) What are the impact pathways for aquaculture on household nutritional improvement? The objectives of the study were to:

- Assess improvements in household food security and nutrition in selected fish-farming communities using measures of household nutrient adequacy (food security) and dietary diversity;
- Measure the effect of aquaculture as an input and technology transfer program on household food security using nutritional indicators; and
- Suggest some policy recommendations regarding aquaculture and nutrition improvements.

METHODS

Measurement of the impact of technology adoption in the agriculture literature, especially in sub-Saharan Africa (SSA) has traditionally been done using monetary and farm production measures, particularly income and expenditure. These measures indirectly capture the impact of adopting the technology using household welfare measures as a proxy (Magrini and Vigani 2014). Some studies have made indirect conclusions about household food consumption using household poverty indexes combined with the income or expenditure consumption measures (see for example Kassie et al. 2011, Amare et al. 2012, Asfaw et al. 2012). In these studies, the impact of adopting an agricultural technology on poverty has been found to be significantly negative. Poverty was used as an indicator of the household's economic access to food. The problem with these measures is the assumptions made about the utilization of food (Hidrobo et al. 2012). In a recent paper published by the World Bank, it was identified that enhancing agricultural productivity does not necessarily improve the food security of a household (Herforth et al. 2012). The Food and Agriculture Organization of the United Nations (FAO) agreed to this assertion by concluding that the fact that a household participates in an agricultural intervention does not necessarily mean their nutrition will improve. To better assess nutritional impacts of policy interventions, a number of frameworks have been introduced to capture the nutritional influence on household health through direct and indirect impact ways. For aquaculture, the direct ways include the household consuming fish from their pond, and also selling the fish to buy other sources of protein. The indirect ways include employment creation, economic growth and environmental benefits. This study focused on the impact through direct consumption and the income effect.

The concept of measuring household nutritional quality and food security is elusive. Such measures are often believed to be based on the diversity in the household's diet. The World Food Program (WFP) and other development organizations have consequently developed and validated some indicators for assessing household food security. Some of the measures are Household Food Insecurity and Access Scale (HFIAS), The Household Hunger Scale (HHS), Food Consumption Score (FCS), and Household Dietary Diversity Scale (HDDS) (Maxwell et al. 2003).

The FCS appears to be the commonly used measure in the literature. For example, Arimond et al., (2010) in their study outlined dietary diversity from a number of foods consumed over a period of seven days and used FCS to capture the quality of the diet as well. The International Food Policy Research Institute (IFPRI) used FCS to assess food security and vulnerability in Malawi and reported that 11.5% of the population fell in the "poor" category, 36.7% in the "borderline" category and 51.8% in an "acceptable" consumption status (IFPRI 2011). The study concluded that growth in staple crops contributed more to calorie intake and poverty reduction than growth in export crops (IFPRI 2011). Saaka and Osman (2013) used FCS because of its accuracy in capturing food quality for the household as well as nutritional value and the frequency of consumption of particular food items. The FCS measure involves the collection of seven days' worth of information of food consumed by the household and are weighted differently according to the energy content of food item (Maxwell et al. 2013). This study adopted the FCS as the measure of household food security due to its ability to give a complete picture of the household's consumption of a specific food item as well as details on food consumption pattern.

Food consumption score (FCS). The FCS is used as a proxy for food security and is measured as a summation of the weighted frequencies of the various food groups consumed (Table 1):

$$FCS = \sum y_i f_i \quad (1)$$

where y_i is the weight or the nutritional value of food group i, f_i is the frequency of food consumption of food group i. Frequency of food consumption is the number of days in a week the food group is consumed. The food groups in equation (1) are cereals and tubers, pulses, vegetables and fruits, meats and fish, sugar, milk, and condiments. We hypothesize that fish-farming households have higher diet diversity and food security than the nonfish-farming households. The assumption is that engaging in fish farming is expected to have a positive and direct impact on the household income. Households will then be able to purchase and consume more diverse food items particularly vegetables, meat, dairy and fresh fruits and a shift away from the cereals and tubers.

In identifying the food security status of a household, the WFP has proposed the following thresholds for the FCS (Table 2): Households with FCS of 0–21 are categorized as having "poor food consumption," those within 21.5–35, "borderline food consumption" and above 35 categorized as having "acceptable food consumption." For households that tend to eat oil and sugar on a daily basis, the threshold are 0 – 28 for "poor food consumption," 28.5–42 and > 42 respectively for "borderline food consumption" and "acceptable food consumption" levels (WFP 2008).

Data and study design. The data used for the study was collected through face-to-face interviews with households in the Ashanti and Brong Ahafo regions in Ghana and in the Morogoro and Mbeya regions in Tanzania. Fish-farming households were selected based on their participation in Aquafish Innovation Lab and AquaFish CRSP training workshops during the past five years. A total of 126 households in Ghana and 55 in Tanzania were interviewed using structured questionnaires. For each fish farming household recruited in Ghana, two nonfish-farming households were selected in the same communities while three non-farming households to one fish farming household was selected in Tanzania. The nonfish-farming households were selected to serve as comparative controls.

Dietary assessment. A three-day-repeated 24-hour dietary recall was collected for each household involving the woman and child. The 24-hour dietary recalls interviews were conducted by two trained personnel of postgraduate nutrition and dietetics students. Usually, one person asked the question and the other recorded. Interviews also were conducted in the local language spoken in the study area. The 24-hour dietary recall included two weekdays and a weekend. Portion sizes of foods consumed were determined using household or handy measures such as tea spoons, desert spoons, orange sizes, egg sizes, matches boxes, sardine tins, stew spoons and soup ladles. These quantities were later on translated to grams based on food composition tables and converted to nutrient intakes using the Nutrient Analysis Templates.

Food consumption frequency. A 42-item, structured food frequency questionnaire (FFQ) was used to collect data on habitual dietary intake for mothers and children in the past six months prior to the study. The essence of the FFQ was to establish if patterns of dietary intake and proportion of intake of specific food groups were different between fish farming and nonfish-farming households. The food items on the questionnaire were grouped into seven main food groups namely: cereals and grains, tubers and roots, meat and meat products, legumes and nuts (pulses), fruits, vegetables and fats and oils. For each food item seven options for frequency of consumption were provided for participants to indicate their habitual consumption of those foods. The options were daily, weekly, fortnightly, monthly, occasionally, once in six months and never.

Fish farming activities and other socioeconomic factors. Households also were asked questions pertaining to household socioeconomic characteristics, especially their income sources from both fish farming and nonfish farming activities. A wealth index was constructed using questions related to household assets. The household income and wealth index were used as indicators of the family's economic status. Information on the education, age, household size, and location also was collected.

RESULTS

Results for Ghana. The statistical summaries of the relevant variables selected for the analysis for Ghana are reported in Table 3. The FCS range from a minimum of 17 to a maximum of 112. A high FCS depicts high diversity in foods consumed by the household. The mean FCS for fish farmers was higher (72.6) than that for nonfish-farming households (68) (Table 3). Fish-farming households also had a higher average income (GHS 4832 = $1,264.92) than nonfish-farming households (GHS 263 = $68.59). The average age was 36 with 93% of respondents being female. Females were actually targeted since they are the traditional care givers. The average years of education for the mother was about eight years and an average of about six people per household. The details of other sample characteristics are found in Table 3.

The data was then analyzed in an econometric framework using the 2SLS analysis approach. In assessing the impact of participation in aquaculture on household dietary diversity, the main challenge is selectivity bias. This is because farmers' participation in aquaculture is self-selective, which poses a potential bias where the participation decision is likely to be correlated with the error term in a regression analysis. The endogenous nature of the participation decision can be addressed econometrically using instrumental variables (IV). The 2SLS approach with instrumental variables captures both the observable and unobservable factors influencing the decision to participate in fish farming and its outcome.

The following represents the conceptual regression equation of the household dietary diversity model:

$$y_1 = \alpha_1 y_2 + \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + u \qquad (2)$$

where y_1 is the dependent variable FCS; x_1 to x_n are exogenous independent variables namely geographic area (urban=1), age, household income, wealth index, mother's education and household size; and y_2 represents fish farming participation variable, which is assumed to be correlated with the error term u. The inclusion of y_2 as a regressor requires the introduction of instrumental variable(s) z, which should be uncorrelated with the error term but is strongly correlated with y_2;

$$corr(z, u) = 0 \;\; but \; corr\;(z, y_2) \neq 0 \qquad (3)$$

The endogeneity of the fish farming participation variable (y_2) was tested using a Durbin-Wu-Hausman, and the result indicated the presence of endogeneity. A correlation analysis showed that fish farming participation was strongly correlated with households that received technical support (0.87) and those who had participated in an AquaFish training (0.97). Therefore, these two variables were used as instruments.

The 2SLS regression results are presented in Table 5, which show that with the exception of household income, geographic area and mother's education that are significant, the rest are not statistically significant. The coefficient of residing in an urban area is positively significant at the 10% as we expected. The household income was also found to be positively significant at the 1%. The mother's education was positively significant at 5%.

Results for Tanzania. The mean FCS for fish farmers was lower (56.0) than that for nonfish-farming households (58.4) as reported in Table 4. This is contrary to what was expected: that participation in fish farming improves the nutritional status of the household. The average income for fish farming was higher (TZS 487,121 = $229.22) than nonfish-farming households (TZS 113,095 = $53.22) but lower compared to households in Ghana. The average age of respondents was 45 with approximately 41% of respondents being female. The average years of education for the mother was approximately two years and an average of six people per household. Other summary statistics are reported in Table 4.

The econometric analysis of the Tanzania data was done using OLS because there was no issue with endogeneity. The dependent variable was also FCS with fish farming, geographic area, age, household income, wealth index, household size, and mother's education as independent variables. The results presented in Table 6 show that with the exception of household income, geographic area and wealth index which are significant, the rest are not significant. This is similar to results obtained for Ghanaian households, which had the mother's education being significant instead of the wealth index.

DISCUSSION

Reports from the literature suggest that aquaculture is more developed in Ghana than in Tanzania, which is also revealed in the higher average FCS in Ghana for fish-farming households than for Tanzania fish-farming households where nonfish-farming households seem to be more food secure. Nevertheless, the mean FCS of 72.6 for fish farmers and 68.0 for nonfish-farming households in Ghana and 56.0 for fish farmers and 58.4 for nonfish-farming households in Tanzania suggest that, on the average, households in Ghana and Tanzania have "acceptable food consumption" patterns based on WFPs thresholds scores reported in Table 2. The income range is higher in Ghana than in Tanzania as well as the average years of education of the mother. A potential problem with comparing the two studies is the difference in sample sizes with Ghana having a higher sample than Tanzania. These could contribute to differences in the results.

The results from the econometric analyses for both countries indicate that household income and residing in an urban area are the common socioeconomic factors that significantly impacted household food security and dietary diversity. The coefficient of 0.00 index points in the Ghana model implies that a 1% change in the household's income will have a very negligible change to the household's access to a variety of foods. A similar result is found for Tanzania households. The impact of income is consistent with results from Kabunga et al., (2011), who also reported that income earned by women especially, positively impacted household food security and welfare. The income variable was hypothesized to be positive.

These results also suggest that a household residing in an urban area in Ghana has the probability of increasing the family's diet diversity and quality foods by 4.95 index points. The coefficient for Tanzania households is also positively significant at the 10% as expected implying that a Tanzania household that resides in an urban area has the probability of having a diverse diet and higher nutritional quality by 10.11 index points. The effect is quite high in Tanzania compared to households in Ghana. Kabunga et al, (2011) as well as Larochelle and Alwang (2014) reported similar results for Rwanda households.

In Ghana, the mother's educational level is statistically significant, which implies that an additional year in school for the mother will increase the household's food security by 0.80 index points. The mother's education has been reported to be a very strong predictor of the household FCS because she is the caregiver, and her influence on the household's nutrition is substantial (Larochelle and Alwang 2014; Karki and Bauer 2004). An educated person knows the right kinds of foods to buy in terms of nutritional quality as well as the dietary diversity to boost health.

In Tanzania, the index for wealth was positively significant at 1%. This is expected because it is a measure of wealth and assumed to influence the purchase and consumption of high quality and nutritionally balanced foods. Saaka and Osman (2013) and Zeng et al. (2014) concluded that the wealth index is a good indicator of the household's socioeconomic status and could be used as a predictor of the household's ability to comfortably access food.

CONCLUSIONS AND RECOMMENDATIONS

The study evaluated the impact of participating in aquaculture on the nutritional status of households in two regions of Ghana (Ashanti and Brong Ahafo) and Tanzania (Morogoro and Mbeya) to assess both direct and indirect pathways for nutritional impact. The study used FCS, which is a relatively better measure of food security when targeting a particular food item, in this case fish. The average FCS value for fish-farming households in Ghana was 72 while that for the nonfish-farming household (control group) was 68. In Tanzania, it was 56 for fish-farming households and 58 for the control group respectively.

A 2SLS method was used to analyze the data for Ghana due to selection bias among the fish-farming group. The household income, mother's education and residing in an urban area were found to significantly affect FCS and consequently dietary diversity and nutritional quality. The impacts of being a fish farmer on household nutritional quality is likely to be higher and more pronounced than what the study results show. This is because of the different pathways of household income and direct consumption impact household food security.

Food security is diverse and complex (Cunningham 2005) and assessing the impact of aquaculture on it will require a combination of methodologies. Therefore, future studies should involve a much larger sample size as well as coverage area of study. The use of a combination of food security indicators as was done by Saaka and Osman (2013) in northern Ghana to measure the impact of adopting fish farming on household food security is recommended. Field observations indicated that most households consumed low value fish due to affordability. Therefore, the nutritional benefits of consuming fish should be part of the messages that accompany aquaculture development strategies in addition to economic development and employment creation.

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TABLES AND FIGURES

Table 1. WFP food groups and weights used in calculating FCS.

Food Items	**Food Groups**	**Weights**
Maize, maize porridge, rice, sorghum, millet, pasta, bread, other cereals; and cassava, potatoes and sweet potatoes	Cereals and tubers	2
Beans, peas, groundnuts, cashew nuts and other nuts	Pulses	3
Vegetables, leave and fruits	Vegetables and fruits	1
Red meat, poultry, eggs, fish	Meat and fish	4
Milk, yoghurt and other dairy products	Milk	4
Sugar and sugar products	Sugar	0.5
Oils, fat and butter	Oil	0.5
Condiments	Condiments	0

Source: WFP (2008)

Table 2. Typical thresholds for FCS for grouping households.

Profiles	**Threshold**	**Threshold with oil eaten and sugar eaten on daily basis (~7 days/week)**
Poor food consumption	0 - 21	0 - 28
Borderline food consumption	21.5 - 35	28.5 - 42
Acceptable food consumption	>35	>42

Source: WFP (2008)

Table 3. Summary statistics of variables for Ghana.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Combined Sample					
FCS	159	70.44	18.51	17.30	112.02
Status	162	0.34	0.48	0	1
Geographic area	162	0.43	0.50	0	1
Age	160	36.14	12.34	19	76
Sex	162	0.93	0.26	0	1
Wealth index	162	329.01	230.40	-111.18	841
Mother's education	162	7.85	4.26	0	16
Household size	162	5.64	3.36	1	25
Household income	155	1,736.74	6,282.37	20	71,000
Fish-farming households					
FCS	55	72.55	20.65	25	112.02
Status	55	1	0	1	1
No of ponds	52	3.51	3.04	0	16
Years of farming	54	6.39	5.11	1	28
Pond size	51	1,801.64	2,620.45	150	12,000
Age	55	46.57	13.82	22	76
Geographic area	52	0.44	0.50	0	1
Sex	55	0.80	0.40	0	1
Wealth index	55	409.92	251.05	-35.37	841
Mother's education	55	7.18	5.34	0	16
Household size	55	7.11	4.16	1	25
Household income	50	4,832.02	10,450.19	80	71,000
Nonfish-farming households					
FCS	106	68.02	19.55	0	109
Fish farming	107	0	0	0	0
Age	107	30.82	7.05	19	63
Geographic area	107	0.42	0.50	0	1
Sex	107	0.99	0.10	0	1
Wealth index	107	287.41	208.28	-111.18	812
Mother's education	107	8.18	3.55	0	14
Household size	107	4.89	2.59	1	21
Household income	105	262.79	436.57	20	2,500

Table 4. Summary statistics of variables for Tanzania.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Combined Sample					
FCS	54	56.96	16.41	1	84.5
Fish farm	54	0.61	0.49	0	1
Geographic area	54	0.81	0.39	0	1
Age	54	45.17	16.86	17	86
Sex	54	0.41	0.50	0	1
Wealth index	54	-1,770,529	489,781.3	-2,612,837	-485,181.7
Mother's education	54	1.89	1.46	1	5
Household size	54	5.87	2.48	1	12
Household income	54	341,666.8	758,932.8	25,000	382,5000
Fish-farming households					
FCS	33	56.01	13.04	31.01	84.5
Fish farming	33	1	0.00	1	1
No of ponds	32	1.78	1.21	1	6
Years of farming	33	7.54	8.48	0	40
Pond size	33	8.07	5.77	1	20
Age	33	47.85	17.84	17	86
Geographic area	33	0.82	0.39	0	1
Sex	33	0.42	0.50	0	1
Wealth index	33	-1,720,552	552,030.1	-2,328,885	-485,818.7
Mother's education	33	1.97	1.51	1	5
Household size	33	6.33	2.56	1	12
Household income	33	487,121.3	942,170.9	25,000	3,825,000
Nonfish-farming households					
FCS	21	58.44	20.92	1	84.5
Fish farming	21	0	0	0	0
Age	21	40.95	14.61	17	60
Geographic area	21	1.15	0.37	1	2
Sex	21	0.38	0.50	0	1
Wealth index	21	-1,849,065	370,837.1	-2,612,837	-927,195.6
Mother's education	21	1.76	1.41	1	5
Household size	21	5.14	2.20	1	10
Household income	21	113,095.3	124,403.4	25,000	425,000.5

Table 5. 2SLS regression results for Ghana.

Variable	Coefficient	Std. Error	z	P > ‖z‖	95% C .I.	
Fish farming	2.70	4.19	0.65	0.52	-5.58	10.98
Geog. area	4.95	3.12	1.57	**0.12***	-1.28	11.13
Age	0.03	0.14	0.21	0.83	-0.25	0.31
HH income	0.00	0.00	4.20	**0.00*** **	0.00	0.00
Wealth index	-0.01	0.01	-0.81	0.42	-0.02	0.01
Mother's educ.	0.80	0.32	2.48	**0.01****	0.16	1.44
Household size	-0.26	0.59	-0.43	0.67	-1.44	0.93
Constant	61.68	5.91	10.43	0.00	49.99	73.37

* = 10% significance level, ** = 5% significance level, *** = 1% significance level.

Table 6. Ordinary least squares regression results for Tanzania.

Variable	**Coefficient**	**Std. Error**	**t**	**P > ‖t‖**	**95% C .I.**	
Fish farming	0.30	5.09	0.06	0.954	-9.94	10.53
Geog. area	10.12	5.90	0.71	**0.093***	-1.76	21.99
Age	-0.06	0.15	-0.04	0.966	-0.31	0.29
HH income	-0.00001	4.24e-06	-2.40	**0.020****	-0.00002	-1.66e-06
Wealth index	0.00002	6.49e-06	2.92	**0.005*****	5.91e-06	0.00003
Mother's educ.	1.33	1.72	0.78	0.440	-2.12	4.79
Household size	0.38	1.05	0.36	0.72	-1.73	2.49
Constant	80.30	14.73	5.45	0.000	50.66	109.93

* = 10% significance level, ** = 5% significance level, *** = 1% significance level.

Establishing School Ponds for Fish Farming and Education to Improve Health and Nutrition of Women and Children in Rural Nepal

Human Nutrition and Human Health Impacts of Aquaculture/Activity/13HHI04UM

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Abstract

Establishing school ponds and a curriculum for school-age children and women’s groups should be an effective approach to educate rural communities about the nutritional value of fish and methods of aquaculture. Four ponds of 76–264 m^2 in size were established, one each in four public schools of Chitwan and Nawalparasi districts in Nepal. A school curriculum was also established to demonstrate methods of aquaculture and educate school-age children on nutritional value of fish. This technology was also disseminated to women’s groups to expand understanding of the value of fish production and consumption for their families.

Carps and Nile tilapia seed were provided to each school from nearby government fish hatcheries and were stocked in each pond at 10,000 fish/ha (7,000 carps and 3,000 Nile tilapia/ha). The materials necessary to maintain ponds, including feed and fertilizer, were also provided to each school. Fish were cultured for one production cycle with the participation of high-school-age students. A course of study was developed for teacher and student education on fish culture. About 30 students of grade eight, nine, and ten and two teachers were selected from each school to receive training on fish culture. Training of teachers and students included fish pond development, managing pond depth, pond preparation, species choice, water color, fertilizing, feeding, grow-out, and harvesting of fish, as well as nutrition education, including fish preparation and eating. Five sets of training were conducted in all. In addition to training of students, informal education activities were also carried out for women’s groups, which included forming two women’s fish farming groups in the school community for each district. A training workshop was organized for each women’s group. The topic was the role of household aquaculture in family nutrition and income. A linkage was developed so the women’s fish farming groups could ultimately work with teachers and students in each school to ensure the long-term sustainability of the school ponds.

The establishment and maintenance and running of these ponds was a very exciting event for the school communities. Often, a number of adults showed up for events like stocking and harvesting, as well as visits during our training exercises. In fact, the ponds were so popular some neighboring farmers established ponds within a few months after our school ponds were completed, and the local people wanted advice and materials to develop a community pond on school property. Pre- and post-training evaluation showed a dramatic increase of awareness and fish consumption rate of participating students.

Introduction

Women play an integral role in aquaculture and fisheries sectors all over the world. Even though women’s roles and responsibilities are changing in some countries, there are constraints that limit female participation in aquaculture (Egna et. al. 2012). Some constraints women face in aquaculture and fisheries include time, land ownership, and access to water, credit, training, and labor. Lack of training opportunities can trap women in vulnerable and poorly paid positions with no prospects of advancement (FAO 1998).

Nepal has diverse agro-climatic and socio-economic characteristics, but suffers from limited communication and transportation networks. Rural poverty is a key factor affecting food security. Under-nutrition places children at an increased risk of morbidity and mortality and is also associated with impaired mental development. A report from the Nepal Demographic Health Survey (2011) found that 41% of Nepali children less than five are chronically malnourished (weight for age between two to three standard errors below the mean value), and 11% are wasted (weight for height or height for age two to three SE below the mean value). This has declined slightly from 49% stunted and 13% wasted in 2006. Similarly, underweight children less than the age of five decreased from 39% to 29% from 2006 to 2011 (CBS, 2011). Sadly, 85% of deaths among children less than five occur during the first year of life, and the overall infant mortality rate is 46 deaths per 1,000 live births. During infancy, the risk of neonatal and post-neonatal deaths is 33 and 13 deaths per 1,000 live births, respectively (MOHP et al. 2012). These deaths are mostly attributed to diarrheal diseases, which can be exacerbated by undernutrition.

There is a global concern that nutritious food must be supplied to women, as well as their children during the first 1,000 days of life. Fish provides valuable nutrients to the world's population, including high-quality proteins (about 6% of world protein supply in 2002); balanced amino acids; vitamins A, D, and B12; iodine and selenium; and long-chain omega-3 polyunsaturated fatty acids. Fish bones, when eaten, are also an excellent source of calcium, phosphorus, and fluorides. For optimum human health, about 33% of total protein consumed should come from animal sources, but only 10% is from this source for the average person in Nepal. At least a three-fold increase in animal protein supply is required for optimum health of many rural people. Nepal should promote small-scale aquaculture by setting immediate and long-term objectives. The immediate need is to increase awareness among rural communities of the potential for backyard fish farming, while in the long term, commercial aquaculture should be encouraged (Bhujel et al. 2008). Also, fish contribution to household food and nutrition security depends upon availability, access, and cultural and personal preferences (Beveridge et. al. 2013).

Fish has been considered "living cash" and a pond a "savings bank" because fish can usually be harvested throughout the year when needs arise (Bhujel et al. 2008, Shrestha et al. 2012). In a recent study conducted by Stepan (2013) on nutrition and fish consumption among household fish farmers in the Chitwan and Nawalparasi districts, fish consumption was seasonal (due to cultural practice and beliefs), and increased income was better correlated with improvements in nutrition rather than with fish consumption. Based on these results, educational efforts were focused on timing of fish harvests, post-harvest practices, and other income generating activities for household farmers.

OBJECTIVES

The overall goal of this project was to use school ponds and education on the nutritional value and methods of aquaculture to help young people understand the value of fish production and consumption for their families. In addition to the education of children, the school ponds can be used to train a group of women in each community on the methods of aquaculture and the value of fish consumption to their families. Specific objectives were:

- To establish school ponds in villages for fish farming and education of school-age children on the value of household ponds; and
- To develop women's fish farming groups at each school village to teach them about fish farming and household health.

MATERIALS AND METHODS

Four public schools were selected in Chitwan and Nawalparasi districts of Nepal. Ponds approximately 76–264 m^2 in area were established at each school. Carps and tilapia were provided for each school from nearby government fish hatcheries, and were stocked in each pond at normal densities. The carp species included common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*), stocked at a combined density of 7,000 fish/ha. Tilapia (*Oreochromis niloticus*) were added to each pond at 3,000 fish/ha. The materials necessary to maintain ponds, including feed and fertilizer, were provided to each school. One cycle of fish culture was demonstrated with the participation of school teachers and students.

A course of study was developed to educate teachers and students about fish culture. About 30 students from grades eight, nine, and 10 and two teachers were selected from each school to receive regular training on fish culture. School students and teachers received regular training from the principal investigators and other experts about fish nutrition, pond measurement and farming activities, with similar lessons for both groups. Training of teachers and students included fish pond development, managing pond depth, pond preparation, species choice, water color, fertilizing, feeding, grow-out, and harvesting of fish. In addition, we included nutrition education, including fish preparation and eating, in the training. Five sets of training were conducted in all. Students and teachers were expected to be responsible for long-term maintenance, sales, and income generated from the school ponds.

We formed two women's fish farming groups in each school community for further training activities. A training workshop was organized by the project team at each school with a women's group. The topic was the role of household aquaculture in family nutrition and income. A linkage was developed so the women's fish farming groups could ultimately work with the teachers and students to ensure long-term sustainability of the school ponds.

Two surveys were designed to test the knowledge of students in fish pond production, as well as their knowledge about the benefits of fish nutrition. The surveys were administered before and after training was given in each school system.

RESULTS AND DISCUSSION

Four public schools were selected for establishment of school ponds in Chitwan and Nawalparasi districts of Nepal (Table 1). Images of the pond in each school are provided in Figures 1–4. Ponds differed in design due to land available for a pond, location within the school, and soil permeability conditions.

Table 1. Details of the schools selected for school pond studies.

SN	School name	Address	Pond size	Pond type
1	Nepal Higher Secondary School	Tandi, Chitwan	13 m x 7 m	Earthen pond with plastic lining
2	Kathar Secondary School	Kathar, Chitwan	14.5 m x 8 m	Earthen pond with plastic lining
3	Prithivi Secondary School	Pragatinagar, Nawalparasi	19 m x 4 m	Concrete tank
4	Janta Higher Secondary School	Kawasoti, Nawalparasi	24 m x 11 m	Earthen pond with plastic lining


Figure 1. Fish pond constructed at Kathar Higher Secondary School, Kathar.

Figure 2. Fish pond constructed at Nepal Higher Secondary School, Tandi.

Figure 3. Fish pond constructed at Prithivi Secondary School, Pragatinagar.

Figure 4. Fish pond constructed at Janta Higher Secondary School, Kawasoti.

The establishment and operation of these ponds was a very exciting event for the school communities. Often, a number of adults showed up for events such as stocking and harvesting, as well as visits during our training exercises. In fact, the ponds were so popular that a neighboring farmer constructed several similar ponds in Kawasoti within a few months of our school pond development, and the local people wanted advice and materials to establish a community pond on school property. Some images of project events at different schools are shown in Figures 5–7.

Figure 5. Fish stocking at Nepal Higher Secondary School, Tandi.

Figure 6. Women's workshop at Kathar, Chitwan.

Figure 7. Women's workshop at Kawasoti, Chitwan.

Training events were provided for teachers at each school and for children in all classes at each school. Details of the teachers involved in each training are provided in Table 2. The training included subjects such as economic and nutritional importance of fish, pond design and development, identification of cultivated fishes, pre-stocking management, liming, fertilization, seed transport and stocking, post-stocking management, water quality management (Color, DO, pH, Transparency, etc.), feed management, weed and pest management, harvesting, post-harvest management, integrated fish farming, introduction to fish diseases, and record keeping. A total of 121 students were trained during this program.

Table 2. Teachers involved in training at each school.

SN	School name	Name of teachers participated in training
1	Nepal Higher Secondary School, Tandi, Chitwan	1.Guru Prasad Adhikari 2.Ankur Paudel
2	Kathar Secondary School, Kathar, Chitwan	1.Rewati Prasad Pandey 2.Bishnu Hari Mainali
3	Prithivi Secondary School, Pragatinagar, Nawalparasi	1. Dhan Bahadur Saru 2. Shiva Hari Adhikari
4	Janta Higher Secondary School, Kawasoti, Nawalparasi	1. Ishwor Bahadur Aryal 2. Krishna Bahadur Basnet

In addition to training students, there were two training programs for each women's group as part of the curriculum. A total of 44 women received training on the school pond project, the importance of fish for human nutrition and income, and fish farming techniques, problems and prospects.

Two surveys were designed, before and after training, to test the knowledge of students and teachers in fish pond production, as well as their knowledge about the benefits of fish to human nutrition. Students indicated a small and non-significant increase in access to fish ponds, as well as consumption of fish in the household. Of course, this study only occurred over a period of a few months so there was little time to change behavior. In comparison, there was a significant increase in knowledge of the students about aquaculture (chi-square test, $p<0.05$), with a median grade of <40% on the pre-test and of 61%–80% on the post-test. Initial knowledge about the nutritive value and production system of fish was very poor. By the end of the training, the knowledge of students on fish production and nutritive value of fish was significantly increased.

Table 3. Household pond ownership and fish consumption of the participating students at different schools before and after training program.

School name	Number of students (n)	Having fish pond (% response of n)		Fish consumption (times/year)	
		Before training	After training	Before training	After training
Nepal	35	5.7	8.6	4.3±4.1	7.7±4.3
Kathar	31	12.9	25.8	22.4±30.3	27.1±41.1
Prithivi	28	7.1	7.1	2.9±3.1	7.3±4.5
Janta	23	17.4	17.4	3.0±3.7	7.7±5.6
Total	117	11.1	14.5	9.1±18.8	13.4±24.3

Table 4. Knowledge of students on fish production and nutritive value of fish at different schools before and after training program. Data indicates the mean percent response of the participant students (n) getting different range of scores.

School name	Number of students (n)	Score obtained (%)							
		Before training				After training			
		<40	40-60	61-80	>80	<40	40-60	61-80	>80
Nepal	35	80.0	17.1	2.9	0.0	0.0	23.0	57.0	20
Kathar	31	71.0	29.0	0.0	0.0	0.0	0.0	42.0	58.0
Prithivi	28	50.0	35.7	14.3	0.0	3.6	17.9	42.9	35.9
Janta	23	82.6	8.7	9.7	0.0	0.0	8.7	60.1	30.2
Total	117	69.2	26.5	4.3	0.0	1.0	13.7	53.0	32.3

CONCLUSIONS

The development of school ponds and women's fish farming groups increased awareness of the value of nutrition and fish consumption in rural households by teaching school children, teachers, and adult women about aquaculture. We hope the schools will continue the fish ponds, and intend to continue some outreach over the next two years. Ponds will help generate income for schools, as well as act as teaching material for students. They also helped in capacity building of teachers who could spread the knowledge on the importance of fish in nutrition to parents during teacher-parent interactions. The development of curriculum will serve as the basis for future expansion of such programs to additional schools.

QUANTIFIED ANTICIPATED BENEFITS

The development of school ponds and women's fish farming groups has significantly increased awareness of the value of nutrition and fish consumption in rural households by teaching school-age children and adult women about aquaculture. It helped generate income for schools from ponds. It has also helped in capacity building of teachers with knowledge on the importance of fish in nutrition and to parents during teacher-parent interactions. As anticipated four school ponds were established, 117 students were educated on the methods of fish farming, and 44 women received training in fish farming and its role in household health. There is also a large interest in other schools to initiate a similar program and spread this methodology to more locations.

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TOPIC AREA:
POLICY DEVELOPMENT

❖

Policy Recommendations to Improve Food Security and Household Nutrition Through Sustainable Aquaculture and Aquatic Resource Management in Cambodia and Vietnam

Policy Development/Activity/13PDV01UC

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Abstract

Changing hydrology, sedimentation, water quality by hydroelectric dams, population growth, and climate change are said to be affected to the fish production, livelihood opportunity, food security, nutrition, and its implication to health. The other five investigations of the project provided science-based information on the impacts of climate and non-climate drivers of change on fish value chains, vulnerable populations, aquaculture production systems, and capture fisheries. The objective of this activity was to provide science-based policy recommendations to government and fisheries and aquaculture communities and households, including vulnerable subpopulations such as women and children on the potential risk of lacking food security and malnutrition due to the impacts of climate and nonclimate drivers of change on fisheries and aquaculture and planned (policy-driven) adaptation strategies through dissemination the appropriate communication products from the other five investigations to target audiences. Two hundred eighty seven (287) target audiences (decision maker at ministerial levels, IFReDI/FiA officers and government officers, national mass media, university academy, scientist and researchers, international agencies, local authorities, farmer, aquaculurists, fishers, fish processors, and housewives received the appropriate communication products, of which 77% were women. The project (October 1, 2013 to December 30, 2015) has provided the direct benefits to stakeholders in both countries Cambodia and Vietnam 19 graduate and undergraduate students; 605 trained farmers, processors, and women; 4600 are direct benefit from the project and 1,001, 200 are indirect benefit from the project. A numerous communication products were provided seven final technical reports of six investigations. They are 1) impacts of climate change on snakehead fish value chains in Lower Mekong Basin of Cambodia and Vietnam; 2) alternative feeds and processing for freshwater aquaculture species; 3) alternative feeds and processing for freshwater aquaculture species; 4) Estimating carrying capacity for aquaculture in Cambodia; 5) food and nutritional consumption survey: women and preschool-age children in Cambodia; 6) nutritional composition of nutrient density of commonly-consumed fish, Other Aquatic Animals, and processed fish consumed by women and children in Cambodia; and 7) policy recommendations to improve food security and household nutrition through sustainable aquaculture and aquatic resource management in Cambodia and Vietnam.

INTRODUCTION

The productive Mekong fisheries are essential to the food security and nutrition of at least 60 million people of the Lower Mekong Basin (LMB). Fish, from capture and culture, are a significant source of income and food security in Cambodia and Vietnam. The combination of high fish biodiversity, high productivity, high exploitation rate, long-distance migrations, and fish trade make protecting these fisheries and aquaculture of great importance. However, they are highly vulnerable to climate and non-climate related drivers of change which have led to flow change and ecological change in the Mekong basin, especially downstream countries like Cambodia and Vietnam. This includes increased temperatures; changes in rainfall patterns; changes in the hydrological regime (water levels, duration of flooding, timing of flooding); changes in run-off or sediment load/movement; and increased instances of extreme weather events (storms, floods and droughts). Saline water intrusion in the Mekong River was about 20 km at the end of the 20th century and is now up to 50 km. And more important the rapid increased population, which is estimated up to 20 million at 2013. These drivers of change have posed significant challenges for fisheries and aquaculture production, household income, livelihoods, markets and trade, gender issues, food security and the nutrition and health of people, especially poor households, in the LMB of Cambodia and Vietnam. However, a complete understanding of the impacts of each individual driver and a combination of drivers is only just beginning.

The other five investigations of this project provided science-based information on the impacts of climate and nonclimate drivers of change on fish value chains, vulnerable populations, aquaculture production systems, and capture fisheries. Adaptation strategies for aquaculture and fisheries systems have examined in several of the investigations of this project. These investigations have addressed the goal of project through fish value chains, development of feeds and feeding strategies and processed products, sustainable snakehead aquaculture systems, estimating carrying capacity for aquaculture, food and nutrition security vulnerability of women, and policy and outreach.

Investigation 6: "Policy recommendations to improve food security and household nutrition through sustainable aquaculture and aquatic resource management in Cambodia and Vietnam," which focused on policy and outreach to address the impacts on vulnerable population.

A suite of potential adaptation options was not sufficient to address these drivers of change. There was a need to provide this information to government and fisheries and aquaculture households and vulnerable populations to be able to make informed and deliberate decisions on adaptation.

The purpose activity was not to generate new information but to disseminate and communicate information generated by the studies in the project, specifically, science-based policy recommendations. This investigation has provided this information through a suite of different communication methods and approaches for each audience.

OBJECTIVES

The objective of this activity was to provide science-based policy recommendations to government and fisheries and aquaculture communities and households, including vulnerable subpopulations such as women and children on the potential risk of lacking food security and malnutrition due to the impacts of climate and nonclimate drivers of change on fisheries and aquaculture and planned (policy-driven) adaptation strategies through dissemination the appropriate communication products from the other 5 investigations to target audiences.

Materials and methods. To achieve the above objective, the methods and actives were set as followings:

Audience analysis. The identification of target audiences (scientists, researchers, government officials, NGOs, fishers, aquaculturists, women) and their specific information requirements and methods of receiving information, and appropriate communication products (e.g, technical report, journal articles, web media) and the style of communication including scope, where and how to receive information, language, technical content.

Project products. The project documents were reviewed for the communication products.

***Communication and dissemination strategy*. **Communication strategy was formulated and implemented by PI/communication expert. The communication strategy was a combination of approaches, techniques, and messages to reach different audiences. At a minimum, the strategy aimed to effectively disseminate the following to key audiences of five technical reports: 1) Marketing, economic risk assessment and trade (MER) - impacts of climate and non-climate drivers of change on fish value chains; 2) Sustainable feed technology and nutrient input systems (SFT) - continuation of snakehead feed work; 3) Climate change adaptation: indigenous species development (IND) - sustainable snakehead aquaculture development in Cambodia; 4) Watershed and integrated coastal zone management (WIZ) or mitigating negative environmental impacts (MNE) - carrying capacity work; and 5) Enhancing food security and household nutrition vulnerability of women and children focus on nutrient dense commonly consumed fish from capture fish and aquaculture in Cambodia; and two science-based policy brief/recommendation.

RESULTS

Two hundred eighty seven (289) target audiences received information with appropriate communication products, of which five were decision maker at ministerial level; twenty one were inland fisheries research and development institute of fisheries administration (IFReDI/FiA) officers and government officers; two national mass media; twenty three were university academy; eight were scientist and researchers; two were international agencies (WorldFish and MRC); thirty were (30) local authorities; and one hundred ninety eight (198) were famers, aquaculurists, fishers, fish processors, and housewife (Table 1). Seventy seven (77%) of target audiences were women receiving the appropriate communication products (Figure 1). The higher number of the female were target audiences receiving appropriate communication products were women as Village Health Workers, farmers, aquaculturists, fishers, fish processors, and housewife, while other sectors were high dominance of men in decision makers of Sector Ministers and Department, head of the key government agencies, sector of department, representative of key line agencies at national and provincial level, leader of Commune Councils.

In quantitative terms, the project conducted a series of national workshops in 2015, and the other series of provincial consultation and dissemination workshops in September 2015. The research was regularly reported as quarterly and annual reports, and presenting in the national and international events. In addition, it was noticed that the research results were disseminated through AquaFish and IFReDI website; and national, regional, international publications and broadcasted on national television for a broader audiences

Numerous communication products of the project were listed. They include:

- Seven final technical reports of six investigations. They are 1) impacts of climate change on snakehead fish value chains in Lower Mekong Basin of Cambodia and Vietnam; 2) alternative feeds and processing for freshwater aquaculture species; 3) alternative feeds and processing for freshwater aquaculture species; 4) Estimating carrying capacity for aquaculture in Cambodia; 5) food and nutritional consumption survey: women and preschool-age children in Cambodia, 6) nutritional composition of nutrient density of commonly-consumed fish, Other Aquatic Animals, and processed fish consumed by women and children in Cambodia; and 7) policy recommendations to improve food security and household nutrition through sustainable aquaculture and aquatic resource management in Cambodia and Vietnam

- Two policy briefs. They are: 1) Role of fish in food and nutrition security in women and preschool children, and 2) Toward sustainable snakehead farming in Cambodia and Vietnam.
- Fact sheets
- National and international journals
- PowerPoint presentations
- Posters
- Successful story and lesson learn
- Video clip
- Hand books/training manuals (Hand Book of Snakehead Culture Using Pellet Feed, and A Manual of The Process of Dried Snakehead (*Channa striata*).

The project (1 October 2013 to 30 December 2015) has provided the direct and indirect benefits to stakeholders in both countries Cambodia and Vietnam as the followings:

1) Impacts of climate change on fish value chains in the Lower Mekong Basin of Cambodia and Vietnam:
    - Two hundred scientists, researchers, resource managers, government officials, and NGOs in Cambodia and Vietnam have better informed and have better information on current and potential impact pathways of climate and non-climate drivers of change and corresponding adaptation strategies for snakehead fish value chains in Cambodia and Vietnam.
    - Ten researchers in Cambodia and Vietnam were trained and have experienced on using value chain analysis to analyze sector-specific impacts of climate and non-climate impact pathways on fish value chains.
    - This study supported research activities of a PhD student, two master students, and dissertations of four undergraduate students.

2) Sustainable feed technology and nutrient input systems continuation of snakehead feed:
    - Women in An Giang province were trained on small-scale farming of snakeheads using formulated feed.
    - Women in An Giang province were trained on processing of salty fermented and dried product from cultured snakehead (*Channa striata*).
    - This investigation has developed a manual of the processes of dried and fermented snakehead (*Channa striata*).
    - It supported dissertations of four undergraduate students (three female and one male). Three faculty members (female) at CTU and two local staff (female) participated in this project. Thirty women were trained on the processes of dried and fermented snakehead. One-hundred manuals of the processes of dried and fermented snakehead (in Vietnamese) were delivered to farmers.

3) Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia:
    - Three undergraduate students were supported and trained by this investigation through their B.Sc. thesis research.
    - About 20,000 farmers in Cambodia were benefit in Cambodia and Vietnam by restarting their snakehead culture leading to increased household income and improved snakehead fish market and trade.

- 250 scientists, researchers, government fisheries officers/managers and policy makers, extension workers, NGO staffs, and private sector working on the issues of snakehead aquaculture in Cambodia as well as in other Mekong riparian countries were better informed and consulted of research methods and findings, and have better recommended policies and strategies for sustainable snakehead aquaculture.
- At least 1,000,000 indirect beneficiaries in Cambodian and other Mekong riparian countries who consume snakehead fish in their protein diets leading to improved their household food and nutrition security

4) Estimating carrying capacity for aquaculture in Cambodia:
    - About 2,000 government regulators/managers and officers in Cambodia have improved understanding of environmental carrying capacity.
    - 100 scientists and researchers who can apply models to the calculation of carrying capacity for specific bodies of water in Cambodia as well as in the Lower Mekong Basin.
5) Enhancing food security and household nutrition vulnerability of women and children focus on nutrient dense commonly consumed fish from capture fish and aquaculture in Cambodia:
    - This investigation has provided recommendations for better nutrition in women and children in Cambodia.
    - Two Master's students were involved in this investigation (one female and one male).
    - Four undergraduate students were also supported for their dissertations (two females and two males). Three IFReDI staff were involved (one female and two males).
    - Two hundred and twelve participants (155 women) attended the series of consultation and dissemination meetings and workshops on results of the investigation, and formulating recommendations for better nutrition in women and children.
    - Three hundred fact sheets and policy briefs were directly provided to the women sampled in the study. One thousand and two hundred (1,200) fact sheets and policy briefs were delivered to IFReDI/FiA staff, scientists, researchers, government officers, NGOs, and women which are direct and indirect benefits from the projects.

CONCLUSION

The project (1 October 2013 to 30 December 2015) has provided the direct benefits to stakeholders in both countries Cambodia and Vietnam 19 graduate and undergraduate students; 605 trained farmers, processors, and women; 4600 are direct benefit from the project and 1,001, 200 are indirect benefit from the project. Seven final technical reports of six investigations. They are 1) impacts of climate change on snakehead fish value chains in Lower Mekong Basin of Cambodia and Vietnam; 2) alternative feeds and processing for freshwater aquaculture species; 3) alternative feeds and processing for freshwater aquaculture species; 4) Estimating carrying capacity for aquaculture in Cambodia; 5) food and nutritional consumption survey: women and preschool-age children in Cambodia; 6) nutritional composition of nutrient density of commonly-consumed fish, Other Aquatic Animals, and processed fish consumed by women and children in Cambodia; and 7) policy recommendations to improve food security and household nutrition through sustainable aquaculture and aquatic resource management in Cambodia and Vietnam. Two hundred eighty seven (287) target audiences (decision maker levels, IFReDI/FiA/MAFF officers and government officers, national mass media, university academy, scientist and researchers, international agencies, local authorities, farmer, aquaculurists, fishers, fish processors, and housewife) received the appropriate communication products, of which 77% were women.

Having seen the qualitative outcomes of this project, in particular the promising achievement of formulated feed of *Channa striata*, the leaders of Fisheries Administration and Ministry of Agriculture Forestry and Fisheries advise IFReDI to accelerate the aquaculture domestication of *Channa striata* and *Channa micropeltes* and the development of formulated feed for these commercial important species aiming at leasing the ban on snakehead fish aquaculture in the country.

The results of the study of nutrition on women and children in rainy season are a basic nutritional knowledge in Cambodia and, more importantly, there is a crucial need to further study on nutrition on women and children in dry season in order to serve as the fundamental data/information for nutrition planning and management for alleviating malnutrition and micronutrient deficiencies among women and children in Cambodia.

QUANTIFIED ANTICIPATED BENEFITS

This investigation has disseminated and communicated information generated by the studies in the project, specifically, science-based policy recommendations. One thousand and three hundred scientists, researchers, government fisheries officers/managers and policy makers, extension workers, NGO staffs, private sector, university lecturers, students, fisheries and aquaculture households in Cambodia and Vietnam as well as in other Mekong riparian countries were better informed and have better information on current and potential impacts of climate and non-climate drivers of change on food security and nutrition and corresponding adaptation strategies.

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TABLES AND FIGURES

Table 1. Target audiences receiving information with appropriate communication products.

Institution	Number of Target Audiences Involved	Gender	
		Male	Female
Decision maker level including Minister, Ministry of Agriculture Forestry and Fisheries	5	5	0
IFReDI/FiA officers and government officers	21	18	3
National Mass Media	2	2	0
Universities academy	23	17	6
Scientists and researcher	8	6	2
International agencies	2	1	1
Local Authority	30	18	12
Farmers, aquaculturists, fishers, fish processors, and housewife	198	0	198
Total	289	67	222

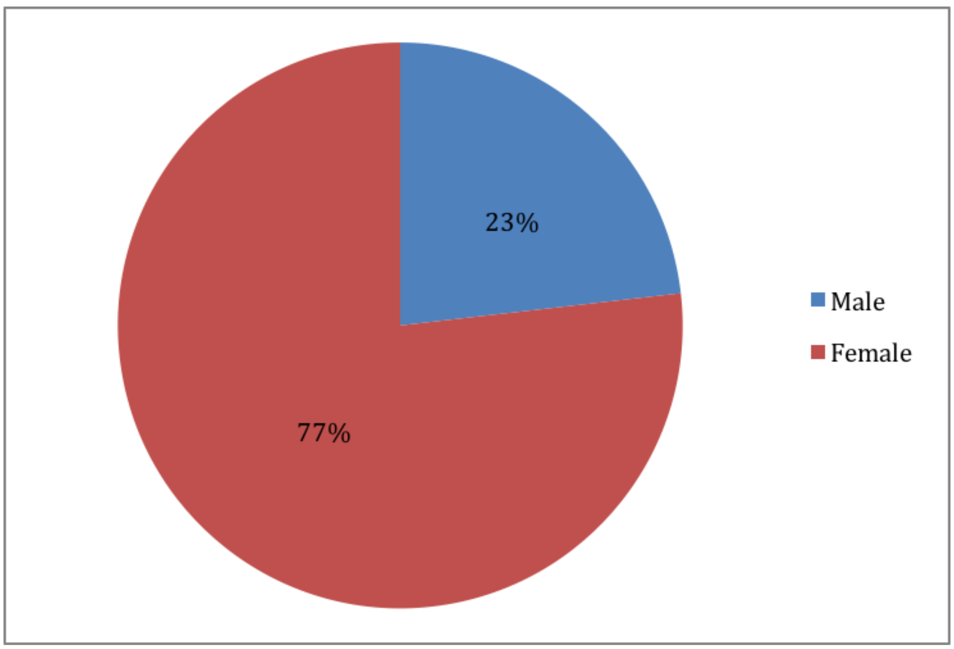

Figure 1. Gender profile of target audiences receiving information with appropriate communication products.

TOPIC AREA:
MARKETING, ECONOMIC RISK ASSESSMENT, AND TRADE

❖

Improving Nutritional Status and Livelihood for Marginalized Women Households in Southwest Bangladesh through Aquaculture

Marketing, Economic Risk Assessment, and Trade/Study/13MER04NC

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Abstract

Mud crab (*Scylla serrata*) fattening and culturing is an emerging industry in Bangladesh. Women-led households directly benefit from the mud crab through added income from the sale of the crab. Mud crabs are considered a delicacy and deemed to have medicinal value. They create high demand in international markets. Currently, 37.8% of crab fattening and culturing facilities are owned and operated by women. Many of the household members of these women-owners are malnourished and live in impoverished conditions because of low incomes and lack of resources to improve their nutrition. Our objective was to perform a pilot study in order to promote the integration of tilapia (*Oreochromis mossambicus*) into traditional mud crab culture, thus diversifying their crops. This may directly lead to improvement of dietary nutrition of women and children and may create a more sustainable method of mad crab fattening and culture. A baseline questionnaire was given to 150 mud crab farmers in the Satkhira, Khulna, and Bagerhat regions of Bangladesh. This questionnaire focused on food consumption and how low-intensity culture species (including mud crab and tilapia) and other seafoods contribute to the dietary nutrition and earned incomes (both actual and potential) of surveyed families. Household demographic and socio-economic information was also collected. The surveys revealed that the majority of mud crab farmers are poorly educated, receive low dietary nutrients, and are malnourished.

The second part of this study was to conduct pilot trials integrating tilapia in mud crab culture. Forty-five farms, 15 from each region originally surveyed, were selected as part of the tilapia/mud crab polyculture demonstration. Five farmers continued with the traditional mud crab fattening procedures. Ten of these farmers were instructed on methods of pond preparation and mud crab and tilapia stocking. Mixed sex tilapia were used to allow continuous breeding. Five of these farmers sold their tilapia products to market while the other five kept the tilapia for direct consumption by their household members. In both groups small tilapia were fed to mudcrab to reduce reliance on wild-caught trash fish as feed for crab. When the tilapia were grown with mud crab the mud crabs grew better with increased production. It was also found

that the women and their household members had a higher income, consumed more high quality protein in their diets leading to better health and well-being, and were less malnourished as determined by the mid-upper arm circumference (MUAC) index.

Substantial on-farm training was conducted to teach farmers how to integrate tilapia in their mud crab operations. Workshops and household nutritional sessions were provided. Details of tilapia integration into traditional mud crab fattening and culture practices were passed down along with the results of income and the nutritional benefits farmers secured. An extension brochure was produced and given to other mud crab farmers in order to disseminate the knowledge further.

This pilot study determined that integration of tilapia into current mud crab fattening and culture practices can boost total mud crab production. This leads to more crab biomass that can be sent to market along with tilapia that may not be consumed by the farmer's household members. This not only increased the income of these women-farmers but also improved the health and nutrition status of all members of their families.

INTRODUCTION

Coastal (southwest) Bangladesh is highly vulnerable to the impacts of global climate change and, due to extreme poverty and malnutrition, is an important target area for the USAID Feed the Future Initiative. Within coastal Bangladesh, three districts (Satkhira, Khulna and Bagerhat) that surround the Sundarban mangrove forest are considered the most threatened, suffering repeatedly from the effects of calamitous storms (e.g., cyclone Sidr 2007, Aila 2009). During periods of high flooding, the average consumption of staple rice falls to 33 % of their minimum nutritional requirement, resulting in acute malnutrition and chronic energy deficiency, particularly in women and children (World Food Programme 2011). While men in this region commonly engage in day labor or have migrated to urban areas to obtain low-income work, the majority of women in this population rely directly on subsistence farming of natural wetland resources. The prevalence of impoverished women-led farming households in coastal Bangladesh, traditionally underrepresented in the economic market chain, make this demographic particularly susceptible to exploitation and thus a key target for improving dietary nutrition and earned incomes of the impoverished Southwest. As fish commonly contribute 63% of dietary animal protein intake for Bangladeshis (Belton et al. 2011), this investigation will focus on two key aquaculture species, tilapia (*Oreochromis* spp.) and the mud crab (*Scylla serrata*), the latter primarily cultured alone but may be integrated with tilapia. We anticipate that integrative culture of these species can significantly improve the nutritional and economic well-being of female-led households as well as the environmental impact associated with crab-fattening where feed inputs are significant and water exchanges are common, leading to excessive inputs to the environment. A key component of this study will be to promote the culture of *both* species by women to foster better food security through diversification of dietary resources. A secondary benefit of this strategy is that tilapia can also be used as feeds for mud crab fattening, which are traditionally reliant on fisheries by-catch. The co-production of both species, combined with ongoing research into crab hatchery development (through activities at WorldFish; Dhaka, Bangladesh) will go a long way towards securing an environmentally sustainable industry and promote better food security for impoverished women aquaculturists in coastal Bangladesh.

The culturing or fattening of mud crab (*Scylla serrata*) is an emerging industry (Azam et al. 1998, Khan et al. 1991) directly benefiting women-led households in coastal Bangladesh. The large-clawed mud crabs are high commodity seafood items due to their delicacy, medicinal value and demand in international markets (Ali et al. 2004, Keenan et al. 1997). Of the 2,428 crab farms in the severely impacted regions (Satkhira, Khulna and Bagerhat), 37.8% are currently owned and operated by women (26-41 % by region; Shushilan unpublished report). Even farms not directly owned by women commonly rely on this demographic for stock collection of juveniles from shrimp ponds or other wetlands. Currently, very little information has been collected or published about these endeavors, yet while women aqua-farmers likely obtain economic benefits from crab fattening, this is solely marketed as an export crop, thus may not directly benefit the dietary needs of women and children. Given a poorly defined value chain, where the roles and participation of women may be underestimated or under-appreciated by local government agencies, little protection from exploitation (by intermediary market buyers) currently exists.

To more directly improve the dietary nutrition of women and children and create a more sustainable method of mud crab fattening, our objective is to promote integration of Nile tilapia (*Oreochromis nilotica*) into traditional mud crab culture, thus providing greater crop diversification. The live mud crab industry holds promise for improving economic opportunities in regions sensitive to global climate change (e.g., seawater incursion, storms), with current annual production estimates at 10–15,000 mt (Zafar and Siddique 2000). Despite economic benefits, the dietary conditions for many women-led households in these regions are extremely poor, and may constitute only staple rice, supplemented periodically with local vegetables and fish (S. Biswas, personal communication 2013). As tilapia farming continues to grow in Bangladesh (Ahmed 2007), including in the Southwest region (Hussein 2009), the integration of tilapia into mud crab culture may enhance the incomes of women-led households through sales in domestic markets, and improve their food security by direct household consumption. The growing number of Bangladesh tilapia hatcheries and the availability of seed stock readily allow for integration of tilapia into traditional mud crab farming.

This study was designed to foster greater participation of women in aquaculture in the impoverished coastal regions of Bangladesh. Through integrative polyculture of tilapia with mud crab fattening, these investigations could promote better food security and dietary nutrition for women-led households through greater crop diversification and training in best management practices for tilapia — mud crab culture. Currently, the production systems for mud crab fattening are less advanced relative to other aquaculture sectors (Begum et al. 2009). This investigation will provide on-site training along with current research into mud crab farming (e.g. captive breeding of seedstock, water quality, cage culture), to achieve sustainable development for this industry.

OBJECTIVES

The focus of this investigation was to better identify the role aquaculture plays in the lives of impoverished women culturists in southwest Bangladesh, with specific focus on the nutritional and economic benefits (both potential and actual benefits) derived from these endeavors and integration of tilapia in mud crab fattening and culture. Through training on best management practices, this work is expected to generate improvements in household nutrition and economic profitability for the benefit of impoverished women in coastal Bangladesh. Specific objectives included:

- Determine present socioeconomic and nutrtional status of households through surveys to understand the contribution of aquaculture to the livelihood of women-led households; and
- Disseminate better management practices, including the integration of tilapia, to facilitate both greater availability of fish for household consumption, and environmental sustainability for the current farming practice of mud crab fattening/culture.

METHODS

Location. These studies were conducted in the Khulna, Satkhira, and Bagerhat districts of southwest Bangladesh, with on-site interviews conducted by S. Biswas, W. Jamandre, U. Hatch, and S. Haque. The workshop and on-site extension training was conducted by S. Biswas and E. Quinitio.

Methods

1. Determine the present socioeconomic and nutritional status of households through surveys to assess the contribution of seafoods, including mud crab and tilapia, in women-led households. Household nutrition surveys were conducted within the study area by AquaFish personnel. A copy of these surveys is shown in Addendum 1 (developed in cooperation with Torab M. A. Rahim, Institution of Nutrition and Food Science, University of Dhaka). These surveys were filled out by the head of the household. They included questions relevant to the income and nutritional status of each member of the household. These surveys focused on food consumption and how low-intensity culture species (including mud crab and tilapia) and other seafoods contribute to the dietary nutrition and earned incomes (both actual and potential) of surveyed families. Household demographic and socio-economic information was collected. 50 households were initially surveyed from each of three areas in Bangladesh, Khulna, Bagerhta, and Satkhira, and served as baseline indicators for the study. A second survey was performed on a subset of those families that participated in the baseline survey and who undertook pilot studies on integrative tilapia-mud crab culture (Study 2A) to determine if income and nutrient consumption increased within the household. Evaluation of nutritional benefits derived from families that integrated tilapia with mud crab culture/fattening were examined. During the program, a subset of targeted households containing women aquaculturists were followed, with each member of the household identified (average 4 per household, including children < 5 years of age, or females of adolescent age or younger) being tracked.

2. Disseminate better management practices for integrated tilapia mud crab culture to facilitate food security and economic well being of women-led households.

2A: Integrated tilapia-mud crab culture practices — A pilot study was conducted to demonstrate the potential benefits of integrated tilapia and mud crab culture to practicing women aquaculturists who utilize mud crab-fattening as a source of income. The benefits of integrating tilapia into mud crab fattening and culture may include:

- Greater supply of nutritious foods for household consumption;
- Improved earnings by the sale of extra tilapia in domestic markets;
- Improved environmental water quality resulting in less stock mortality and environmental impacts; and
- A decrease in the reliance of fisheries by-catch for use as crab feeds. The latter benefit, used through feeding of extra juvenile tilapia to crabs, may also improve the environmental sustainability of this industry.

All participating households were given a data collection notebook to record farming activities including crab stocking, feedings, tilapia (kg) harvested, proceeds from crab and/or tilapia sales, and input costs associated with crab feeding (see Addendum 2). Evaluation of nutritional benefits derived from integrating tilapia into mud crab culture will be examined as part of Study 2.

Participating members from women-owned farms or from women-led households were included within the sample set identified in Study 1 (N = 45 ponds). Sites were selected to have a salinity range (5–20 ppt) tolerant for Nile tilapia (*Oreochromis niloticus*) breeding and mud crab fattening (Popma and Masser 1999, Shelly and Lovatelli 2011). An equal number of ponds from all three districts (Kulna, Satkhira, and Bagerhat, 15 per district) were used. Ponds were assigned to one of three treatment groups (N = 45, n = 15): (T1) control — only traditional mud crab fattening or culture practiced, (T2) integrated tilapia-mud crab farming where the tilapia are sold to market, and (T3) tilapia-mud crab farming where the tilapia are directly consumed by the household. In the tilapia groups, small juveniles (~10g, produced by tilapia breeding within the ponds) were harvested weekly for use as supplemental crab feeds. Treatments 2 and 3 were stocked with mixed-sex tilapia of breeding size (3 female:1 male) at a density of 1 fish/m^2. The study was conducted over a single tilapia production phase (2 crab fattening cycles or 1 crab culture). Mud crabs were stocked at an equivalent, standardized density (2–3/m^2) for all ponds. The tilapia were raised only on pond primary productivity derived from excess crab feeds, and fertilized (28 kg N, 7 kg P/ha) only if productivity is low (> 20 cm Secchi disk depth) (Figure 1 and 2).

2B: On-site training workshop — In Bangladesh, aqua-farmers have been practicing mud crab fattening mainly in earthen ponds; however, escape through burrowing is a common problem. High mortality and poor survival are the main production constraints. Introduction of cage culture and other innovative enclosures is new in Bangladesh though alternatives have been adopted in many Southeast Asian countries, e.g., bamboo (DA, Region VI 1988) and net cages (Kuntiyo 1992) in the Philippines, bamboo enclosure and cage in river and canals in Myanmar (Felix et al. 1995), and floating cage culture in Vietnam and Malaysia (Sivasubramain and Angel 1992). E. Quinitio (Co-PI) evaluated current mud crab fattening and culture practices and conducted on-site training and 2 workshops on best management practices. The workshops were designed to help women aquaculturists improve their farm practices including potential integration of tilapia. An analysis of the best management practices for tilapia and mud-crab farming was presented with suggestions for future improvements based on research gleaned from other Southeastern Asian countries with similar environmental conditions and culture practices. Site identification and logistical support for the training and on-site workshops and integrated tilapia-crab culture was undertaken by S. Biswas, and focused on a diverse range of topics regarding current and future practices of the industry (e.g., culture systems, integrative aquaculture, and hatchery/nursery technologies).

RESULTS AND DISCUSSION

1. Determine the present status of household dietary nutrition through surveys to assess the contribution of seafoods, including mud crab and tilapia, in women-led households. Baseline surveys were conducted with existing crab farmers to determine their socio-economic and dietary nutrition status. 150 households were surveyed in total, 50 from each region (Khulna, Bagerhta, and Satkhira).

The baseline analysis found that 52% of the crab farmers have > 5 years of experience in crab fattening but little experience with crab-tilapia polyculture. About 24% of the farmers in Khulna have > 10 years experience in crab fattening while only 18% of farmers in Bagerhat have > 10 years experience in crab fattening. The majority of respondents were involved in crab fattening (66%). The other respondents were involved in fish culture (22%), crab trading (5%), fish trading (2%), or another type of small business (5%) (Figs. 3 and 4). About 37% and 24% of the ponds were either leased or under a multiple ownership arrangement, respectively, where the ponds are owned by more than one household. About 53% of the farmers had taken a loan to fund their farming practices. The incomes of the respondents ranged from BDT (Bangladesh taka) 4,500 to BDT 20,000.

The survey also revealed that more than 78% of the surveyed farmers did not receive any formal training related to crab farming. As for formal education, the average maximum schooling for the farmers was five years after which they started farming to help support the income of their families. The surveys indicated that 49% of the respondents had been educated to the primary school level, whereas 40% had some high school education and 11% had been educated beyond the high school level.

The survey revealed that many of the respondents were deficient in protein uptake and that the average weight of the farmers was 40-60 kg and the average MUAC ranged from 19–30 mm and many were found to be in a state of moderate acute malnutrition (MAM), mainly women and children.

Around 64% of the crab collectors used filtered pond water, 5% used pond water directly, and 8% used rainwater for drinking purpose whereas none of them had their own well. However, 23% of the crab collectors used well water provided by the local government or those belonging to schools or neighbors.

2. Disseminate better management practices for integrated tilapia mud crab culture to facilitate food security and economic well being of women-led households.

2A: Integrated tilapia-mud crab culture practices. This study was conducted as a pilot study to determine if introducing tilapia into mud crab culture could increase the well-being of households of women who own farms. Forty-five women-owned mud crab farming households were selected from the 150 households surveyed in Study 1, 15 from each of the three regions, Khulna, Bagerhta, and Satkhira. Five farms from each region continued in the traditional mud crab fattening and culture practices (T1, control), five farms in each region cultured tilapia along with the mud crabs and sold the tilapia at market (T2), and the last five farms in each region also cultured tilapia along with the mud crabs but kept the tilapia for consumption by the household members (T3). No additional feed was supplied to the ponds to support the tilapia; tilapia subsisted on biota naturally found in the ponds.

Regardless of the amount of tilapia produced in T2 and T3, mud crab production did not vary (Figure 5). Crab growth, though, increased when grown in the presence of tilapia (Table 1). The crabs were fed 10% of the tilapia in the ponds every week. The tilapia could be providing valuable nutrients and feed biomass to the crabs to increase growth and thus production of mud crabs in the ponds including tilapia.

The addition of tilapia into mud crab culture also increased protein availability to the farmer's households. MUAC was higher in women who cultured tilapia along with mud crabs (Figure 6). In T3, this could be due to direct consumption of the tilapia grown in the ponds. Although slightly lower than in T3, the increase in MUAC in T2 may be due to greater profits from supplemental sale of the tilapia and thus more money to buy more nutritious foods.

The addition of tilapia in crab fattening and culture ponds had benefits in increasing nutrient-rich foods available to the farmer's households. The households consumed greater amounts of protein-rich foods after the study than they did before the study (Figure 7). The respondents indicated an increase in protein consumption from 32% of their diets in the baseline study to 67% of their diets in the follow-up study (Figure 8). This is a significant increase in protein consumption for these households. They also had significant increases in the amounts of sugars consumed before and after the study (43% to 52%, respectively).

The other offshoot of this study were that more women were becoming income earners in each of the households (Figure 9). This is important because this leads to a total increase in income for the entire household, income that can be included in purchasing necessary foods for the health and well-being of all members of the household.

The inclusion of tilapia in mud crab fattening and culture farms in this pilot study led to greater overall growth and production of mud crabs. This in turn could increase income to the farmers, not only through the greater production of mud crabs but also supplemental sales of tilapia not kept by the farmer's families for consumption.

2B: On-site training workshop. On-farm training and workshops were provided to describe this new technology to the farmers and for improving mud crab fattening and culture. It mainly targeted women crab farmers in order to give them valuable information on the methods and outcomes of integrating tilapia into their crab fattening and culture facilities. Items discussed were methods to include and grow tilapia along with the mud crabs and methods of proper water quality maintenance and pond preparation such as dike construction, water exchange facilities, use of fertilizer and lime, physiochemical parameters, crab and tilapia feed, stocking density, management during stocking, post-stocking management, feed utilization and feed conversion, harvesting and handling of crabs and fish, marketing, grading of crabs, and record keeping. This session also allowed the farmers to ask questions about crab and tilapia farming to members of the research and extension team.

Household nutritional sessions also were given to assess and exchange nutrition information to the farmers. Topics included the MUAC measurements, changes in protein and other food nutrient uptake, and issues of malnutrition that may be resolved with these new culture methods. These sessions educated the farmers in basic concepts of food and nutrition.

An extension factsheet was produced which detailed the pilot study and its benefits income, nutrition, and health of the participants (see Addendum 3). This brochure was given to the participants of the training workshop and to other crab farmers in the region. This brochure included details on the methods and function of crab/tilapia polyculture with information on how these practices can lead to better food security and well-being for the women farmers and their families.

CONCLUSION

Forty-five mud crab farmers were trained in the new technology of growing tilapia along with mud crab fattening and culture. This technology had the added benefits of increasing income status along with the health and well-being of the farmers and their families. The health status of these farmers was greater after the introduction and more members of their families are moving into these more successful culture systems. Through outreach and extensions workshops and sessions, more farmers have been educated in these techniques. As these farmers become more successful, the technology will spread and the average incomes of the nation's residents will continue to rise.

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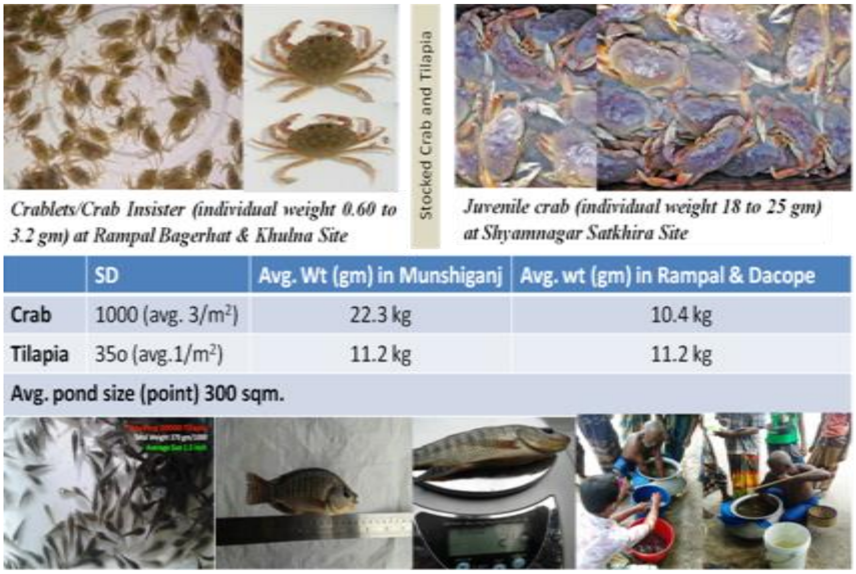
TABLES AND FIGURES

Table 1. Weight gain of mud crabs in the mud crab/tilapia pilot study.

Production	Gained weight (KG)									Others below the size of male & female	Avg. Weight (Kg) /point
	Male					Female					
Grade with Rate	XXL +500	XL +400	L +300	M +250	SM +200	F1 +180	F2 +180	F3 +160	F4 +130		
Production in Shyamnagar, Satkhira (after 3.5 to 4.0 months)											
T-1	1.400	2.800	4.400	5.500	9.200	1.600	2.300	4.350	5.300	24.400	61.250
T-2	2.100	3.300	4.200	6.400	12.300	1.850	2.500	6.230	11.220	29.100	79.200
T-3	1.550	2.200	5.350	7.350	11.800	1.000	2.740	9.350	12.050	32.150	85.540
Production in Rampal, Bagerhat (after 3.5 to 4.0 months)											
T-1	2.050	2.340	5.150	5.500	8.860	1.800	2.500	4.750	8.450	23.750	65.150
T-2	2.210	3.400	4.600	7.100	10.250	2.750	2.300	7.300	12.020	31.200	83.312
T-3	1.610	2.330	5.150	6.050	11.500	2.100	1.940	10.150	11.450	33.010	85.290

Figure 1. Methods of mud crab plot installation.



	SD	Avg. Wt (gm) in Munshiganj	Avg. wt (gm) in Rampal & Dacope
Crab	1000 (avg. 3/m²)	22.3 kg	10.4 kg
Tilapia	35o (avg.1/m²)	11.2 kg	11.2 kg
Avg. pond size (point) 300 sqm.			

Figure 2. Tilapia stocking.

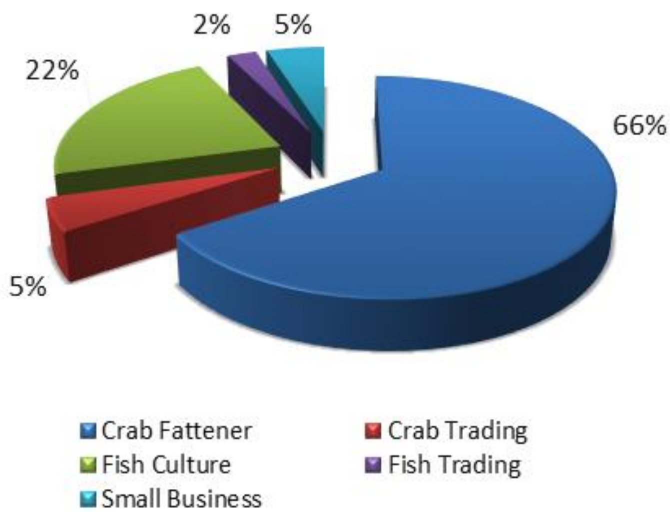


Figure 3. Occupation status of household members involved in mud crab fattening and culture.

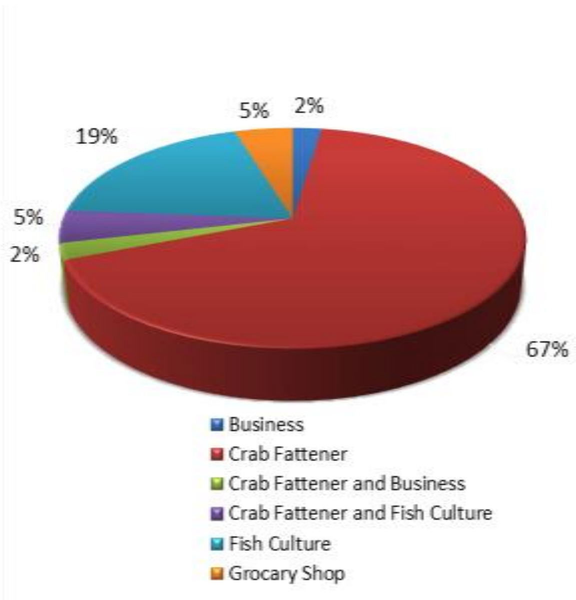


Figure 4. Income status of household members involved in mud crab fattening and culture.

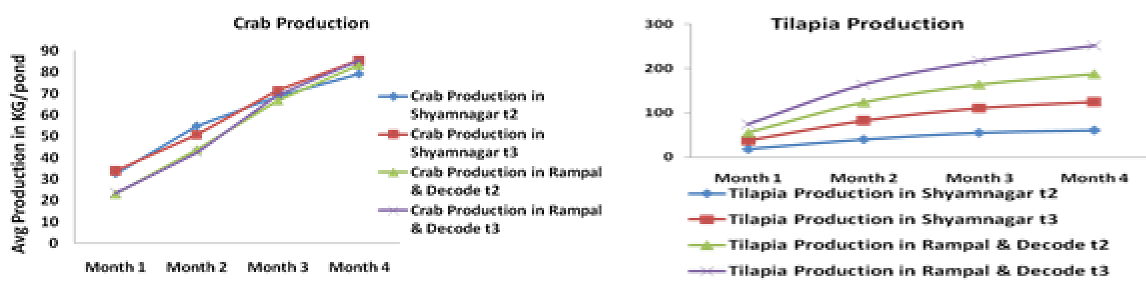


Figure 5. Production of mud crabs and tilapia on integrated farms. Mud crab production increased in spite of the inclusion of tilapia in crab culture.

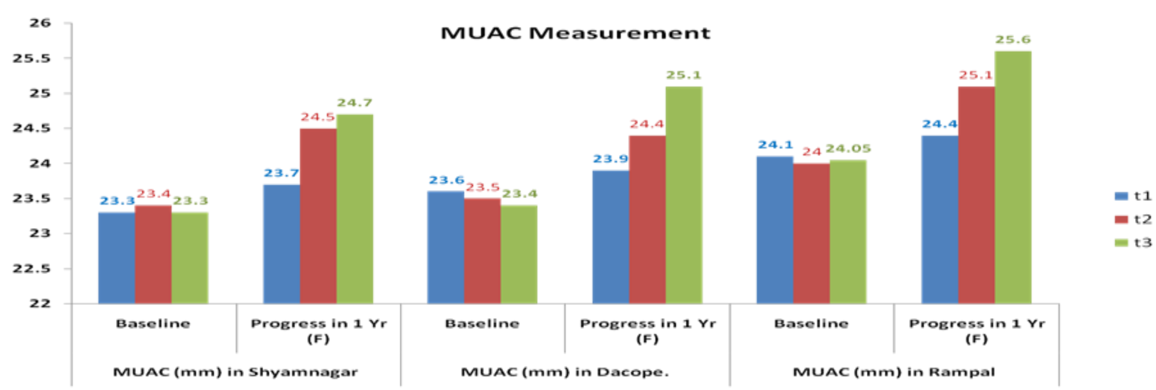


Figure 6. Mid-upper arm circumference (MUAC) of women mud crab farmers surveyed in this study. The MUAC of women on farms that raised tilapia along with their mud crabs was greater than those who did not raise tilapia. This may be due to direct consumption of tilapia raised and to the purchase of food from the increased profits from sale of tilapia.

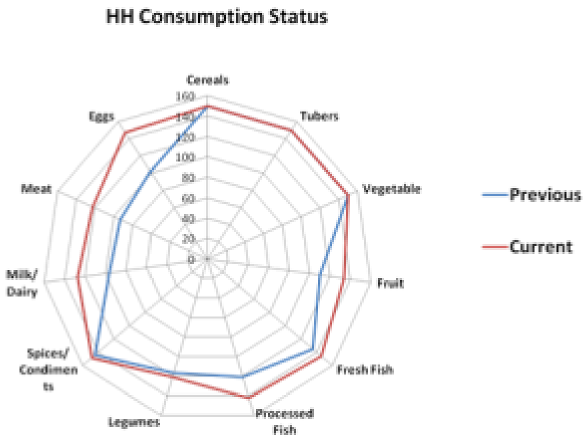
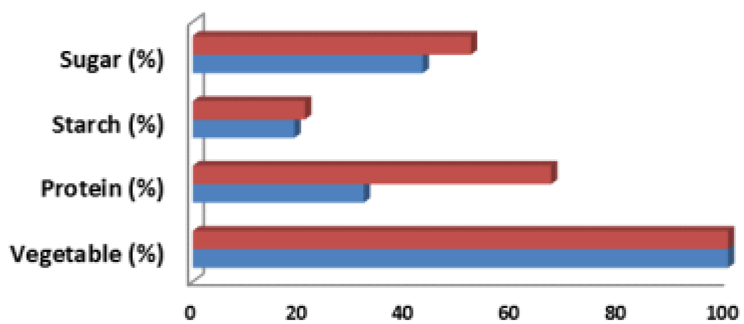


Figure 7. Household consumption of food groups identified. Consumption of protein-rich foods increased after tilapia were included in mud crab fattening and culture practices.



	Vegetable (%)	Protein (%)	Starch (%)	Sugar (%)
Recent Study	100	67	21	52
Baseline Study	100	32	19	43

Figure 8. Proportion of food compositions consumed by study respondents. Respondents took in more protein and sugar after inclusion of tilapia in mud crab fattening and culture facilities.

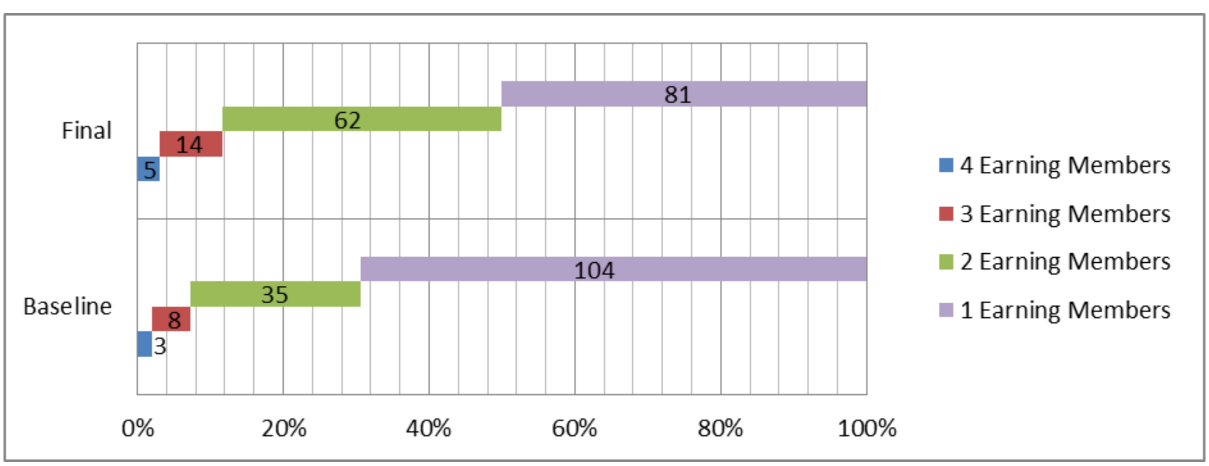


Figure 9. Proportion of the number of household income earning members in mud crab fattening and culture.

APPENDECIES

Appendix 1. Improving Nutritional Status and Livelihood for Marginalized Women Households in Southwest Bangladesh through Aquaculture and Value Chain Analysis.

Implemented by: AquaFish Innovation Lab, BAURES, University of Dhaka, and Shushilan, NGO

<table>
<tr><td colspan="6">Baseline Survey
Household Questionnaire for Respondent /HH Head</td></tr>
<tr><td colspan="6">PART-A: Socioeconomic Condition of the HH</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">1. Survey information</td></tr>
<tr><td colspan="6">Name of the interviewer:……………………………………………………………………………Date of interview:_____/____/______</td></tr>
<tr><td colspan="6">HH Survey Number: GPS Location:</td></tr>
<tr><td colspan="6">2. Location Details:</td></tr>
<tr><td colspan="6">District: Upazila: Union:</td></tr>
<tr><td colspan="6">Village: Para/Cluster:</td></tr>
<tr><td colspan="6">3. Observation: HH/Family Details</td></tr>
<tr><td colspan="2">3.1. Name of the Household Head: ………………………………………………………………………</td><td>Male</td><td></td><td>Female</td><td></td></tr>
<tr><td colspan="6">3.2. Name of the Father/Husband of HH Head: ………………………………………………</td></tr>
<tr><td colspan="2">3.3. Name of the Respondent: : ……………………………………………………………………..</td><td>Male</td><td></td><td>Female</td><td></td></tr>
<tr><td>3.4. Religion:</td><td colspan="5">Muslim = 1; Hindu = 2; Christian = 3; Other = 4</td></tr>
<tr><td colspan="6">3.5. Contact/Cell Phone of HH (if any member):</td></tr>
<tr><td>3.6. Profession of the HH Head:</td><td colspan="3">01. Farmer (Own land)
02. Farmer (Others land)
03. Day labour
04. Trained/factory labour
05. Transport labour (handling)
06. Driver (rickshaw/boat/van)
07. Samll businessman
08. Govt. service</td><td colspan="2">09. NGO service
10. Private service
11. Homemaker
12. Students
13. Crab fattener
14. Fish culture
15. Fish trading
16. Others</td></tr>
<tr><td>3.7. Education level of HH Head:</td><td colspan="5">Highest class passed (mention as class number)</td></tr>
<tr><td>3.8. No. of Household member:</td><td colspan="5">Eat together for last six months</td></tr>
<tr><td colspan="6">4. Land based information:</td></tr>
</table>

4.1. Area of dwelling house (dec.):	4.2. Status of dwelling: (Own= 1; rented= 2; relative= 3; other…………..)
4.3. Total area of land under your possession (dec.):	4.4. No. of Pond:
4.5. Total area of pond/Gher (dec):	4.6. Pond status: (Single owned -1; Joint owned-2; Single leased-3; Joint leased-4)

5. Family income pattern:

5.1. How many person of your famiy earn money? Male: ______Female:______

5.2. What is your monthly income from major sources?	Name of Major Income Sources: ……………………………………………………………………………
5.3 What is your additional monthly income from other/secondary sources?	Name of other/secondary Income Sources: ……………………………………………………………………………

6. Family expenditure pattern:	Subject	Amount in Tk. Or %
How much money isspent for your family?	6.1. Food	
	6.2. Education	
	6.3. Investment in farming	
	6.4. Transportation	
	6.5. Garments	
	6.6. Medicine	
	6.7. House rent	
	6.8. Non food HH goods	
	6.9. Fuel (cooking+ lights)	
	6.10. Others	

7. Information about HH Financial System:

Have any household savings? Yes: No: Amount…………………BDT

Have any household loan/credit? Yes: No: Amount…………………BDT

If Yes, please mention the purpose of the loan/credit: Crab culture / Tilapia Culture / Others

Have any communication with other NGO/Financial Institution? Yes: No: Name………………………..

PART-B: Household Nutrition

8. Hausehold Composition

No	**Name**	**Sex (Code)**	**Age**	**Marital status (Code)**	**Education (Code)**	**Anthropometry**		
						Wt. (kg)	**Hgt. (cm)**	**MAUC (mm)**

1								
2								
3								
4								
5								
6								
7								

Code: (For Sex M = 1, F = 2) Marital status: (Yes 1, No 2) Education (Illiterate 1, <primary 2, SSC 3, HSC 4, Other 5)

9. HH Food Consumption Status:

Select a mother to recall all the foods she consumed yesterday, from the time she woke up in the morning till she went to bed at night includes beverages and small foods consumed as snacks in between the major meals, weather home or outside the home.

No.	Question	Response Code	Re-sponse
1	Cereals (Rice, Bread etc.)………………………………………….	1= Yes; 0= No, 9= Don't know	
2	Tubers (Potato, Sweet potato)……………………………………..	1= Yes; 0= No, 9= Don't know	
3	Vegetables (Spinach, Amaranth, Kangkong, Gourd/Pumpking, Jute, Eggplant, Chichinga, Tomato, Beans, Gourd, Green Banana, Potol, Data, Green papaya, Pumpkin, Cauliflower, Cabbage, Cucumber, Snackbeans, Carrot, khonkhol, Bit etc etc.)……….	1= Yes; 0= No, 9= Don't know	
4	Fruits (Mango, Jackfruit, Guava, Orange, Apple, Water melon, Safoda, Coconut, Other local fruits etc.)……..	1= Yes; 0= No, 9= Don't know	
5	Fresh Fish (Large , Small)	1= Yes; 0= No, 9= Don't know	
6	Processed Fish (dry, icing, salting, smoking…….)	1= Yes; 0= No, 9= Don't know	
7	Legumes (Dal (any)e.g. Lentil, Kheshari)	1= Yes; 0= No, 9= Don't	

		know	
8	Spices/condiments (Chilies, herbs, pickle etc.)	1= Yes; 0= No, 9= Don't know	
9	Milk/Dairy (Milk, Curd etc.)	1= Yes; 0= No, 9= Don't know	
10	Meat	1= Yes; 0= No, 9= Don't know	
11	Eggs	1= Yes; 0= No, 9= Don't know	
12	Fats/Oils (Edible oil. Butter, Ghee, Animal fat etc.)	1= Yes; 0= No, 9= Don't know	
13	Sweets (Misti, Sugar, Molases, Honey etc.)	1= Yes; 0= No, 9= Don't know	
14	Drinks/Beverages (Tea, Coffee, Coke, Pepsi, RC, 7up, Fanta, Merinda, Pran juice, Mango juice, Frutika etc.)……	1= Yes; 0= No, 9= Don't know	
15	Others (Specify)	1= Yes; 0= No, 9= Don't know	

10. Food consumption and how low-intensity culture species (including mud crab and tilapia) and other contribute to the dietary nutrition and earned incomes

Food Items/ Species	**Sources**(Quantity/day)				**Intensity of consumption**(No.)			
	Own ponds	Purchased from market	Self-caught Fro	Others (Specify)	Meal/day	Day/week	Week/ month	Month/ ye

			m open wate r bod y						ar
Tilapia									
Mud Crab									
Carp fishes									
Small fishes									
Shrimp/prawn									
Other sea fishes									
Pangus									
Catfish (Shoal/taki/magur/ shing									
Others ………………..									

<table>
<tr><th colspan="6">PART-C: Crab Culture-Production and Marketing</th></tr>
<tr><td colspan="3">11.1. Is the HH has involved in Crab aquabusiness? Put (✓)</td><td colspan="3">Grow-out / Fattening / Trading / Collection / Transportation</td></tr>
<tr><td rowspan="2">11.2. No. of pond for crab fattening/ Grow-out</td><td rowspan="2" colspan="2"></td><td colspan="2">11.3. Pond surface area (decimal)</td><td></td></tr>
<tr><td colspan="2">11.4. Pond/compartmentsize Please take the data for each compartment (Length x Width)</td><td>………..ft. x ……….ft.
………..ft. x ……….ft.
………..ft. x ……….ft.</td></tr>
<tr><td colspan="3">11.5. Pond type: Put (✓)…..Seasonal / Perennial</td><td colspan="3">11.6. Water source: Ground water / Rainfall / Rivers/Others</td></tr>
<tr><td>11.7. Experience in crab fattening/culture (Year)</td><td colspan="2"></td><td colspan="2">11.8. Main source of the crab… Put (✓)</td><td>Sundarbans / Shrimp farm / Market</td></tr>
<tr><td>11.9. Has the HH received any training on crab fattening/culture?</td><td>Yes=1
No=0</td><td></td><td colspan="2">11.10. Collect baby crab from….. Put (✓)</td><td>Sundarbans / Shrimp farm / River</td></tr>
<tr><td rowspan="3">11.11. If yes; give details</td><td colspan="2">Name of the Training</td><td colspan="3"></td></tr>
<tr><td colspan="2">Duration and Year</td><td colspan="3"></td></tr>
<tr><td colspan="2">Organized/conducted</td><td colspan="3"></td></tr>
</table>

<table>
<tr><td colspan="2"></td><td>by</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2">11.12. Stocking density for Crab per Square meter/dec.</td><td>Fattening:</td><td rowspan="2">11.13. Collect soft shell Crab for fattening…. Put (✓)</td><td rowspan="2">Sundarbans / Shrimp Farm / River</td></tr>
<tr><td>Culture:</td></tr>
<tr><td rowspan="3">11.14. Use of feed for crab</td><td></td><td>Name of feed</td><td>Quantity</td><td>Frequency/day</td></tr>
<tr><td>In Fattening</td><td></td><td></td><td></td></tr>
<tr><td>In Culture</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">11.15. Purchase soft shell crab from…..Put (✓)</td><td colspan="2">Collect by self / Depots / Direct from fisherman</td></tr>
<tr><td colspan="2" rowspan="2">11.16. How many period/cycle practices</td><td>Fattening: No.</td><td colspan="2">Days require for each cycle:</td></tr>
<tr><td>Culture: No.</td><td colspan="2">Days require for each cycle:</td></tr>
<tr><td colspan="2">11.17. Total investment in each cycle for crab fattening/culture</td><td>Tk.</td><td>11.18. Total return in each cycle for crab fattening/culture</td><td></td></tr>
<tr><td colspan="3">11.19. What activities are done before marketing the crab as final product?</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>11.20. Where sell the final product (Crab)? Put (✓) & write %</td><td>Sell to Foria</td><td>Other crab farmers</td><td>Shrimp farmers</td><td>Depots</td><td>Local Markets</td><td>Others</td></tr>
<tr><td>11.21. Distance (km) & time (hour) required for marketing</td><td colspan="6">……………………………..km and …………………………..hr</td></tr>
<tr><td>11.22. Which type of basket you usually use for crab marketing?</td><td colspan="3"></td><td colspan="3">11.23. What problems you face with it?</td></tr>
<tr><td>11.24. Which type of vehicle you usually use for crab marketing/transportation?</td><td colspan="3"></td><td colspan="3">11.25. Is it available/ convenient/costly?</td></tr>
<tr><td>11.36. Which is more important to you? Put (✓)</td><td colspan="3">Production of tilapia/crab for own consumption and nutrition</td><td colspan="2">Production of tilapia/crab for sale</td><td>Production and consumption/nutrition are equally important</td></tr>
<tr><td>11.26. What types of problems you face in crab marketing?</td><td colspan="6"></td></tr>
<tr><td>11.34. What can be your suggestion to solve the existing problems in crab marketing?</td><td colspan="6"></td></tr>
<tr><td>11.35. Your recommendations to improve the marketing systems for crab?</td><td colspan="6"></td></tr>
</table>

Signature of the interviewer………………………………………….

Appendix 2. Farmer's Data Collection Notebook.

(Research on Integrated Mud Crab-Tilapia Farming)

Farmer's ID:	
Name of Farmer	
Father/ Husband Name	
Village	
Union	
Upazila	
Zilla	
Mobile No	
Farmer's Type	Treatment

1. General Information of Farmer

1.1 research Topics:Research on Integrated Mud Crab-Tilapia Farming			
1.2 Research Type	Treatment - T_1	Treatment - T_2	Treatment - T_3
1.3 Pond/Point Type: Crab Fattening			
1.4 Pond/Point Area:................Sqm. Length:.....................m × Wide:...................m)			
1.5 Pond/Point area:..........................dec.			
1.6 Crab Stocking/sq.m......................			
1.7 Breeding size Tilapia stocking ammount; Male................; Female			
1.8 Ammount of total Crab Stocking...................			
1.9 Ammount of total Tilapia stocking..................... (Male............; Female ....)			
2.0 Another Fish (White fish/prown) Stocking ammount ....) If Applicable Total.................KG/dec.			

2.Stocking and restocking information

Date	Crab/ Tilapia/ Other Fish		Expendeture	
	Ammount	Weight (KG)	Crab/ Tilapia/ Other Fish Price	Other Expendeture
Total				

3.Another Materials Expendeture

Materials	Ammount/ Number (KG/ Dec/ Hand/ Feet)	Unit	Price	Transportation Cost	Total Ammount
Pata/ Bana					
Blue Filter Net					
Bamboo					
Rope					
Labor					
....					
....					

4.Feed for Crab

Date	Rice/ Fish/ Snail......	Ammount (KG)	Price (BDT)	Transportation Cost	Total Ammount
Total					

1. Fertilizar and another input information of Pond/ Point (If applicable)
   ($T_2$and T_3 Saatchi disk measurement of the pond. If 40cm cross then apply 113gm urea and 28 gm Phosphate for each dec.As the feed for Tilapia fish.

Date	Saatch Disk Reading (cm)	Urea (gm)	Phosphate (gm)	Lime/Medicine/Others	
				Ammount	Price
Total					

2. Crab Live and growth Information

Investigation No	Starting Weight (gm)	Starting Length (cm)	Final weight (gm)	Final Length (cm)

3. Crab Harvesting Information

Date	Grade	Ammount (Number/gm)	BDT	Transportation Cost	Total Ammount
Total					

4. Tilapia and Other Fish Harvesting Information (If applicable)

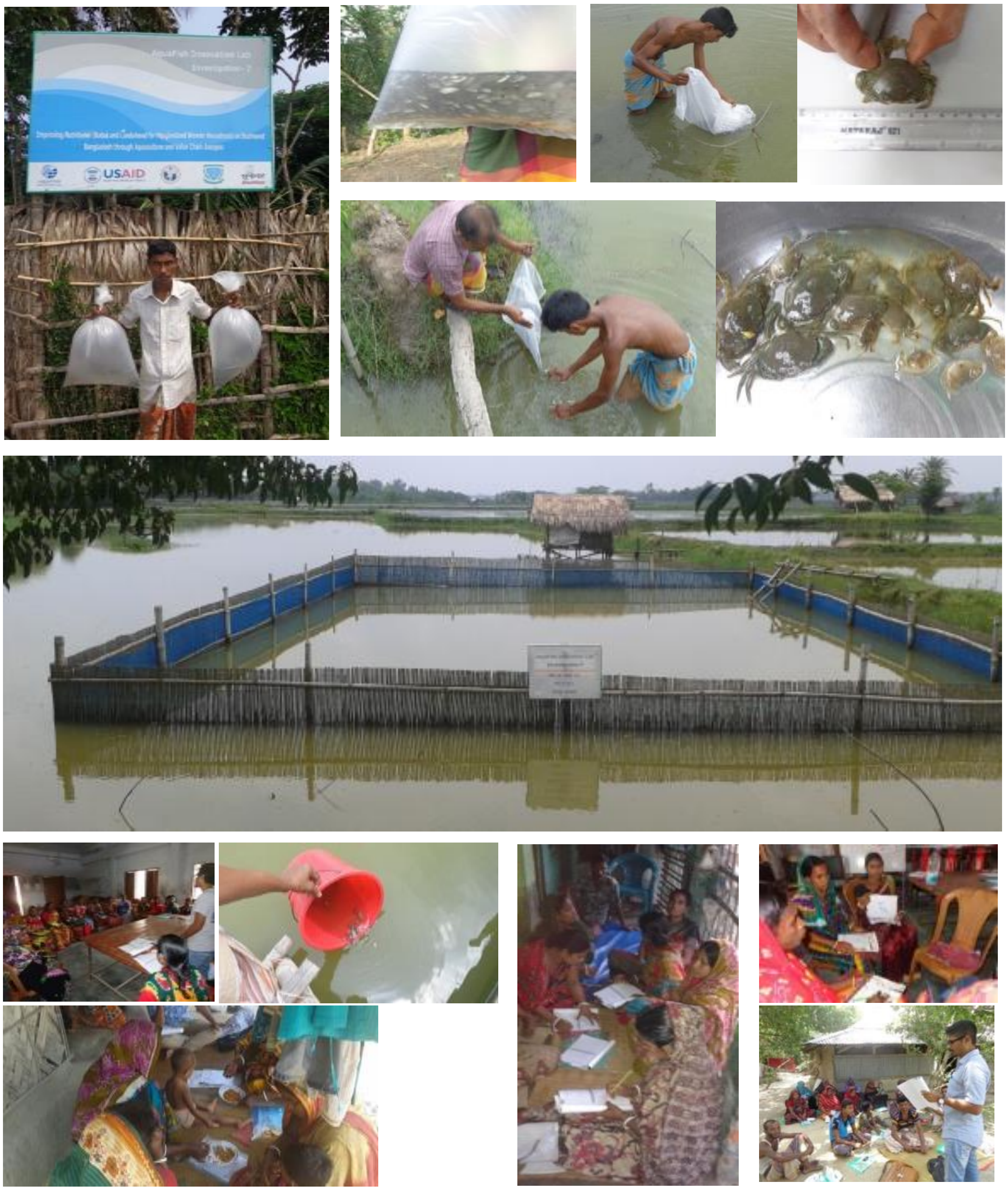
Date	Hervested Fish	Use as a crab feed (kg)	Sell to Market (kg)	Used as a family food consumption (kg)	Market Price /kg	Total Amoount	Expendeture
Total							

5. Others

Research Monitoring and Comments
➢ ➢

Visitors Comments		
Comment	Name, Address/ Organization	Signeture and Date

Appendix 3. Photo Gallery.



Improving Nutritional Status and Livelihood for Marginalized Women Households in Southwest Bangladesh through Aquaculture, Part II

IMPROVING NUTRITIONAL STATUS AND LIVELIHOOD FOR MARGINALIZED WOMEN HOUSEHOLDS IN SOUTHWEST BANGLADESH THROUGH VALUE CHAIN ANALYSIS

Marketing, Economic Risk Assessment, and Trade/Study/13MER04NC

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ABSTRACT

This study analyzed the value chain of mud crab in Southwest Bangladesh and identified areas to improve the livelihood opportunities of women crab culturists in this region. Tracer methodology was employed to map the existing value chain of mud crab spanning three districts, namely Khulna, Satkhira and Bagerhat. A total of 156 respondents were interviewed composed of six crab collectors, 45 mudcrab culturists, six assemblers (three in local/district-based depots and three in national or Dhaka-based depots), three soft-shelled crab processors and exporters of live crabs in Dhaka, one exporter association (with 86 active members) in Dhaka, and 10 consumers. A combination of individual and panel interviews as well as focus group discussions were employed to gather data and information needed to answer the key questions related to value chain mapping. This approach enabled the study to provide improved analysis of the dynamics in the chain and the behavioral and institutional features of the transactions involved. Secondary data were used extensively to establish a good understanding of the mud crab industry. These include data on volume and value of production, yield, prices and other market information, among others. Finally, key informants from relevant agencies such as the Bangladesh Ministry of Fisheries and Livestock, Department of Forestry, among others were also interviewed.

The mud-crab industry in Bangladesh has been emerging as an important source of income and employment for its fishery sector. Export value of live crabs is now ranked ninth and the third fastest growing fishery product. The major destination of live crabs is export markets whose demand is growing, particularly China, Singapore, and Malaysia. This rapidly expanding export opportunity contrasts with limited domestic demand from non-Muslim consumers and foreign tourists. Consumption of crab is not yet accepted by the majority Muslim Bangladeshi population; although not forbidden by their faith, it has not generally been an accepted part of their diet.

Marketable live crabs are collected in the wild but excessive levels of harvest of these natural populations has resulted in unsustainable volume of catch and inconsistent quality. Crab culture and fattening has recently emerged to improve sustainability.

The crab value chain is composed of crab collectors, crab growers/culturists/fatteners, assembler-agents at local, district and national depots, exporter-processors and end users. At this time, retailers and institutional buyers do not play a significant role.

Schedules of volume, price and product requirements (grade, size, sex, gonad and claw conditions) are provided by exporters through assembler-agents 3 times per week. To meet volume or "quota" requirements, assembler-agents extend credit (*dadon*) or advanced payments to crab collectors and crab growers to facilitate procurement. Virtually all other transactions are settled in cash. In terms of cost and profit share of value chain players, exporters-processors dominate with 38% and 57%, respectively. District level assemblers and wild crab collectors accounted for 19% and 16% profit share while the local assembler and crab growers have the lowest profit shares of 4.4% and 2.4%, respectively.

High incidence (20%) of in-transit mortality and unmarketable quality result from poor road, transportation and packaging practices. To deal with these problems, exporters have begun to get involved in processing crab to maintain the quality and quantity demanded by their customers. If this trend continues, vertical integration of the crab value chain could result in reduced benefits at the local level. The principal objective of this project initiative to improve the well-being of Bangladeshi women would be greatly undermined.

The major logistical issues and concerns that hamper the overall efficiency and sustainability of the value chain include:

- Natural sources of crab seeds becoming unsustainable;
- Poor grow out and feeding technologies in mud crab culture;
- Poor road conditions, packaging and handling practices;
- Limited working capital; and
- Poor processing technology.

Additionally, the external influences that are harmful to the value chain include:

- Frequent floods due to heavy rains;
- Poor water quality; and
- Lack of government efforts to stimulate domestic demand for crabs.

To address the above issues and concerns, the following measures are recommended:

- Establish crab hatcheries;
- Improve cultural and value adding technologies via techno transfer and credit programs;
- Improve product packaging and handling systems; and
- Provide efficient marketing and promotion programs.

INTRODUCTION

The culturing or fattening of mud crab (*Scylla serrata*) is an emerging industry (Azam et al. 1998; Khan *et al*. 1991) directly benefiting women-led households in coastal Bangladesh. The large-clawed mud crabs are highly sought commodity seafood items due to their delicacy, medicinal value and demand in international markets (Ali et al. 2004, Keenan et al. 1997). Of the 2,428 crab farms in the severely impacted regions (Satkhira, Khulna and Bagerhat), 37.8% are currently owned and operated by women (26%–41% by region; Shushilan unpublished report). Even farms not directly owned by women commonly rely on this demographic for stock collection of juveniles from shrimp ponds or other wetlands. Currently, very little information has been collected or published about these endeavors, yet while women aqua-farmers likely obtain economic benefits from crab fattening, this is solely marketed as an export crop, thus may not directly benefit the dietary needs of local women and children. Given a poorly defined value chain, where the roles and participation of women may be under-estimated or under-appreciated by local government agencies, little protection from exploitation (by market intermediaries) currently exists. Through greater investigation of the mud crab value chain in the lives of women culturists, this study will identify key opportunities and constraints for this industry, for which women play important roles.

OBJECTIVES

This study is designed to assess the existing value chain for mud crab and to identify areas for improvement. The specific objectives are as follows:

- To provide an overview of the mud crab industry;
- To map out the specific value chain for mud crab;
- To analyze the performance of the mud crab value chain in terms of efficiency and overall responsiveness;
- To identify areas for improvement in the value chain such as behavioral, institutional and process; and
- To provide specific policy recommendations to improve the mud crab industry**.**

THEORETICAL FRAMEWORK

Value chains may be referred to as the intra- and inter-linkages of producers, processors, transporters, trans-shipment/depot facilities, and resellers that take part in the production, delivery, and sale of a particular product. In the mud crab value chain, players include the crab collectors, crab culturists, crab traders, depot operators, exporters and key customers both in domestic and export markets.

Value chain should be managed through effective coordination relative to tactical and strategic actions on identified strengths, weaknesses, opportunities, and threats across players of the chain. In the mud crab value chain, one of the most attractive opportunities is the surge in demand. However, such demand has become considerably stringent to meet quality, food safety and reliability requirements. Meeting such requirements appears to be due to the weakness of existing mud crab value chain, especially involving the small-scale or marginal sector. The value chain analysis (VCA) as a systems approach, draws contributions from various disciplines and scrutinizes different areas for improvement, such as economic and operational efficiencies and business relationships:

Economic efficiency. Economic efficiency is achieved when production of goods and services is maximized at lowest possible cost and well-being of sector participants is improved. This condition also includes minimization of transaction costs. Such costs are incurred with market operations entailing the exchange of goods and services, including cost of acquiring information, costs of negotiating and enforcing contracts, among others.

Business relationship. Value-chain players, from upstream to downstream, should work in partnership with each other based on long-term benefits such as increased competitiveness and improved quality. By coordinating value chain processes or activities and working more closely with suppliers, distributors, and customers, business relationships can result in greater benefits.

One indicator of successful value chain performance is a good business relationship based on high level of trust and integrated information sharing and process planning. The lack of trust among negotiating parties often generates a situation where every transaction has to be scrutinized, thereby increasing the transaction costs, resulting in reduced efficiency and cost effectiveness.

Operational efficiency. Operational efficiency is achieved when the right arrangement and coordination of people as well as processes employing improved technology work closely together to enhance productivity and value of the business while driving down cost of operations to a desired level. However, operational efficiency should not be viewed only as a way of enhancing profitability but also vital to ensuring consumer satisfaction.

Operation management and logistics provide conceptual and analytical tools in improving operational efficiency. Achieving such efficiency involves ensuring that value chain processes are efficient in terms of using limited resources and effective in terms of satisfying the consumers' requirement. This also entails competently managing inbound and outbound logistics with regards to setting up optimal raw material sourcing strategies, distribution schemes, and scheduling.

Crab seed stock reliability and product quality are crucial logistical issues. Earlier studies have identified important constraints associated with this logistic system. This includes instability in supply of crab seed stock and consistency of product quality. Analysis of the logistic system in the mud crab supply chain would generate valuable insight for formulation of effective strategies in addressing these problems.

METHODS

Overall strategy of analysis used value-chain methodology used in the Philippine tilapia (Jamandre and Hatch 2010) and Indonesian seaweed marketing systems to analyze the value chain of mud crab in Bangladesh with particular emphasis on improving the benefits that accrue to poor coastal women from this culture system. Ferdoushi and Xiang-Guo (2010a) have provided an excellent description and analysis of mud crab production economics and Ferdoushi and Xiang-Guo (2010b) will be useful in connecting the role of women in production with participation in the market system.

Areas of the study. This study covered the major mud-crab-producing districts of Southwest Bangladesh, namely Khulna, Satkhira and Bagerhat (Figure 1). Tracer methodology was employed to identify the respondents. A total of 156 respondents were interviewed composed of six crab collectors; 45 mudcrab culturists; six assemblers (three in local/district-based depots and three in national or Dhaka-based depots), three soft-shelled crab processors and exporters of live crabs in Dhaka; one exporter association (with 86 active members) in Dhaka; and 10 consumers.

Primary data were gathered through pretested semistructured questionnaires. They were designed to collect quantitative and qualitative information needed in detailing the following six key questions:

- Who are key customers and what are their product requirements (quality standards and volume requirement);
- How do product, information and money flow through the value chain;
- What are the activities and services provided at each step in the chain;
- What are the roles of each key player involved in the chain;
- What are the critical issues related to logistics; and
- What external influences impinge on members of the chain.

Answers to these questions enabled an improved understanding of the dynamics in the chain and the behavioral and institutional features of the transactions involved.

Secondary data were used extensively to establish a good understanding of the mud-crab industry in the study area. These include data on volume and value of production, yield, prices and other market information. Finally, key informants from relevant agencies such as the Bangladesh Ministry of Fisheries and Livestock, Department of Forestry were interviewed.

RESULTS AND DISCUSSION

Overview of the industry. Mud crab of genus *Scylla*, also known as green crab or mangrove crab, constitute an important secondary crop in traditional shrimp or fish culture systems in Asian countries including Bangladesh. Mud crab aquaculture has been practiced for many years, based primarily on capture and fattening of juvenile crabs from the wild. There is an unmet demand for mud crabs and this has led to over-exploitation in many areas. The mud crab, *Scylla serrata* is widely distributed in the Pacific and Indian oceans. It is available in brackish coastal waters and estuaries and has great potential for aquaculture. Crab culture and fattening are however still in the experimental stage in South Asia (Samarasinghe et al. 1992). The importance of live mud crab as an export commodity has opened up great opportunities. Considering its increasing demand in local and international markets, it has been gaining popularity among coastal communities in Khulna and Chittagong regions (Azam et al. 1998). The annual average volume of live crab imports from 2009–11 average to more than 106,000 tons (Table 1a) valued at around US$600 million (Table 1b) with China, Japan and South Korea topping the list of crab importers (FAOSTAT 2014).

Moreover, the annual export volume of live crab is estimated to be more than 89,000 tons (FAOSTAT 2014). The world's top three exporters of live crabs (Table 2a) are UK, Myanmar and Indonesia with respective yearly average export volume of 13,000 tons, 11,000 tons and 9,000 tons. Bangladesh is presently world's ranked 6 earning around US$ 21 million by exporting more than 6,000 tons of live crabs to China, Hong Kong, Singapore and Malaysia.

The mud crab *Scylla serrata* is currently the most commercially important species and is widely distributed in the Indo-Pacific region, including the Bay of Bengal. Bangladesh has a coastline of 710 km with 618,780 hectares of mangrove tidal flat and 80,000 hectares of prime area which is suitable for brackish water aquaculture (Anon 2003). Mud crabs are indigenous in coastal waters of 15–30 ppt salinity. Shrimp and crab thrive in similar environmental conditions and are quite abundant in places 40–50 km inland from the Bay, in the creeks and canals of the brackish water estuaries (Khan and Alam 1991). Mostly non-Muslims, e.g., Hindu and Buddhists, are the traditional consumers. The majority of Muslim population does not accept mud crab as a food item. Nevertheless, attitudes are gradually changing in the Muslim community recently.

The trade performance of the aquaculture reflects its relative importance in the Bangladesh economy. Tables 3a and 3b registered the volume and value of the top 9 fish exports of Bangladesh from 2010 to 2014. Most of the production areas were located at Dhaka, Chittagong and Khulna districts. The total export earnings during the period are about US$2.7 billion with live crabs contributing around US$14 million. Although live crab is ranked 9 in terms of export share, it is now the third fastest growing export item with annual growth rate of about 34%, next to live eel and shrimp.

Women are more involved at the early stages such as collection of crablets, and fattening. The role of women in latter stages like product packaging, handling (outbound logistics) and processing is not substantial, but could be potential areas for their involvement. Crab collection is getting more risky and less sustainable. Moreover, establishment of crab hatcheries would improve the well being of women through more sustainable and secured sources of crab seedstocks.

Key players and roles in the mud crab value chain. The key players in the value chain generally includes the following:

Crab collector. The crab collectors who are most often women are responsible for catching crabs from Sundarbans or mangrove forests (63%), shrimp gher pond (26%), and rivers (11%) then sells them to the nearby mud crab growers and agent-assemblers at local depots. The common collecting gears used are rope with series of baits deployed in shallow part of the mangrove forest or deep canals and crabs lured with the baits are scooped or caught using hook, bamboo tube traps, rakes, scoop nets, and net box-type traps (Figure 2). Usually, traps are deployed from 09:00–10:00 h and retrieved at 18:00 h depending on the tide level and season. The duration of collection is 8–10 hours. Higher volume of crabs (15–20 kg/day) is collected during the peak season (June–August) while about 10 kg/day of crabs is gathered during the lean season (December–February) per collector. The size range of crabs collected is 50–200 g. Crabs with < 150g BW are sold to crab fatteners while crabs with >150 g BW are brought to and sold to primary or local depot. Most collectors have been engaged in this activity for more than 10 years now. Some collectors were also mud crab growers and directly deal with local depots who are their regular creditor-financiers. In addition to the declining and unstable crabs caught in the area, the cost of getting no objection certificate (NOC) and related government fees are becoming more stringent and prohibitive. Accordingly, collection of crabs and small crab deeper into the mangrove forests and rivers are too risky from extortions or harassments by pirates or bandits hovering inside the forests in addition to the threats of wild animal attacks.

Mud crab grower. The mud crab grower is responsible for fattening small crab collected from mangrove forests, rivers and coastal areas to meet the product grade requirements of the major export markets such as China, Malaysia, Singapore, Hongkong and others. Khulna, Satkhira and Bagerhat Districts of Southwest Bangladesh are the major mud crab farms areas. Scylla olivacea or the orange mud crab is the major mud crab species in the region (Figure 3). Crabs with a body weight (BW) of >150 grams are fattened to 180-200 g BW in about 10–12 days. During the fattening period mud crabs were tied to prevent them from escaping and fed with tilapia and mollusks. The unavailability of formulated diet cannot reduce their dependence on fish and mollusks. Water change is through the natural inflow and outflow of tidal water. The water parameters in the earthen ponds (either with or without bamboo fence, Figure 4.) are normally not monitored.

A brief farm profile and crab fattening practices among two groups in Satkhira and Bagerhat districts are outlined in Table 4. Generally, both groups relied on wild crab seed stocks (through crab collectors) that are inconsistent in quality and availability. All growers operated in ponds less than 1 hectare that they either owned or leased. Most of them were engaged in fattening for more than five years while culturing juveniles to marketable size of crab is very recent. It only takes 10–12 days to fatten crabs but 2–2.5 months to culture and fatten juveniles. Both groups experienced 20% mortality rates, generally attributed to poor water quality, high water temperature and other poor cultural practices. This condition may compromise sustainability of current fattening systems; therefore, both groups recognized the need for hatchery, better culture system using cages and feed formulation.

Three-tiered depot system. Local depots are the first tier that serve as assembly or local transshipment points that are operated by local assembler-agents whose main role is to consolidate the mud crabs from the crab collectors and growers. At the local depot, the initial grading, sorting and weighing and its selling prices are determined based on exporter requirements communicated through district assemblers. All fattened mud crabs targeted export markets. Rejects, e.g., underweight, undeveloped gonads, physical defects, were either sold back to crab growers for further fattening or sold in local communities. Because the major role of the depot is to meet volume and quality requirements of export suppliers, several approaches are employed to capture the desired supply volume including; credit provision (or "dadon"), advance payments, and transportation arrangements. Once the assigned "quota" is met by the local depot, mud crabs are brought to the second tier or district-based depot which serve as a larger assembly or trans-shipment point and performs the same function as the local depots at the district level. In this tier however, the district assembler-agent (or depot operators) are more aggressive and proactive to consolidate and/or assemble crabs from various local depots given the long travel distances and poor road conditions, in order to minimize further in-transit mortalities and other handling losses. These losses impact negatively on their "commission earnings" if not reduced. After assembling the required volume allotted for the district, mud crabs were packed in 50–60 kg vertical bamboo baskets before finally transported to the third tier depot based in Dhaka. This tier serves as the national depot that will assemble all exportable crabs from all sources in the country such as Chittagong, Khulna, Cox's Bazar, Bagerhat, Satkhira, etc. Rejected crabs (e.g., dead, deformed, or crashed) at this point were either processed, chilled and exported or retailed to institutional buyers like hotels and restaurants that cater to foreign customers and niche markets.

Exporter-processor. The main role of the exporter-processor is to consolidate, grade and package live mud crabs for their final export markets. In addition to live form, chilled or frozen soft-shelled crab are gaining popularity in other Asian markets such as China, Singapore, Malaysia, and Hong Kong. Soft-shelled crabs are generally rejected by live crab export markets and domestic demand is very low. In order to recoup losses from these rejects, exporters recently started to export processed crab meat. Most of the latter operate in Dhaka particularly at Khalpar, Uttara near the Dhaka international airport.

End user. The typical end user of the Bangladeshi mud crabs is a foreign consumer who buys them from retailers in their home countries. Domestic consumers of crabs in Bangladesh are limited to Hindus and high-end consumers such as tourists and affluent customers in hotels and restaurants.

Product requirements. All product grade and volume requirements are specified by export markets are communicated through Bangladeshi exporters to lower levels of the chain. The product grades are usually disseminated by Dhaka-based exporters to third tier depot operators with the schedule of commission fees and prices presented in Table 5.

Value-chain map. The value -hain product flow is shown in Figure 5. The general product flow of mud crab begins from the crab seed stock collector to the grower, then to local assembler-agent (at local depot) to the district assembler-agent (at district depot) to the exporter-processor at national depot in Dhaka then to the end consumer in export markets.

The crab collector gathers small crabs and juveniles from Sundarbans mangrove forests and river channels. Small crab (body weight <150 g) and juveniles are sold to nearby crab growers for further fattening while crabs with body weight >150 g are sold to assembler-agent at local depot. The local assembler pays the net price of the crab after deducting loans (or dadon) to crab collectors. Usually crab collectors borrowed some funds from the local assembler-agents in order to finance collection activities such as fuel and oil of boats, food allowances during collection time and other expenses. Likewise, before anyone can collect crabs, he/she has to secure and pay an NOC from the Department of Forestry. This NOC permit specifies the conditions and length of time for crab collection. Normally, this permit lasts for 14 days, and it needs to be renewed thereafter. No issuances of NOC are done during breeding season of December to February. Unfortunately, this period coincides with the peak of demand in major export markets such as China, Singapore and Hong Kong.

The small crabs sold to mud-crab growers are tied and fattened with trash fishes and mollusks in earthen ponds for 10–12 days. Juveniles however are cultured and fattened in about 2–2.5 months. The marketable mud crabs are brought to and sold by the grower to assembler-agents at local depot. Initial sorting and grading are done before the sale. Guided by district depot price quotes (Table 5), the local depot assembler will reclassify the crabs and pay them to the growers on a piece rate basis. Daily transactions begin from 04:00–06:00 h. Once the volume of crab assembled reached at least 200 kg, they are packed and loaded in 50–60 kg bamboo basket and delivered to district depot assemblers, typically a four-hour trip by public transport. Information on volume and delivery schedules of crabs is usually transmitted using mobile phones between the assembler-agents at local and district depots.

At the district depot, crabs from different local sources are reclassified, cleaned and repacked in 50–60 kg basket based on price and grade quotes set by exporters in Dhaka (Table 6) before transporting them to national depot in Dhaka. The trading time in district depot is about 10 hours daily to accommodate late deliveries from other local depots. As the required shipment volume is reached, the district assemblers pay the commission fees and defray the associated costs of assembling and transporting the crabs to the local assembler-agents. Mortalities and other rejected crabs are sold at nearby markets at very low prices because of low domestic demand. It requires about 24 hours to move product from district depots to central market trans-shipment in Dhaka before final shipment to international end users.

Crabs from the districts arrive at the national depots in Dhaka usually during night time and early morning in order to meet international flight schedules. At the national depots, crabs are finally graded, cleaned, weighed and packed in 50 kg plastic container baskets. Exporters pay the district assemblers 10% commission fees and reimburse them for their transportation expenses. Incidences of high in-transit mortalities and rejects (20%) are observed due to poor roads and packaging conditions. Thus, exporters resorted to salvaging the value of their crabs through processing. This function is now emerging as attractive venture due to the increasing export demand. Most of the exporters and district assemblers have strong familial relationship with each other, thus, mutual trust and confidence are highly established among them.

A small number of institutional buyers for expensive hotels and restaurants purchase small quantities of rejected crabs at the national depot to address demand of international tourists and affluent customers. Nonetheless, there are few specialty shops like Lavender and Unimark in Gulshan-2. Dhaka that occasionally sell crab.

Prices, costs and margins in the value chain. Table 7 summarizes the distribution of prices, costs and margins across the actors of the mud crab value chain. These market data were specified as averages regardless of grades and sex of mud crabs for each key player in various levels of the chain. The profit margin for each player was based on costs of collection, production and operation and price margins. Exporters in Dhaka experienced the highest cost and profit of around 34% and 57%, respectively.in the entire value chain while the assemblers in the district depot and crab collectors shared the second and third highest margins. The profit shares of the assemblers at local depot and crab fattener or culturist were at the bottom with only 4.37% and 2.92% each.

Costs and profit shares are not conversely related with each other since the export prices were set and quoted by the exporters based in Dhaka. The behavior of the assemblers (or agents) at various depots may have the tendency to dampen their buying prices at the expense of the crab fatteners or culturists who received a low residual value for their product. Crab collectors are more flexible than crab farmers because they have more alternative buyers and sell more product forms (i.e., marketable crabs, small crabs for fattening and juveniles for culture).

The average selling price of mud crab from the crab collectors to the export markets ranges from Tk150 to Tk802 per kg. The big price difference is due to high transportation or logistic costs as well as poor bargaining skill of crab culturists.

Logistical issues and concerns. The major logistical issues and concerns that hamper the overall efficiency and sustainability of the value chain are summarized below and the details for each player are outlined in Table 8.

Firstly, the natural sources of small crab and seed stocks are becoming unsustainable due to the increasing demand for crabs in export markets. International demand is expected to exert increasing pressure on supply of crabs. Likewise, the peace and order or hostile situation in the Sundarbans mangrove forests exacerbates the risks and costs of crab collection.

Secondly, poor cultural and feeding technologies of mud crab growers will compromise their productivity and profitability. Heavy dependence on trash fish and mollusks as feeds increases time required for fattening and cultural period under earthen pond conditions thus reducing profitability. There is no established feeding regime or feeds for mud crab culture.

Thirdly, the poor road conditions, packaging and handling practices as well as storage facilities resulted to high (20%) incidence of in-bound mortality and rejects for live crab export markets.

Fourthly, frequent international flight delays affect export sales and put pressure on limited capital of exporters and assemblers at various levels along the chain to finance trading and assembling activities. Disruptions in timing of product flow are crucial to providing consistent availability and high quality product to international final consumers. This imposes a risk on the entire value chain from collector to final user, thus discouraging some potential participants.

Lastly, processing technology and practices are at a low level relative to many international production systems. Export markets for processed crab meats require quality standards and protocols that currently are difficult for the Bangladeshi production and marketing system to achieve. Failure to satisfy these international standards and protocols drastically affects international marketability.

External influences. The most crucial external influences that negatively influence the value chain of mud crab in Bangladesh are both natural and human. Frequent floods associated with heavy rains are natural events that will be difficult to mitigate. Poor water quality from human activities based on increasing population has no readily available short term solutions. Currently, there are few, if any, government programs to stimulate domestic consumption of crab. Fortunately, this is one external influence that can be easily addressed.

Recommendations and areas for improvement. To address the above issues and concerns, the following measures are recommended:

- Establishment of crab hatcheries — With crab hatcheries, the value chain will have more reliable sources of crab seeds that would insure regular and consistent supply of quality products. A public-private partnership scheme may be employed to capitalize this action, which would benefit women considerably as they are primarily involved in crab collection;
- Improve cultural and value adding technologies through tech transfer and credit programs — With improved technologies, productivity and efficiency would be attained in conformance with good agricultural and manufacturing practices. These strategies would entail better measures for reducing grow out mortalities, shorter culture periods through better nutrition program, and undisrupted production and marketing schedules;
- Improve product packaging and handling system — Better product packaging will reduce in-transit mortalities and incidence of unmarketable product;
- Provision of efficient marketing infrastructures and promotion programs — The critical role of good farm-to-market roads and marketing infrastructure would ensure long-term viability of the entire value chain. Through an aggressive promotion program, domestic demand for crabs will be improved and help boost overall sales; and
- Women's role in latter stages of value chain, e.g., product packaging, handling (outbound logistics) and processing, is not substantial. but could be potential areas for women involvement. Crab collection is getting more risky and less sustainable. Establishment of crab hatcheries would improve the well being of women through more sustainable and secured sources of crab seedstocks.

CONCLUSION

Mud crab culture and fattening in ponds is now an emerging activity in Bangladesh mud crab industry. This investigation has assessed the existing value chain of mud crab in Southwest region of Bangladesh and identified areas to improve the opportunities of women crab culturists through the value chain analysis.

The study covered three major producing mud crab districts, namely Khulna, Satkhira and Bagerhat. Tracer methodology was employed to identify respondents. A total of 146 respondents were interviewed composed of six crab collectors; 45 mud crab culturists; six operators (three in local/district-based depots and three in national or Dhaka-based depots), three soft-shelled crab processors and exporters of live crabs in Dhaka; on exporter association (with 86 active members) in Dhaka; and 10 consumers.

Of the world's top exporters of live crab, Bangladesh is ranked 6, earning around US$21 million by exporting more than 6,000 tons of live crab to China, Hong Kong, Singapore and Malaysia in 2009–11. During that period, average total value and volume of live crab imports of the world's top importers was US$600 million and 106,000 tons. These data indicate a tremendous opportunity for Bangladesh crab exports. World demand is available if the Bangladesh crab sector can develop an adequate production-marketing system to meet international standards and protocols.

Crab has not been a generally accepted part of the diet of the majority Hindu population of Bangladesh. However, Muslim, who are a minority in Bangladesh, do consume crab and recently crab consumption by Hindu Bangladeshi's is gaining acceptance. As a result, increasing demand for crab has both international and domestic components.

The trade performance of aquaculture reflects its relative importance in the Bangladesh economy. Most of the production areas were located in Dhaka, Chittagong and Khulna districts. Total export earnings during 2010–14 were about US$2.7 billion, with live crab contributing around US$14 million. Although live crab is ranked 9 in terms of export share, it is now the third fastest growing export item with annual growth rate of about 34%, behind only live eel and shrimp.

The value chain of mud crab is composed of crab collectors, crab growers or fatteners or culturists, assemblers at local depot, assemblers at district depot, assemblers at national depot, exporters-processors and end consumers. Because the major destination of live crabs are the export markets, the requirements regarding product grades, volume, sex and delivery schedules are imposed by the exporter-processors based on demand orders of foreign buyers. The condition of domestic demand at all levels does not make those small retailers and institutional buyers regular members of the value chain.

The product flow begins from collection of crabs from natural sources such as the Sundarbans mangrove forests and river channels. Small crab below marketable size and juveniles are sold to crab growers for fattening and culture. Marketable crabs are brought to and sold at local depot through an assembler-agent. After meeting a reasonable volume (as agreed between the assemblers at district and local depots), crabs are transported to district depots in bamboo baskets. The trading transaction in local depot is shorter (about 4 hours) than the district (about 10 hours) due to wider geographical spread of local depots serving the district depot. Dead, weak, deformed and cracked or broken shells crabs are rejected for export markets. Higher incidence of mortality and rejects are observed the longer the travel distance and time of crabs from the local depots to the national depot in Dhaka owing to the poor road conditions and packaging practices while in transit. The rejects and dead crabs are then processed at the exporters' area in order to recoup losses in the process. With the continuing surge of export demand for processed crab meat, the processing function is now becoming a regular part of the value chain.

The requirements for export transactions are more rigorous. Delivery requirement is three times per week at 1,000–1,500 kg of per transaction. The quality requirement is more specific of the *Scylla serrata* species with differences in sizes and kind of fat for the different market such as: 200–500 g/pc, male or female with green fat for the Hong Kong market and 750–1,000 g/pc, male or female with green fat for the Singapore market. The mud crabs are generally packed in 50 kg plastic baskets before being exported.

Information regarding prices, grades, volumes and delivery schedules among chain actors are exchanged through mobile phones but internet exchanges are common between exporter-processor and importers in foreign markets. Only crab collectors, crab growers and assemblers at local depots conduct face-to-face communication. Such mode is more effective to address product quality and volume requirements and to facilitate crab payments and repayments of loans (dadon).

Cash transactions are generally observed across the value chain with some credit arrangements between the assemblers at local and district depots with crab collectors and crab growers. All other transactions between the assemblers and the exporters are done in cash. Moreover, the payments of foreign buyers to the exporters in Dhaka are made through bank transfer.

Because price quotes and product requirements emanate from exporters, they dominated the price determination process across all segments of the value chain. Exporter cost and profit shares (about 57%) of the exporter dominated the other players in the value chain. The rest of the players shared the remaining profit with the crab growers and local assembler at the bottom. However, with the inclusion of loan cost (or dadon) of the crab collectors, the assembler at the local depot had a higher profit share.

Considering the volume of transactions, quality requirements, type of packaging, delivery schedules and payment transactions, the value chain reflected a reasonable degree of efficiency and responsiveness. There is evidence of good business relationships among key players due to trust gained from familial and socio-cultural affiliations.

The major logistical issues and concerns that hamper the overall efficiency and sustainability of the value chain are summarized below but the details for each player are outlined in Table 8.

Firstly, the natural sources of small crab and seed stocks are becoming unsustainable due to increasing export demand. This increasing international demand is expected to exert pressure on the supply of crabs based on wild stocks. Also, security issues in the Sundarbans mangrove forests, where these wild stocks are located, exacerbate the risk and cost of crab collection.

Secondly, the inadequate cultural and feeding technologies of mud crab growers will compromise their productivity and profitability. Heavy dependence on trash fish and mollusks as feeds might prolong the time needed for fattening and cultural period under earthen pond conditions, resulting in reduced profitability. There is no formulated diet for mud crab culture.

Thirdly, the poor road conditions, packaging and handling practices as well as storage facilities resulted to high (20%) incidence of in-transit mortality and rejects for the live crab export markets.

Fourthly, frequent international flight delays affect export sales and put pressure on limited trading capital of exporters and assemblers to finance forthcoming transactions. Inconsistent timing in the chain will add a source of risk that will reduce incentive to participate in the sector.

Lastly, the processing technology and practices are inadequate to meet international standards. Export markets for processed crab meats require rigorous quality standards and protocols. Failure to satisfy these international market standards dramatically affects the Bangladesh crab sector's ability to become an important player in international markets.

The most crucial external influences that negatively influence the value chain of mud crab in Bangladesh are both natural and human. Frequent floods associated with heavy rains are natural events that will be difficult to mitigate. Poor water quality from human activities based on increasing population has no readily available short term solutions. Currently, there are few, if any, government programs to stimulate domestic consumption of crab. Fortunately, this is one external influence that can be easily addressed.

RECOMMENDATIONS

To address the above issues and concerns, the following measures are recommended:

Establishment of crab hatcheries. With crab hatcheries, the value chain will have more reliable sources of crab seeds that would insure regular and consistent supply of quality products. A public-private partnership scheme may be employed to useful in pursuing this strategy. Establishment of hatcheries would provide greater security and employment opportunities for women who have traditionally collected crab from the wild.

Improve cultural and value adding technologies through tech transfer and credit programs. With improved technologies, productivity and efficiency would be attained in conformance with good agricultural and/or manufacturing practices. These strategies would entail a better measure of reducing grow out mortalities, shorter culture periods through better nutrition program and undisrupted production and marketing schedules.

Improve product packaging and handling system. With better designs of product packages, in-transit mortalities and rejects will be reduced.

Provision of efficient marketing infrastructures and promotion programs - the critical role of good farm-to-market roads and marketing infrastructures would ensure long term viability of the entire value chain. Through an aggressive promotion program, domestic demand for crabs will be improved and help boost overall sales of the value chain.

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Table 1a. Volume of live crab imports by country of destination.

Country or Area	2009	2010	2011	Total	Annual Ave.	Share	Growth	Rank
	Volume Shares (in tons)							
Japan	31,823.00	18,577.00	12,049.00	62,449.00	20,816.33	19.61%	-38.38%	2
China	16,095.00	23,905.00	30,653.00	70,653.00	23,551.00	22.19%	38.38%	1
Korea Rep	13,493.00	8,623.00	8,407.00	30,523.00	10,174.33	9.59%	-19.30%	3
Canada	4,254.00	5,369.00	6,891.00	16,514.00	5,504.67	5.19%	27.28%	6
Singapore	5,469.00	5,357.00	5,578.00	16,404.00	5,468.00	5.15%	1.04%	7
USA	3,288.00	3,414.00	1,626.00	8,328.00	2,776.00	2.62%	-24.27%	12
France	7,582.00	7,119.00	6,621.00	21,322.00	7,107.33	6.70%	-6.55%	5
China,H.Kong	5,096.00	6,176.00	4,145.00	15,417.00	5,139.00	4.84%	-5.85%	8
Spain	8,059.00	7,882.00	8,285.00	24,226.00	8,075.33	7.61%	1.46%	4
China,Taiwan	4,206.00	4,370.00	4,383.00	12,959.00	4,319.67	4.07%	2.10%	9
Malaysia	3,106.00	3,021.00	3,166.00	9,293.00	3,097.67	2.92%	1.03%	10
Portugal	1,900.00	2,117.00	1,885.00	5,902.00	1,967.33	1.85%	0.23%	13
Italy	853.00	881.00	1,201.00	2,935.00	978.33	0.92%	19.80%	14
Thailand	3,608.00	2,424.00	2,395.00	8,427.00	2,809.00	2.65%	-17.01%	11
China, Macao	751.00	799.00	592.00	2,142.00	714.00	0.67%	-9.76%	15
Total (top 15)	109,583.00	100,034.00	97,877.00	307,494.00	102,498.00	96.57%	-5.44%	
Others	4,010.00	3,615.00	3,283.00	10,908.00	3,636.00	3.43%	-9.52%	
Grand Total	113,593.00	103,649.00	101,160.00	318,402.00	106,134.00	100%	-5.58%	

Source: FAOSTAT (2014)

Table 1b. Value of live crab imports by country of destination.

Country or Area	2009	2010	2011	Total	Annual Ave.	Share	Growth	Rank
	Value Shares ('000US$)							
Japan	135,438.00	126,921.00	108,902.00	371,261.00	123,753.67	20.65%	-10.24%	1
China	67,759.00	119,336.00	181,418.00	368,513.00	122,837.67	20.50%	64.07%	2
Korea Rep	71,452.00	63,412.00	85,398.00	220,262.00	73,420.67	12.25%	11.71%	3
Canada	25,433.00	34,582.00	50,974.00	110,989.00	36,996.33	6.17%	41.69%	5
Singapore	39,670.00	46,311.00	54,197.00	140,178.00	46,726.00	7.80%	16.88%	4
USA	29,152.00	32,811.00	17,097.00	79,060.00	26,353.33	4.40%	-17.67%	9
France	35,312.00	34,325.00	33,466.00	103,103.00	34,367.67	5.74%	-2.65%	6
China,H.Kong	28,148.00	33,747.00	27,401.00	89,296.00	29,765.33	4.97%	0.54%	7
Spain	28,346.00	29,964.00	30,503.00	88,813.00	29,604.33	4.94%	3.75%	8
China,Taiwan	22,765.00	23,804.00	24,051.00	70,620.00	23,540.00	3.93%	2.80%	10
Malaysia	9,766.00	10,253.00	11,024.00	31,043.00	10,347.67	1.73%	6.25%	11
Portugal	7,599.00	9,302.00	8,140.00	25,041.00	8,347.00	1.39%	4.96%	12
Italy	5,434.00	6,000.00	7,446.00	18,880.00	6,293.33	1.05%	17.26%	13
Thailand	5,391.00	3,726.00	4,216.00	13,333.00	4,444.33	0.74%	-8.87%	14
China, Macao	1,862.00	2,610.00	2,861.00	7,333.00	2,444.33	0.41%	24.89%	15
Total (top 15)	513,527.00	577,104.00	647,094.00	1,737,725.00	579,241.67	96.67%	12.25%	
Others	21,979.00	19,107.00	18,812.00	59,898.00	19,966.00	3.33%	-7.31%	
Grand Total	535,506.00	596,211.00	665,906.00	1,797,623.00	599,207.67	100%	11.51%	

Source: FAOSTAT (2014)

Table 2a. Volume of live crab by country of origin.

	2009	2010	2011					
Country or Area	Volume Share (tonne)			Total	Annual Ave.	Share	Growth	Rank
China	3,591.00	3,580.00	3,457.00	10,628.00	3,542.67	3.94%	-1.25%	9
Indonesia	7,743.00	9,347.00	11,815.00	28,905.00	9,635.00	10.72%	15.71%	3
Canada	6,292.00	7,859.00	7,155.00	21,306.00	7,102.00	7.90%	5.32%	5
UK	14,008.00	13,824.00	13,096.00	40,928.00	13,642.67	15.18%	-2.19%	1
USA	5,941.00	7,756.00	12,136.00	25,833.00	8,611.00	9.58%	29.01%	4
India	5,808.00	3,213.00	3,102.00	12,123.00	4,041.00	4.50%	16.04%	8
Myanmar	12,587.00	11,731.00	11,442.00	35,760.00	11,920.00	13.27%	-3.09%	2
Philippines	2,984.00	3,316.00	4,208.00	10,508.00	3,502.67	3.90%	12.68%	10
Bangladesh	5,147.00	6,890.00	7,044.00	19,081.00	6,360.33	7.08%	12.03%	6
Pakistan	3,185.00	6,361.00	5,574.00	15,120.00	5,040.00	5.61%	29.12%	7
France	2,252.00	2,051.00	1,946.00	6,249.00	2,083.00	2.32%	-4.68%	12
Australia	617.00	506.00	502.00	1,625.00	541.67	0.60%	-6.26%	15
Korea Rep	549.00	495.00	711.00	1,755.00	585.00	0.65%	11.27%	14
Viet Nam	1,597.00	720.00	830.00	3,147.00	1,049.00	1.17%	13.21%	13
Ireland	3,159.00	3,200.00	3,128.00	9,487.00	3,162.33	3.52%	-0.32%	11
Total (top 15)	75,460.00	80,849.00	86,146.00	242,455.00	80,818.33	89.95%	4.54%	
Others	10,147.00	9,602.00	7,349.00	27,098.00	9,032.67	10.05%	4.92%	
Grand Total	85,607.00	90,451.00	93,495.00	269,553.00	89,851.00	100.00%	4.21%	

Source: FAOSTAT (2014)

Table 2b. Value of live crab by country of origin.

Country or Area	2009	2010	2011	Total	Annual Ave.	Share	Growth	Rank
	Value Shares ('000US$)							
China	19,149.00	23,174.00	34,910.00	77,233.00	25,744.33	5.46%	23.89%	5
Indonesia	54,281.00	78,049.00	95,652.00	227,982.00	75,994.00	16.13%	22.11%	1
Canada	50,113.00	67,951.00	*73,227.00*	191,291.00	63,763.67	13.54%	14.45%	2
UK	48,209.00	53,399.00	55,316.00	156,924.00	52,308.00	11.10%	4.79%	3
USA	26,049.00	39,610.00	60,373.00	126,032.00	42,010.67	8.92%	34.83%	4
India	28,298.00	19,908.00	25,707.00	73,913.00	24,637.67	5.23%	-0.17%	6
Myanmar	25,531.00	21,851.00	25,370.00	72,752.00	24,250.67	5.15%	0.56%	7
Philippines	18,222.00	22,088.00	26,946.00	67,256.00	22,418.67	4.76%	14.40%	8
Bangladesh	15,632.00	21,279.00	26,655.00	63,566.00	21,188.67	4.50%	20.46%	9
Pakistan	5,562.00	13,769.00	12,882.00	32,213.00	10,737.67	2.28%	47.04%	13
France	12,847.00	11,743.00	12,261.00	36,851.00	12,283.67	2.61%	-1.39%	12
Australia	7,809.00	8,002.00	9,700.00	25,511.00	8,503.67	1.81%	7.90%	14
Korea Rep	9,032.00	11,700.00	19,179.00	39,911.00	13,303.67	2.82%	31.15%	11
Vietnam	10,808.00	4,229.00	4,892.00	19,929.00	6,643.00	1.41%	15.06%	15
Ireland	14,391.00	15,831.00	17,957.00	48,179.00	16,059.67	3.41%	7.81%	10
Total (top 15)	345,933.00	412,583.00	501,027.00	1,259,543.00	419,847.67	89.13%	14.18%	
Others	53,559.00	52,007.00	48,121.00	153,687.00	51,229.00	10.87%	13.54%	
Grand Total	399,492.00	464,590.00	549,148.00	1,413,230.00	471,076.67	100.00%	12.97%	

Source: FAOSTAT (2014)

Table3a. Volume of Bangladesh fish exports.

Products	2010	2011	2012	2013	2014	Total	Share	Rank	Growth
	Volume (MT)								
Prawn	5,714.07	7,120.29	7,060.25	6,678.93	6,503.58	33,077.12	7.78%	3	3.94%
Shrimp	39,235.85	40,859.61	35,677.78	37,274.39	34,733.03	187,780.65	44.16%	1	-2.72%
Carp	4,756.98	8,270.20	11,298.55	7,239.05	2,847.69	34,412.47	8.09%	2	3.47%
Catfish	2,076.15	2,367.42	1,698.21	2,037.25	2,281.52	10,460.54	2.46%	6	4.43%
Hilsha	3,107.17	8,538.77	6,173.65	473.20	n.a.	18,292.79	4.30%	5	18.26%
Dried fish	622.27	1,200.08	1,039.91	1,278.15	2,894.58	7,034.99	1.65%	8	57.22%
Live Crab	691.86	1,189.32	710.12	610.73	549.22	3,751.25	0.882%	9	1.89%
Shark fin & carapase	954.46	838.00	2,757.99	2,599.40	2,393.32	9,543.17	2.24%	7	50.81%
Others	18,701.83	22,789.73	20,555.01	18,963.04	15,761.86	96,771.47	22.76%		-3.14%
Total	77,643.28	96,469.24	92,028.86	83,971.74	75,122.49	425,235.61	100.00%		0.09%

Source: Ministry of Fisheries and Livestock of Bangladesh (2015)

Table 3b. Value of Bangladesh fish exports.

Products	2010	2011	2012	2013	2014	Total	Share	Rank	Growth
			Value (US$)						
Prawn	74,132,300.00	96,659,529.00	107,029,602.83	92,129,179.00	103,068,809.00	473,019,419.83	17.70%	2	9.77%
Shrimp	113,332,669.00	364,964,986.43	321,723,189.00	303,515,999.00	384,419,326.00	1,487,956,169.43	55.68%	1	57.79%
Carp	9,992,835.00	24,296,240.50	30,075,907.14	19,690,026.88	7,867,911.04	91,922,920.56	3.44%	4	18.09%
Catfish	6,750,730.00	10,482,130.16	7,320,206.29	8,357,003.65	9,050,913.17	41,960,983.27	1.57%	6	11.89%
Hilsha	17,731,340.00	48,956,554.33	35,885,147.58	3,133,655.10	n.a.	105,706,697.01	3.96%	3	19.38%
Dried fish	3,579,798.00	4,287,795.76	3,519,001.94	4,634,264.00	6,611,465.60	22,632,325.30	0.85%	7	19.05%
Live Eel	1,888,223.00	4,477,213.75	9,698,593.30	17,966,402.60	17,631,972.00	51,662,404.65	1.93%	5	84.28%
Live Crab	1,486,533.00	3,037,552.00	2,479,985.00	3,833,372.10	3,590,555.00	14,427,997.10	0.54%	8	33.56%
Shark fin & carapase	1,808,071.00	805,135.00	1,798,258.00	1,803,383.00	2,046,602.00	8,261,449.00	0.31%	9	20.41%
Others	63,056,144.00	80,659,857.77	77,229,840.84	78,004,985.45	76,041,013.58	374,991,841.64	14.03%		5.54%
Total	293,758,643.00	638,626,994.70	596,759,731.92	533,068,270.78	610,328,567.39	2,672,542,207.79	100.00%		28.67%

Exchange rate = Tk 75:US$1.00
Source: Ministry of Fisheries and Livestock of Bangladesh (2015)

Table 4. Mud-crab-fattening practices in Satkhira District.

Particulars	Profile	Profile
1.Name	A) Group 1	B) Group 2
2.Status/Gender	10 (6Female + 4Male)/group)	Members: 60Female + 22Male
3.Site of farm/Ownership/Area	Horinagar, Satkhira District/Lease Taka 8,000/yr/1,500 sqm Area = 200 sqm (247 decimal = 1 hectare)	Barsingh, Atulia Shyamnagar, Satkhira District 536 sq ft/compartment; owned
4.Years in fattening or grow-out of mudcrab	Fattening:7 yrs; grow-out: first year (3–4 months)	Fattening: 5 yrs; started after the cyclone in 2009; started crab culture for livelihood (wanted to save money for a bigger pond) Association: 4 yrs
5. Source of mudcrab for fattening/grow-out	Sundarbans; go to collectors (in boats)	Mushi market
6.Size range and cost/kg (buying price); Selling price	Purchased atTaka 100/kg Sold at Taka 300-400/kg	Purchased at Tk 300–400/kg (10 kg /household) for about 150 g; sold at Tk 600–700/kg for 180–200 g crabs
7.Stocking density (SD)	Fattening: 40 kg/decimal; grow-out: 20 kg/decimal (247 decimal= 1 hectare)	10 kg of crabs/run/household; for bigger ponds >10kg Crabs classified into 3 : soft, immature and hard-shelled
8.Culture duration	Grow-out: 20–30 g juvenile crabs after one molting transferred to grow-out ponds (to reduce SD) and cultured for 2.0–2.5 months prior to harvest; vacated pond to be used again for another batch of 20–30 g; harvest size 100g in grow-out pond	Pond: 10–12 days; crabs remained tied
9. Type & amount of feeds; Frequency of feeding	About 90% of feeds –tilapia (Taka 50–60/kg); once daily p.m. at 10% BW for fattening; 20% BW or 10 kg crabs for grow-out	Tilapia purchased from market at Taka 30-40/kg; 1 kg of tilapia for every 10 kg of crab
10. Water management	2–3 days interval; salinity: 12–18 ppt during rainy season & up to 30 ppt during dry season	Water change based on regular natural inflow/outflow of water; water not changed especially in cages (water change not possible if waste from household, etc. drained to waterways)
11. Harvesting method (selective/total harvest	Selective harvesting - fattening; Total harvest for grow-out and transfer to bigger pond for further culture; Classification- female crabs are more expensive	Selective harvesting
12. Handling and transport procedures	Tying; put in sacks and bring to depots	Tying; put in sacks and bring to nearby market/depot
13. Survival rate	About 20% mortality; crabs are tied during culture	20% mortality (8kg/10kg); crabs are tied during culture
14. Number of runs/yr	Fattening :15–16 runs/yr	20–24 runs/yr
15. Problems encountered	20% mortality in fattening; source of seedstock dwindling	High water temp and low salinity; deterioration of water quality
16. How do you perceive the future of MC industry	Need for hatchery	Many people depend on mudcrab as livelihood therefore, this will continue; save money to have bigger ponds
Remarks	Rejected crabs for export —for home consumption or sell locally at low price	Cage culture — more practical to use, if water quality gets bad, these are lifted from the pond

Table 5. Commission fees by sex, grade and price of crab at local depot

Sex	Grade	Weight (g/crab)	Buying Price (Tk/kg)	Selling Price (Tk/kg)	Commission (Tk/kg)
Male	XXL (2pcs/kg)	500	470	500	6
	XL (3 pcs/kg)	400	370	400	5
	L (4 pcs/kg)	300	270	300	5
	M (5 pcs/kg)	200	170	180	2
	SM (6 pcs/kg)	150	80	90	nil
Female	F1 (5pcs/kg)	180	400	420	5
	F2 (6 pcs/kg)	145	270	350	5
	F3(10 pcs/kg)	100	170	200	2

Table 6. Price schedule by sex, weight and shell/claw conditions of crab at Dhaka depot

Sex	Grade	Weight (g/crab)	Shell Condition	Claw Condition	Buying Price (Tk/kg)	Selling Price (US$/kg)	Tk/kg
Male	XXL (2pcs/kg)	500	Hard	Full meat	600	13.70	1,027.50
	XL (3 pcs/kg)	400	Hard	Full meat	475	11.85	888.75
	L (4 pcs/kg)	300	Hard	Full meat	375	9.70	727.50
	M (5 pcs/kg)	200	Hard	Full meat	300	8.09	606.75
	SM (6 pcs/kg)	150	Hard	Full meat	150	6.72	504.00
	WXXL	500	Soft	Partial meat	220	nil	
	WXL	400	Soft	Partial meat	180	nil	
	WL	300	Soft	Partial meat	130	nil	
	WM	250	Soft	Partial meat	115	nil	
	WSM	150	Soft	Partial meat	90	nil	
Female	F1 (5pcs/kg)	200	Hard	Full gonad	600	14.46	1,084.50
	F2 (6 pcs/kg)	180	Hard	Full gonad	400	13.36	1,002.00
	F3(10 pcs/kg)	150	Hard	Full gonad	300	9.52	714.00
	F4 (12 pcs/kg)	80	Hard	Full gonad	275	8.50	637.50
	KS1	180	Hard	Partial gonad	225	11.12	834.00
	KS2	120	Hard	Partial gonad	150	7.50	562.50
	VIR	100	Hard	Eggless	100	nil	
	PICH	80	Hard	Eggless	35	nil	

Table 7. Distribution of prices, costs and profit margins by chain actors (2015)

Chain Actor	Item	Amount	Cost Share (%)	Profit Share (%)
Crab collector	Selling Price(Tk/kg)	150.00		
	Cost of Collection (Tk/kg)	76.00	4.76%	
	Profit Margin (Tk/kg)	74.00		16.23%
Crab farmer	Selling Price(Tk/kg)	300.00		
	Cost of Production(Tk/kg)	151.67	17.94%	
	Buying price(Tk/kg)	135.00		
	Profit Margin(Tk/kg)	13.33		2.92%
Assembler at local depot	Selling Price(Tk/kg)	334.17		
	Cost of Operation(Tk/kg)	14.25	19.67%	
	Buying price(Tk/kg)	300.00		
	Profit Margin(Tk/kg)	19.92		4.37%
Assembler at District depot	Selling Price(Tk/kg)	466.67		
	Cost of Operation(Tk/kg)	18.08	23.77%	
	Buying price(Tk/kg)	361.67		19.06%
	Profit Margin(Tk/kg)	86.92		
Dhaka exporter-processor	Selling Price(Tk/kg)	802.65		
	Cost of Operation(Tk/kg)	195.00	33.85%	
	Buying price(Tk/kg)	345.83		
	Profit Margin(Tk/kg)	261.82		57.42%
Value Chain Total Cost(Tk/kg)		1597.50	100.00%	
Value Chain Total Profits(Tk/kg)		455.98		100.00%

Table 8. Logistical Issues and Transaction Costs of Each Key Player

Key Players	Issues and Concerns	Transaction Costs
Crab collectors	Harvest of marketable crabs are getting fewer and irregular. Cost of renewing permits (NOC) and other related expenses are more exorbitant Limited working capital	High security risks due to the presence of lawless elements at sundarban areas
Crab growers	• Irregular availability of crab seeds and feeds • Unfair prices due to lack of bargaining power • Limited working capital • Use of traditional technology	Growth opportunities are limited for existing and potential entrants in crab farming
	Lack of formulated diet	Culture and fattening period is longer
	Product uniformity and consistency is hard to meet	Low or poor bargaining power
	High in-transit mortality (20%)	Loss of sales (lower product values)
	Poor product handling	
	Frequent road blocks due to political rallies, etc	Delays in product delivery and marketing

Table 8 Continued.

Key Players	**Issues and Concerns**	**Transaction Costs**
Assemblers-agents at district depots	Schedule of product arrival not predictable	High cost of meeting normal load capacity
	Poor handling practices	• Poor handling practices • Handling Losses
	• No uniform product grades and standards • Difficulty in meeting desired product volume and quality	Opportunity cost of capital due to advance payments (after 15 days)
Processors of chilled crabs	Poor product quality	• Lower product value • High incidence of unsold products
	Limited market outlets	Expansion opportunities are limited
Exporters	Unpredictable flight schedules	High cost of delayed shipment
	No defined location of national depot in Dhaka	High cost of foot-loose market operations
Domestic Consumers	Low effective demand for crab due to religious and cultural barriers No marketing effort to promote crabs in the country	High cost of social rejection
	Only low quality products are available in the domestic market	High buying prices Limited availability and choices

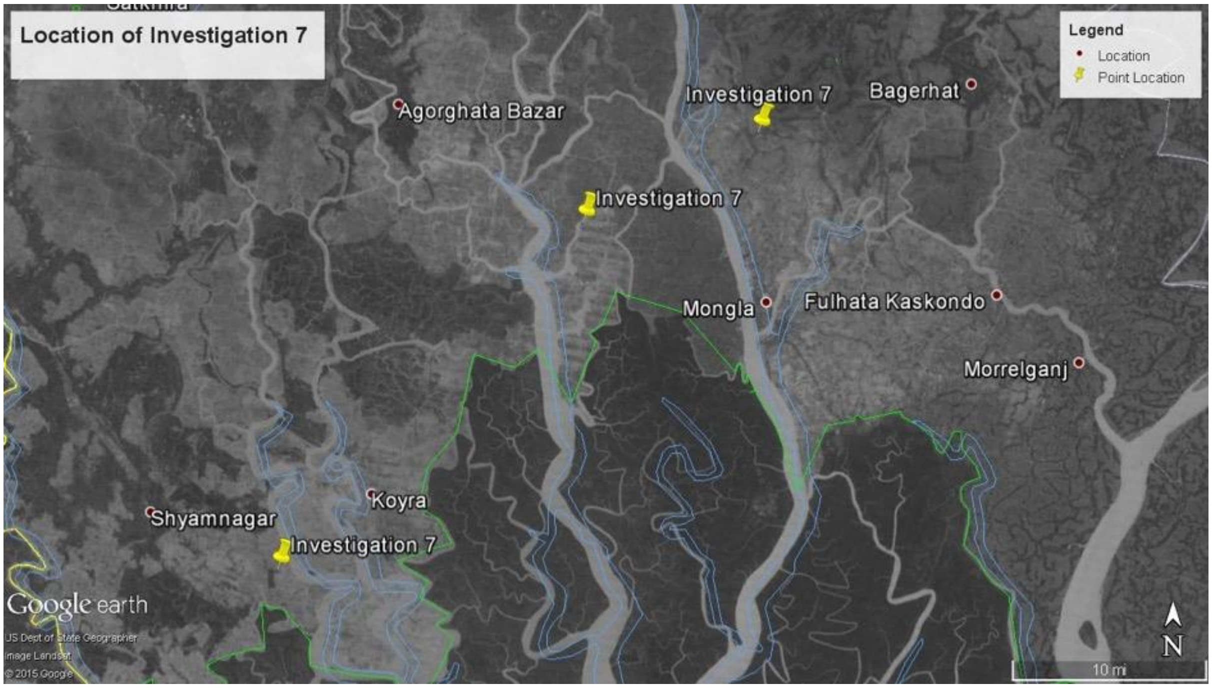

Figure 1. Satkhira, Khulna and Bagerhat districts as study areas.

Figure 2. Various traps used for collecting mud crabs.

Figure 3. *Scylla serrate*

A

B

Figure 4. Earthen ponds without (A) or with bamboo compartments (B) for mudcrab culture

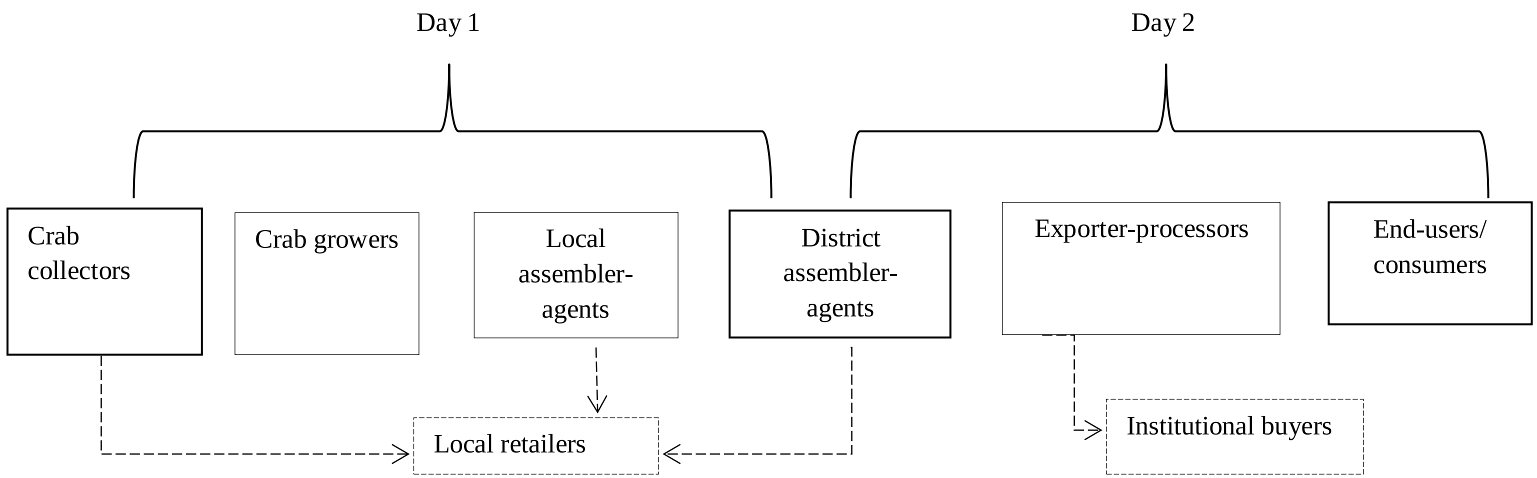

Figure 5. Product flow.

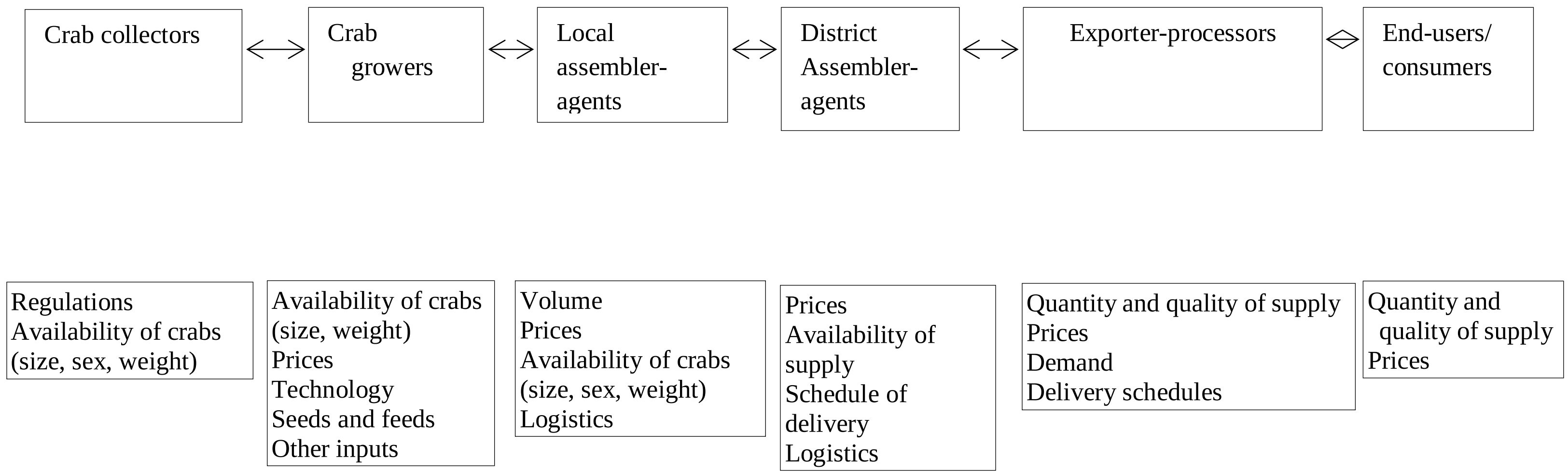

Figure 6. Information flow.

Development of a Cell-Phone Based Seafood Market Information System (SMIS) in Ghana: Application to Tilapia

Marketing, Economic Risk Assessment, and Trade/Study/13MER01PU

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ABSTRACT

For small-scale fish producers and artisanal fishermen in Ghana, readily available market information on prices and demand for tilapia at different fish markets helps inform production and harvesting decisions. Minimizing the information gaps along the tilapia value chain greatly improves efficiencies and reduces post-harvest losses in tilapia marketing and the value chain as a whole. This investigation developed a cell-phone-based seafood market information system (SMIS) with a focus on tilapia in Ghana. This is because tilapia is the dominant fish species that is farmed and caught in inland waters. The SMIS has a database of current farm-gate and market prices of tilapia in selected locations in Ghana assembled by fisheries officers and selected agents. The SMIS is web-based and provides tilapia market information online as well as via voice and SMS/text messaging to users. There are two types of subscribers to the system — registered and ad-hoc users. The system can send out (push) farm-gate and market price information to only the registered users. However, to request (pull) information on tilapia prices from the system, both registered and ad-hoc users can access the system either by dialing or SMS/text messaging to a 10-digit phone number or a four-digit short code. When a user requests information, the voice feature of the system includes messages in English and three native languages — Twi, Ga and Ewe. The new technology has been tested with fisheries officers, selected fish farmers and fish traders. The future plan is to expand the capabilities of the system to include capture fisheries to benefit the marine artisanal fisheries subsector.

INTRODUCTION

An analysis of tilapia value chain in Ghana under a previous Aquaculture and Fisheries Collaborative Research Support Program (AquaFish CRSP) project revealed challenges in the flow of information along the value chain, especially information relating to tilapia supply, demand and prices. The lack of vital market information often led to inefficiencies, inequity, and post-harvest losses. For small-scale fish producers and artisanal fishermen, readily available market information on prices and demand for tilapia at different fish markets helps inform production and harvesting decisions. Minimizing the information gaps along the tilapia value chain greatly improves efficiencies in tilapia marketing and the value chain as a whole.

The information gaps in the value chain call for a marketing information system for tilapia in Ghana to reduce the information asymmetry between fish producers and sellers. A market information system involves processes to generate, store, analyze, and disseminate marketing information on a regular basis, which is accessible to stakeholders. A similar system is in use in Indonesia (InfoFish 2010, 2008) and Kenya (KMFRI 2010). In Indonesia, the Fish Marketing Information System provides a platform for a transparent and fair fish trading and improves market access for fish products from Banda Aceh to regional markets (InfoFish 2010). The system in Kenya involves price data from fish landing sites and inland urban markets, which is continuously relayed to a central database where it is packaged into a format that users can access in real time by sending a query through mobile phone. The targeted beneficiaries of the Kenya system include small-scale fishermen, fish farmers, fish processors and traders at landing sites and markets, who are reported to increased fish trading activities and incomes through improved access to market information (Nyabundi 2014).

A seafood marketing information system (SMIS) in Ghana will be useful for efficient operation of the tilapia value chain. There are opportunities for improved communication and increased information flow along the tilapia value chain in Ghana through the use of mobile phone technology. This is because mobile phone penetration in Ghana is 94%, making this an ideal channel linking fish producers and artisanal fishermen with markets. Mobile-based service opens these communication pathways and allows market data and information to be programed and can be easily accessed by users from a mobile device via voice and/or short messaging service (SMS) anytime. These services could result in increases in fish quality and yield, reduce post-harvest losses, as well as increase incomes for farmers and traders. An efficient market information system via the mobile technology has an important role to play in improving aquaculture productivity and value chain efficiency in Ghana. A marketing information system for tilapia in Ghana can result in a more organized tilapia market data collection, the storage of important tilapia market data, better coordinated marketing intelligence information, and access to market information to make business decisions. It will also assist in building capacity to improve the skill of stakeholders on fish marketing.

OBJECTIVES

- Develop an electronic system for tilapia market information exchange;
- Develop a phone-based market-information-sharing platform for fish producers, fishermen, seafood marketers, and consumers; and
- Train fish farmers, fishermen, women fish processors, markets and traders on the use of the market information system developed under the first two objectives to enhance trade and profitability.

METHODOLOGY

Before commencing the development of the system, a series of meetings were held with the Fisheries Commission (FC) in Ghana about the usefulness of the system. The plan is to eventually use fisheries officers in the field to populate the database with farm-gate and market price information, and FC becomes the custodian of the final product.

The first step involved in developing the system was to identify various points of tilapia fish supply and demand in major producing and marketing regions in Ghana. A visit to selected supply and demand centers helped to identify important variables for which data and information was collected, e.g., prices, trends, etc. The data was collected from the various stakeholders including fish producers, middlemen, fish marketers and retailers and then transmitted to a central database at Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and Farmerline.

The services of a programming company, Farmerline, was used to program an electronic information system into which the data and information collected from the supply-and-demand centers were transmitted, creating a database/platform. The system was set up in a form that can easily be accessed by users from a mobile device via voice or SMS anytime (Figure 1). This procedure involved detailed programming by Farmerline who build the electronic platform using the Infolink framework, which is a web based application (calls are sent from the internet). The technology behind Infolink web component is built with Laravel (PHP framework) and Twitter Bootstrap. The telephony component is built with Plivo in combination with Freeswich. There is GoIP (hardware containing GSM sim cards) attached to the server. The sim cards in the GoIP takes the command from the web application and makes the call like a normal phone call.

Farm-gate and market data are to be collected on a regular basis by fisheries officers to a central database. This can be done from a mobile phone, a tablet or a computer. The database is then packaged into a format that users can access in real time by querying the system from a mobile phone. The features of the system include the ability to query for particular price information by both voice and SMS; communicate with large numbers of users; and messages received in native languages as well as English. Users would dial or text to a 4-digit number and will receive messages through either voice or SMS on farm-gate and market price information in the database. The application for the 4-digit short code is being processed by the Ghana National Communication Authority. Queries can be made for market information at selected locations. The SMIS is web-based and also provides fish market information on-line in addition to via voice/SMS to stakeholders.

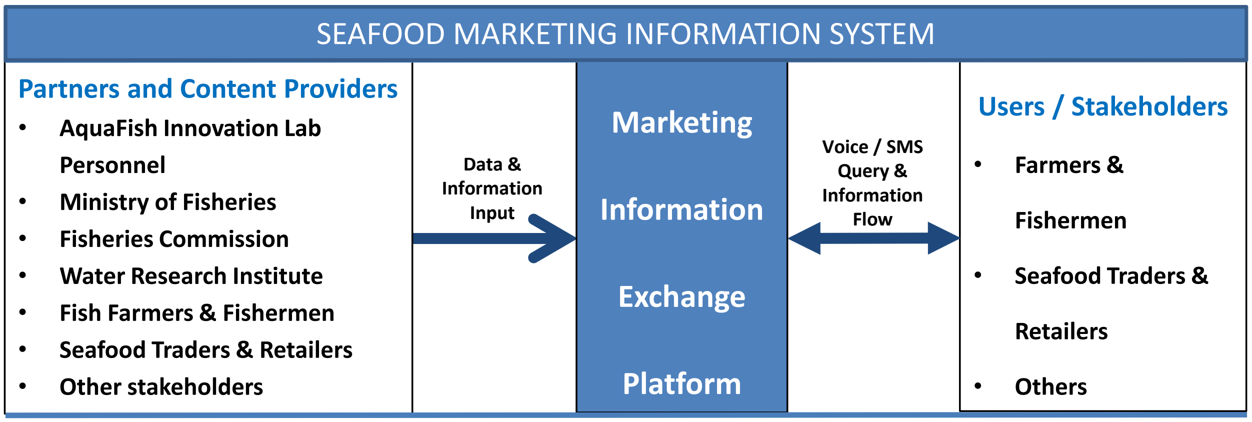

Figure 1: A schematic diagram of seafood marketing information system (SMIS).

There will be two types of users: registered and ad hoc. The ad-hoc users are not registered on the system and have to query the system for market information for specific locations. The registered users are registered in the system with their contact information including mobile phone numbers, and they can query the systems and receive information related particular locations as well as automatically receive market information relevant to their address in a very timely manner. Registered users can also receive market information through periodic electronic bulletins.

Detailed statistics can be obtained on the number of users and how messages are received. The system also includes a tool that allows the conduct of timely and longitudinal surveys with users. The survey tool will include recorded questions and users would answer by simply pressing buttons on their phone, and their responses are recorded immediately. The new technology was tested with fisheries officers and selected fish farmers at a workshop on 9 July 2015 and for fish traders on 13 July 2015.

Key features

- The SMIS has a database of current farm-gate and market prices of tilapia in selected locations in Ghana assembled by fisheries officers and selected agents;
- There is a robust and flexible data entry mode designed to allow aggregators to easily update user information through a mobile phone, tablet or a computer;
- The SMIS is web-based and provides tilapia market information on-line as well as via voice and SMS/text messaging to users;
- There are two types of subscribers to the system — registered and ad-hoc users. The system can send out (push) farm-gate and market price information to only the registered users. However, to request (pull) information on tilapia prices from the system, both registered users and ad-hoc users can access

the system either by dialing or SMS/text messaging to a 10-digit phone number or a four-digit short code;

- The SMIS is able to send calls and messages to registered users, currently at a capacity of 50;
- When a user requests information, the voice feature of the system includes messages in English and three native languages — Twi, Ga and Ewe; and
- The system has a response structure that ensures that users can request and obtain price information whenever they want.

Workshop information

Fisheries Officers and Selected Fish Farmers' Workshop

- Providence House Hostel, Kotei, Kumasi, on 9 July 2015
- Attendance — 23 males and 3 females

Market Womens' Workshop

- International Center for Innovative Learning, KNUST, Kumasi, on 13 July 2015
- Attendance — 5 males and 35 females

CONCLUSION

The tilapia SMIS will eventually become a pay-per-use system because of airtime minutes. However, it will be cost-effective when there are numerous users of the system. The SMIS at this stage is a pilot technology that functions with a focus on tilapia. The services it provides help to address market information asymmetries between buyers and sellers of tilapia and improves the bargaining power of smallholder fish farmers/fishers in their interactions with fish traders. These benefits are lacking in the marine artisanal fisheries subsector though fish from capture fisheries form part of the whole seafood value chain in Ghana. Future plans will therefore expand the functionality of the current SMIS to (1) have applicability to the marine artisanal fisheries subsector, (2) provide buyer-seller matching services, and (3) provide potential group marketing services for smallholder fish farmers and fishers.

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Impacts of Climate Change on Snakehead Fish Value Chains in the Lower Mekong Basin of Cambodia and Vietnam

Marketing, Economic Risk Assessment, and Trade/Study/13MER03UC

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Abstract

The productive fisheries of the Lower Mekong Basin of Cambodia and Vietnam are essential to the food security and nutrition of 60 million people. Yet these fisheries, both culture and capture, are susceptible to the impacts of climate change. This paper reports on a study undertaken to examine the vulnerability, as perceived by snakehead (*Channa striata*) fish farmers in Vietnam and fishers in Cambodia, to the impacts from climate change. Perceived impacts on various actors in the value chain are identified, as well as adaptation strategies currently being utilized and planned for the future. Recommendations are suggested to contribute to assisting snakehead farmers and fishers in adapting and preparing for the impacts of climate change.

Introduction

The productive Mekong fisheries are essential to the food security and nutrition of the 60 million people of the Lower Mekong Basin (LMB). Fish, from capture and culture, are a significant source of income and food security in Cambodia and Vietnam. Freshwater fish consumption in Cambodia and Vietnam ranges up to 40 kg/person/year, placing them amongst the top three countries in the world. Fish contributes 81% of the population's protein intake in Cambodia and 70% in Vietnam. Mekong inland fisheries provide employment to 1.6 million of the 14 million Cambodians. In the Mekong Delta in Vietnam, 60% of the people are part-time fishers and 88% of the 'very poor' households depend on fisheries. Freshwater fish and fish products are traded throughout the LMB countries and internationally, and markets for many products are well developed. Women play a very important role in fisheries sector, including capture and aquaculture. More than 80% of the fish traders and processors in the LMB are women. However, many capture fisheries resources have been largely over exploited and, as a result, development of aquaculture has been encouraged to provide the protein, income, employment, and export earnings for Cambodia and Vietnam. The combination of high fish biodiversity, high productivity, high exploitation rate, long-distance migrations, and fish trade make protecting these fisheries and aquaculture of great importance. However, they are highly vulnerable to climate and nonclimate (specifically water development such as hydropower dam development) related drivers of change. This includes increased temperatures; changes in rainfall patterns; changes in the hydrological regime (water levels, duration of flooding, timing of flooding); changes in run-off or sediment load/movement; and increased instances of extreme weather events (storms, floods and droughts) (Keskinen et al. 2010; Hoanh et al. 2010; Västilä et al. 2010; Lauri et al. 2012). Saline water intrusion in the Mekong River was about 20km at the end of the 20th century and is now up to 50km. These drivers of change will be felt throughout the fish value chain and will pose significant challenges for fisheries and aquaculture production; food security and the nutrition and health of people, especially poor households; household income; livelihoods; markets and trade; and gender issues in the LMB of Cambodia and Vietnam. However, a complete understanding of the impacts of each individual driver and combination of drivers is only just beginning. Adaptation is urgently needed to foster there salience of the fisheries and aquaculture sectors. Adaptive strategies can take the form of processes, actions, or outcomes in order to better adjust to, cope with, and manage changing conditions (Smit and Wandel 2006). Adaptation mechanisms can be differentiated along several dimensions: by the purpose of adaptation (whether the adaptation is planned or unplanned), by the timing of implementation, by spatial and temporal scale, by sector of activity, or by which actors are designing and implementing the mechanisms (Adgeret al. 2007; Smit et al.1999). It will be important to identify a suite of potential adaptation options for the various biophysical and technical conditions of capture and culture fisheries in the LMB.

This paper will present the results of a study which examined the vulnerability, as perceived by snakehead (*Channa striata*) fish farmers in Vietnam and fishers in Cambodia, to the impacts from climate change. Since there is a ban on snakehead aquaculture in Cambodia, data was collected on the actors in the snakehead capture fisheries value chain. Perceived impacts on various actors in the value chain are identified, as well as adaptation strategies currently being utilized and planned for the future. Recommendations are suggested to contribute to assisting snakehead farmers and fishers in adapting and preparing for the impacts of climate change.

METHODS

The value chain approach is a useful tool to study specific challenges facing a sector resulting from various drivers of change, such as climate change, including small firms' and fishers' competitiveness in changing markets. Critically, such analyses can reveal context- and sector-specific adaptation strategies to enhance a sector. A value chain is defined as "the full range of activities which are required to bring a product or service from conception, through the different phases of production, delivery to final consumers, and final disposal after use" (Kaplinsky and Morris 2001). A value chain approach can be used to examine both micro and macro aspects, including the complex networks of production and trade comprising the fisheries and aquaculture sector. The value chain perspective is important because it offers insights that would not surface in studies focused on individual economic agents or particular policy frameworks.

The value chain analyses conducted for snakehead fish through a previous study served as the foundation for this current analysis (Sinh et al. 2014). The previous study described the value chains of captured (Cambodia) and cultured (Vietnam) snakehead in the Lower Mekong Basin (LMB). The important actors involved in the value chain of cultured snakehead in Vietnam were seed producers, farmers, traders and processors (Figure 1). The important actors involved in the value chain of captured snakehead in Cambodia were fishers, traders and processors (Figure 2).

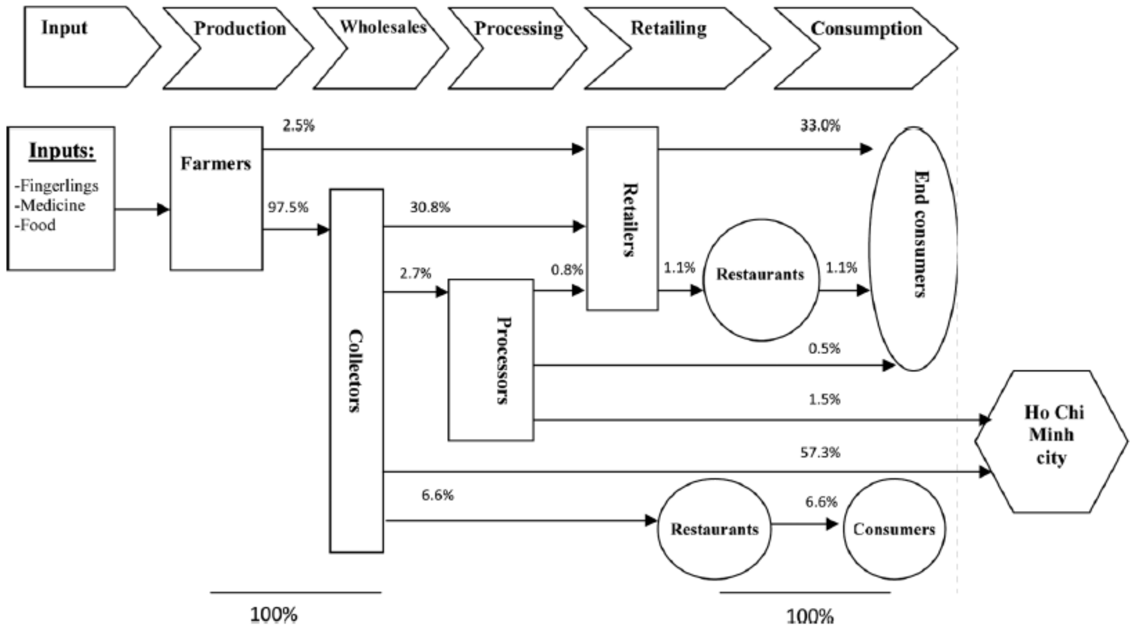

Figure 1. Value chain for cultured snakehead in Vietnam.

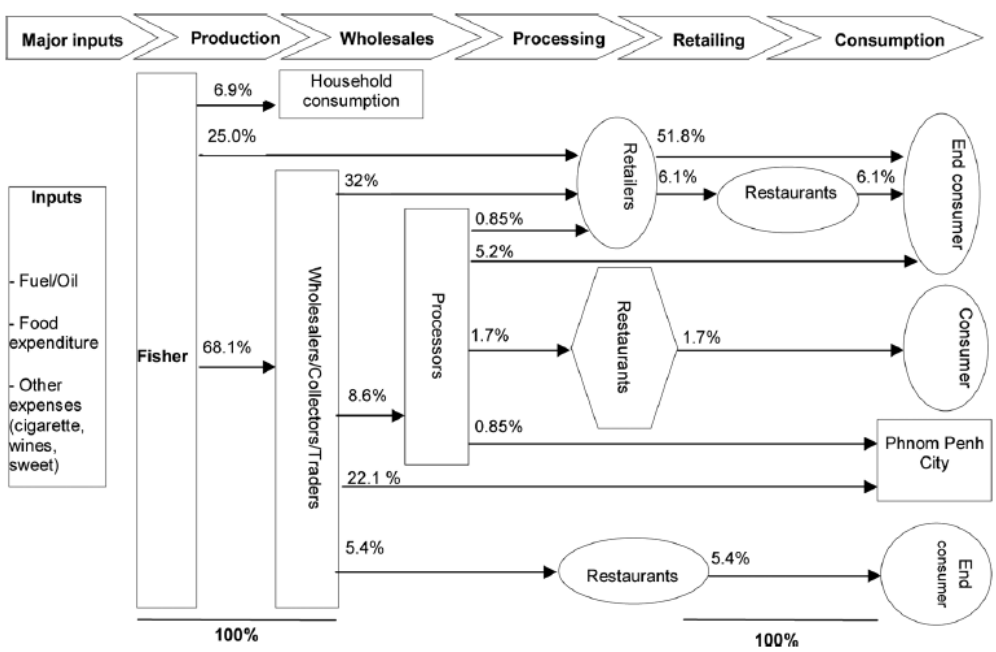

Figure 2. Value chain for captured snakehead in Cambodia.

Respondents were asked questions on climate change impacts, vulnerability, and adaptation strategies along the major capture and culture snakehead fish value chains. The study was structured using the vulnerability assessment framework of Allison et al. (2009) to understand the vulnerability of actors in the fish value chain to the key drivers of climate change. Vulnerability is defined as "a combination of the extrinsic exposure of groups or individuals or ecological systems to a hazard, such as climate change, their intrinsic sensitivity to the hazard, and their lack of capacity to modify exposure to, absorb, and recover from losses stemming from the hazard, and to exploit new opportunities that arise in the process of adaptation" (Allison et al. 2009). The key drivers of vulnerability in this system will be changes in rainfall and wind, flooding, drought, air temperature, water temperature, storm and salt water intrusion (Tra Vinh province in Vietnam), the principal expected impacts of climate change on fisheries and ecosystems in the Lower Mekong basin region (Keskinen et al. 2010; Hoanh et al. 2010; Västilä et al. 2010; Lauri et al. 2012).

This study was conducted in both countries between February to November 2014. The study was conducted in five provinces in Cambodia including Kandal, Kampong Chhnang, Kampong Thom and Siem Reap, and Phnom Penh city. Secondary data was collected from reports of the Fisheries Administration and the Inland Fisheries Research and Development Institute (IFReDI). The primary data was collected through interviews of 52 fishers, 36 traders, and 15 processors in the study provinces through semi-structured questionnaires. The sample size is reported in Table 1.

The study was conducted in five provinces in Vietnam including An Giang, Dong Thap, Tra Vinh, Vinh Long and Hau Giang. Secondary data were collected from reports of five Departments of Agriculture and Rural Development in the study Provinces and Districts, as well as related research on snakehead. The primary data was collected through interviews of 75 snakehead seed producers, 152 farmers, five traders (large scale traders) and 22 processors in the study provinces through semi-structured questionnaires. The sample size is reported in Table 2.
An Access software and Excel database was developed and data were analyzed using EXCEL and SPSS. The vulnerability assessment was conducted based on data on exposure, sensitivity, potential impact, adaptive capacity, and vulnerability and analyzed using two formulas (Glick, Stein and Edelson 2011):

- Potential Impact (PI) = Exposure (EX) + Sensitivity (SE)
- Vulnerability = PI + AC (Adaptive Capacity)

RESULTS

Snakehead culture in Vietnam. Ninety-two percent (92%) of seed producers, 74% of farmers, 83% of traders, and 82% of processors reported that they were aware of climate change (Figure 3). The respondents reported that the main events that they consider as climate change in their area were changes in rainfall patterns, drought, and water and air temperature changes. The climate change events of most concern to seed producers and processors was changes in rainfall patterns, while of most concern to farmers and traders was drought. All of the respondents reported that they felt that the major changes to occur from climate change over the next ten years will be drought and hotter weather.

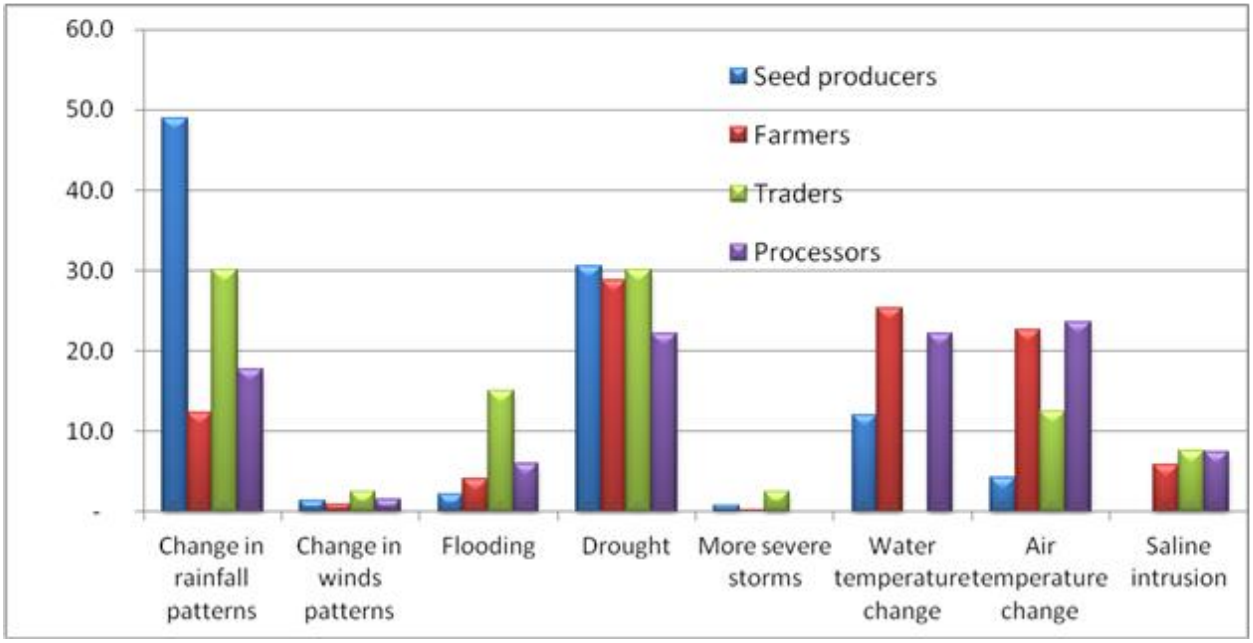

Figure 3: The percentage distribution of climate change events for actors in snakehead culture in Vietnam.

Seed producers reported that the main impacts of climate change on their business has been reduced seed production and disease. More specific impacts have been that fish get disease easier, overall decrease in productivity and lower survival rate (Figure 4). The responses were consistent across all five change in the next ten years will be a decrease in seed quality and disease provinces studied. Seed producers reported that they expect the impacts of climate. A vulnerability assessment for seed producers identified higher air and water temperature, and drought as having the strongest impact and causing the greatest vulnerability. Flooding and wind change factors had a lower impact and vulnerability (Figure 5). All the identified factors can cause low egg hatching rates and seed production. It also impacts on reproduction of snakehead brood stock and leads to low seed production.

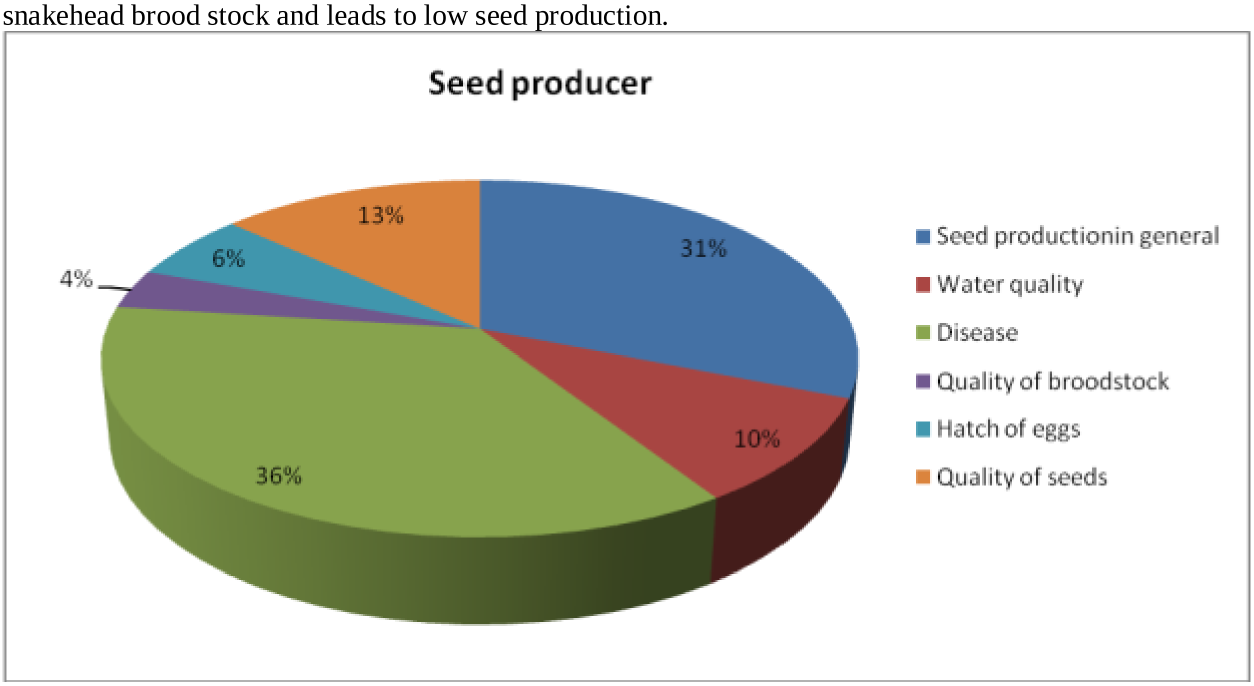

Figure 4: Main impacts of climate change on seed producer in Vietnam.

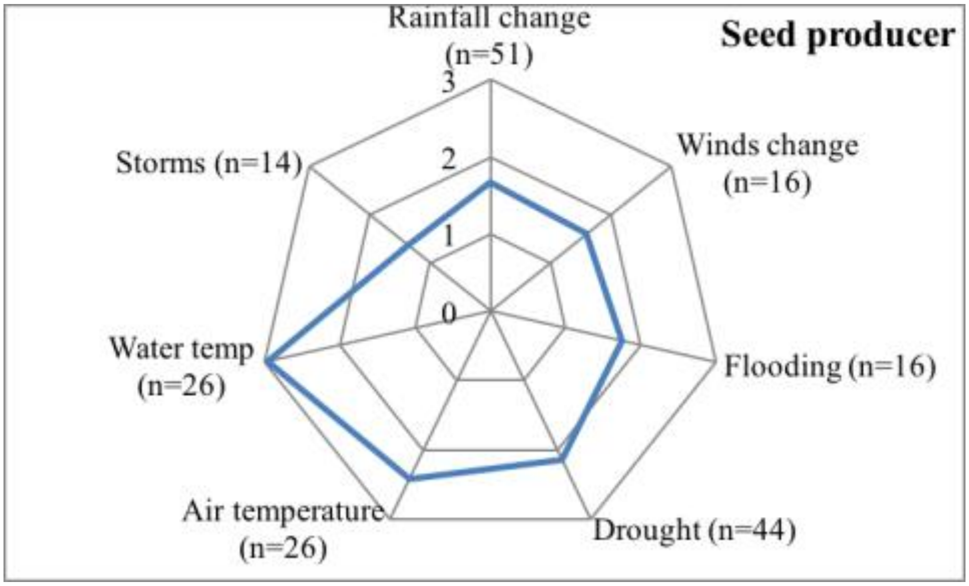

Figure 5. Vulnerability assessment matrix of seed producer in Vietnam.

Farmers reported that the main impacts of climate change on their business has been lower quality of snakehead seed, lower survival rate, water quality and disease (Figure 6). More specific impacts have been lower yields, reduction in cultured area and lower market price. The responses were consistent across all five provinces studied. Farmers reported that they expect the impacts of climate change in the next ten years will be decreased quality of snakehead seed, disease, and lower survival rate.

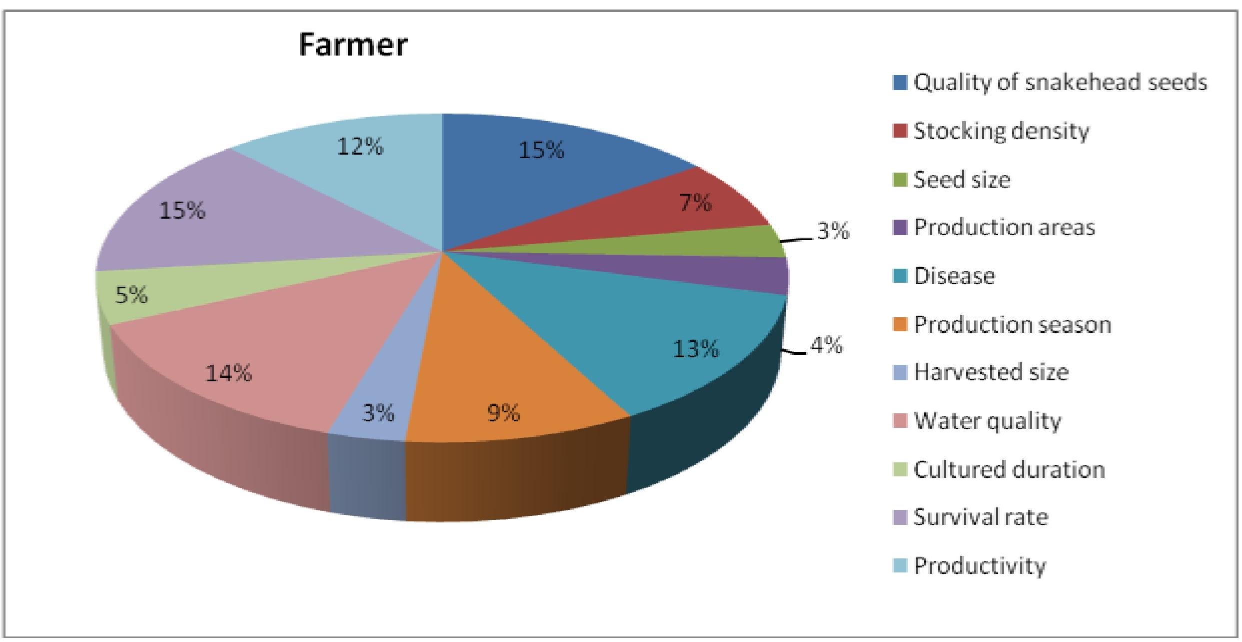

Figure 6. Main impact of climate change on farmer in Vietnam.

A vulnerability assessment for farmers identified drought, storms and higher water temperature factors having the strongest impact and causing the greatest vulnerability for snakehead culture (Figure 7). Drought, salinity, wind change, and flooding have a lower impact and vulnerability. Salt water intrusion impacts fish disease tolerance because snakehead is a fresh water species. It causes fish death and low survival rate. Storms and higher water temperature condition cause low production.

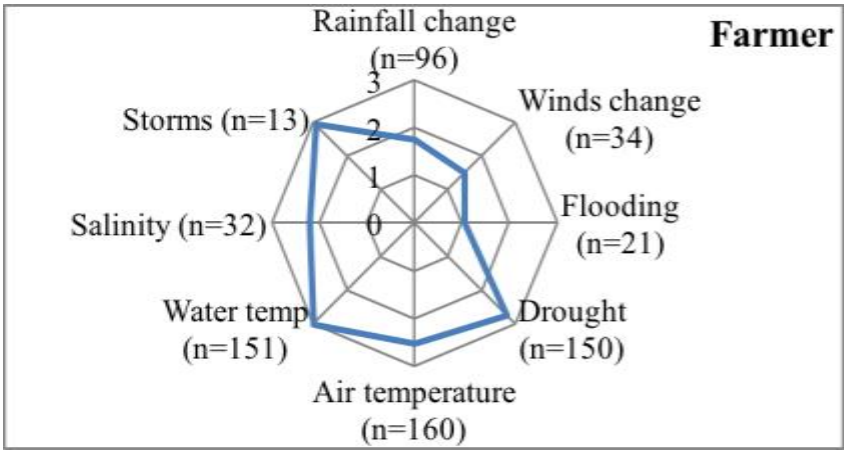

Figure 7. Vulnerability assessment matrix of farmer in Vietnam.

Traders reported that the main impacts of climate change on their business has been higher purchase price of fish, higher fish loss, and decrease in income (Figure 8). The responses were consistent across all five provinces studied. Traders reported that they expect the impacts of climate change in the next ten years will be higher snakehead purchase prices and lost markets.

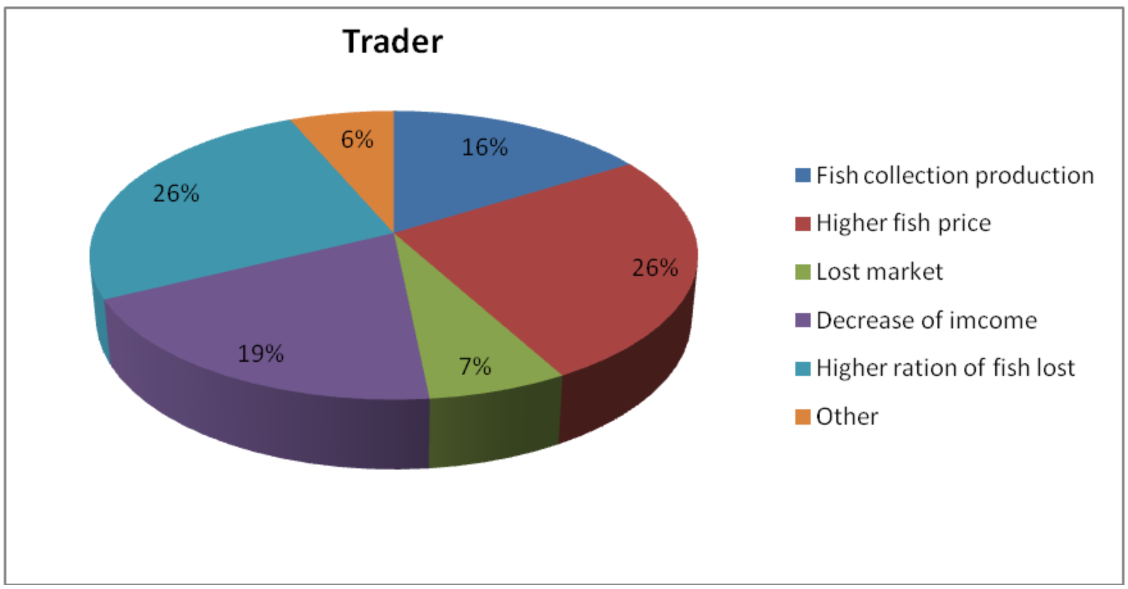

Figure 8. Main impact of climate change on trader in Vietnam.

A vulnerability assessment for traders shows that storms, higher water temperature, and salt water intrusion, drought and flooding factors have the strongest impacts and cause the greatest vulnerability (Figure 9). Wind change factors have a lower impact and vulnerability. Storms and salt water intrusion impact fish culture yield and low survival rates because snakehead is a fresh water species. Storms and higher water temperatures cause lower production. As a result, snakehead traders have less fish available to purchase.

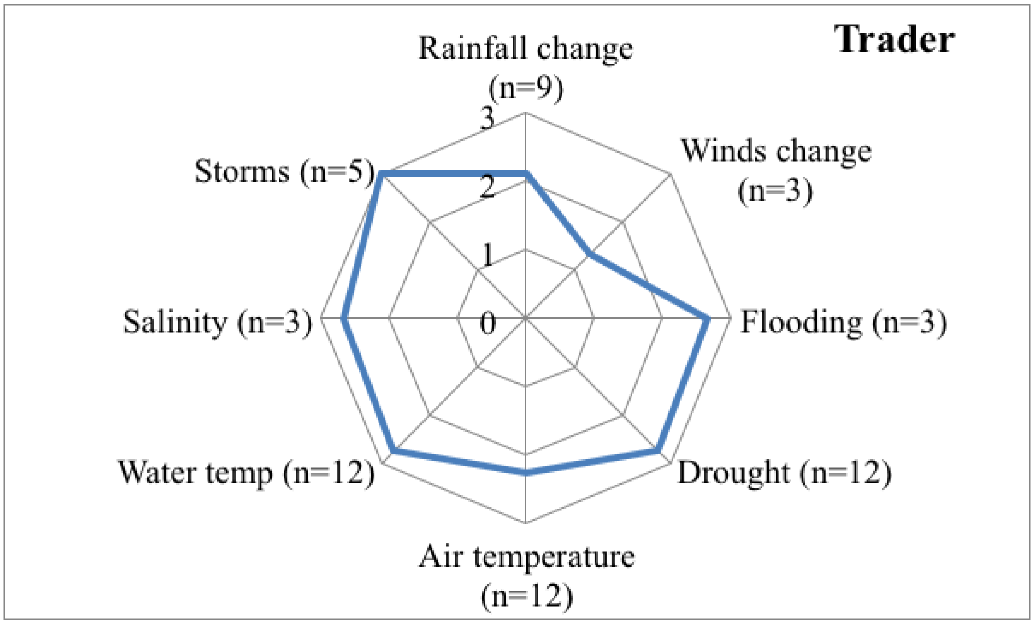

Figure 9. Vulnerability assessment matrix of trader in Vietnam.

Processors reported that the main impacts of climate change on their business have been lower quantity of fish available (processing products) and increasing price of raw fish (Figure 10). The responses were consistent across all five provinces studied. Processors reported that they expect the impacts of climate change in the next ten years will be increased price of raw fish and lower quantity of fish available.

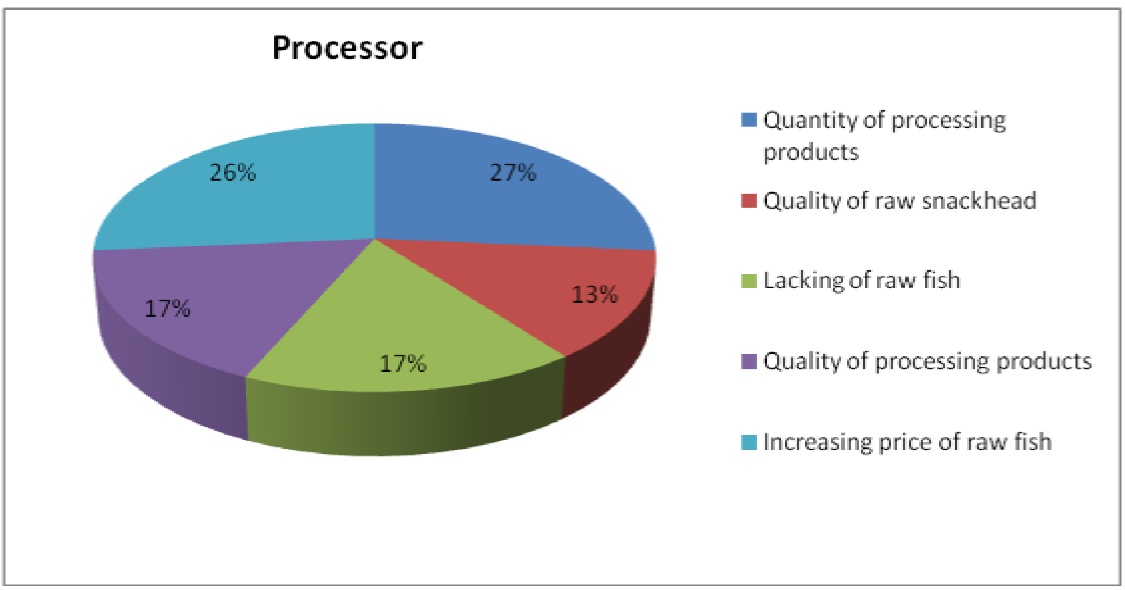

Figure 10. Main impact of climate change on processor in Vietnam.

A vulnerability assessment for processors shows that change in rainfall, increase in water and air temperatures, and storm factors have the strongest impact and cause the greatest vulnerability (Figure 11). Wind change, flooding, and salinity have a lower impact and vulnerability. Heavy rainfall and storms cause difficulty in processing and transporting fish.

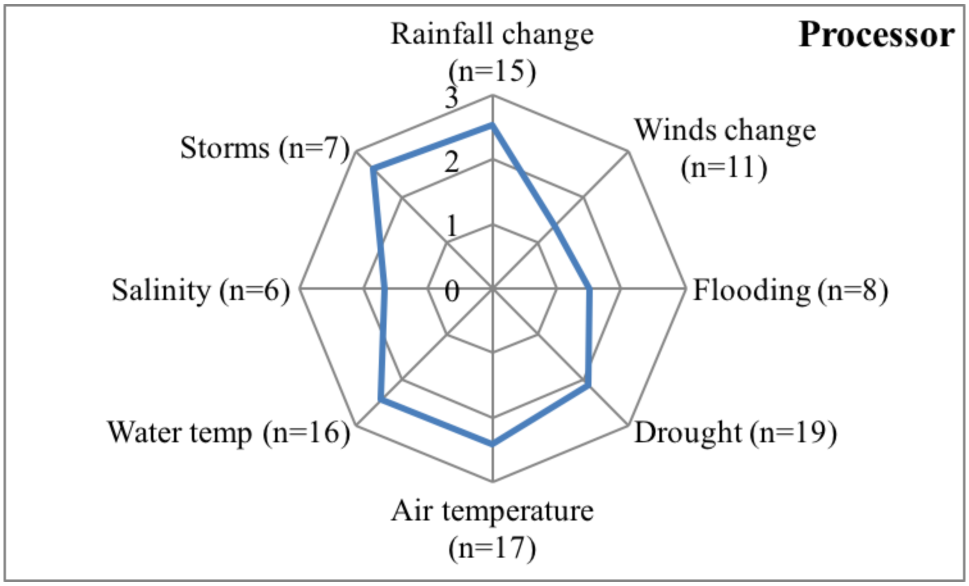

Figure 11. Vulnerability assessment matrix of processor in Vietnam.

The seed producers were asked how they plan to adapt to the impacts of climate change (Figure 12). The adaptation measures included changing the scale of seed production, temporarily stopping seed production, and selecting better brood stock.

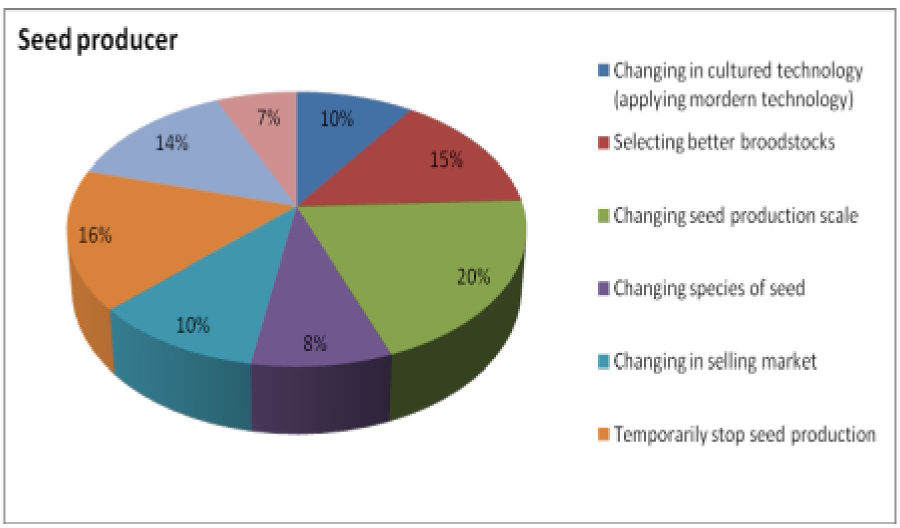

Figure 12. Adaptation strategy to the climate change of seed producer in Vietnam.

The farmers were asked how they plan to adapt to the impacts of climate change (Figure 13). The adaptation measures included changing to another culture method, stopping culture, applying more modern technology, and increasing inputs which will add to production costs.

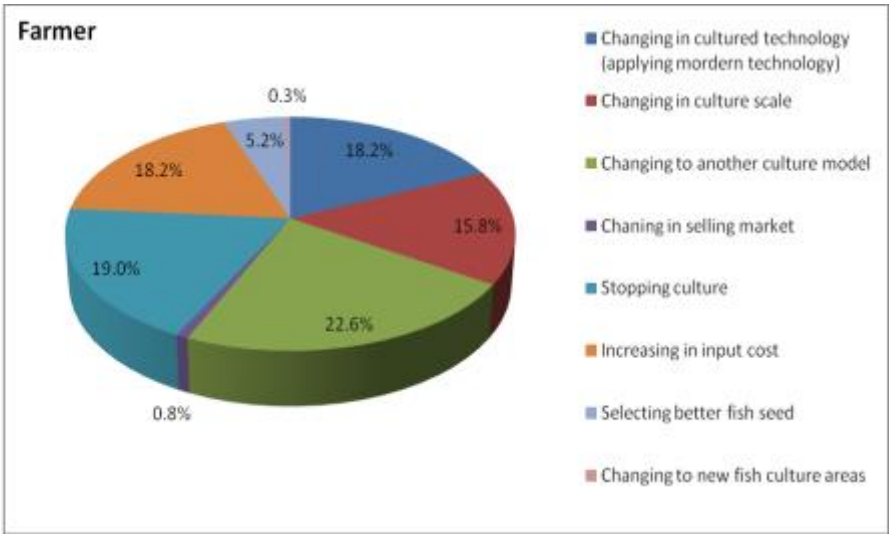

Figure 13. Adaptation strategy to the climate change of farmer in Vietnam.

The traders were asked how they plan to adapt to the impacts of climate change (Figure 14). The adaptation measures included choosing other fish species for their business, buying fish from other regions/areas, and increasing input which will add to production costs.

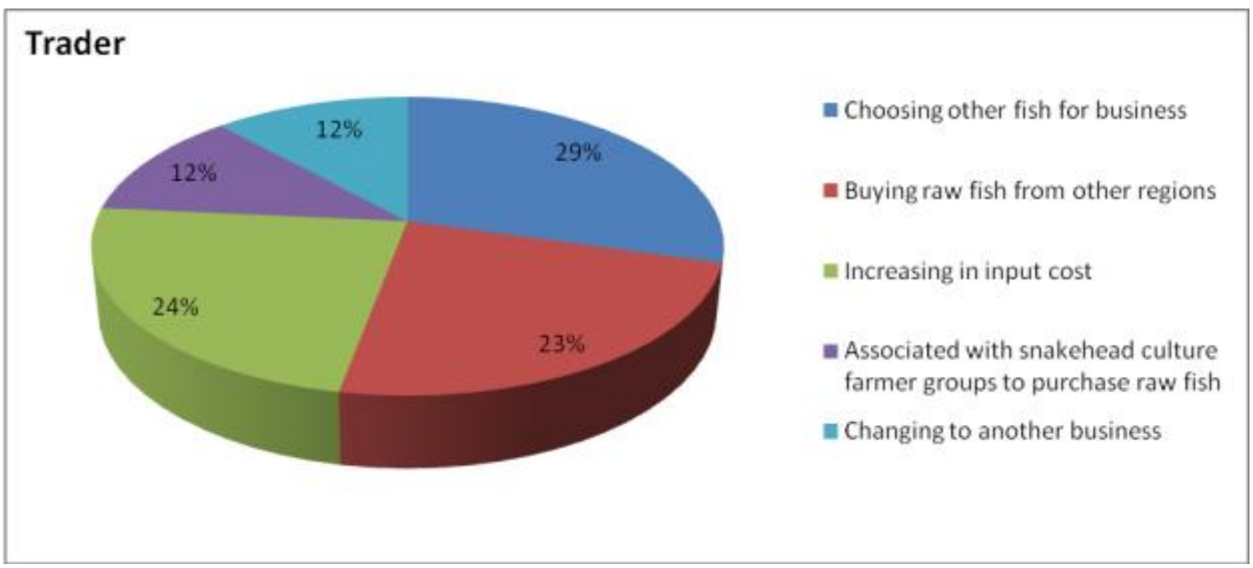

Figure 14. Adaptation strategy to the climate change of trader in Vietnam.

The processors were asked how they plan to adapt to the impacts of climate change (Figure 15). The adaptation measures included changing the scale of processing and temporarily stopping processing.

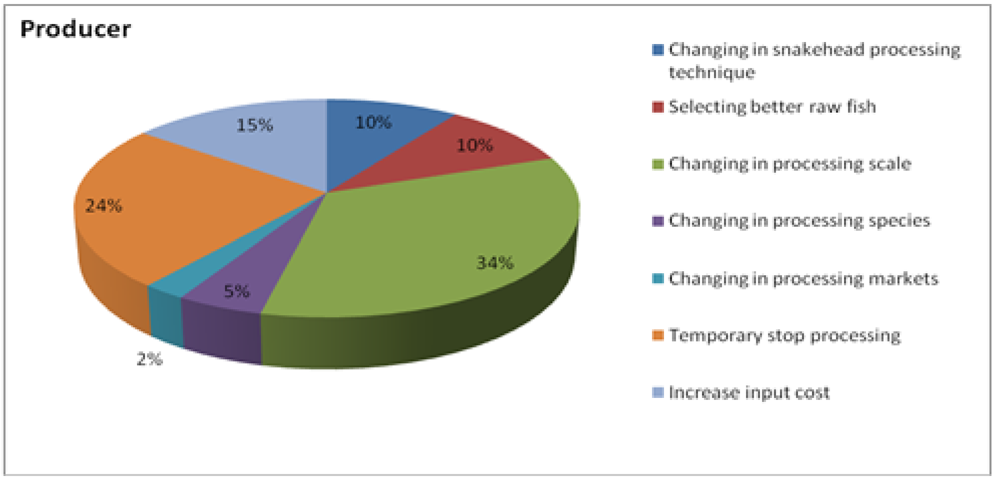

Figure 15. Adaptation strategy to the climate change of trader in Vietnam.

The vast majority of all respondents (seed producers 91%, farmers 93%, traders 92%, processors 95%) reported that other actors do not work together to deal with the impacts of climate change (Figure 16). The vast majority of respondents (seed producers 96%, farmers 88%, traders 92%, processors (90%) also reported that government has not assisted them in dealing with the impacts of climate change.

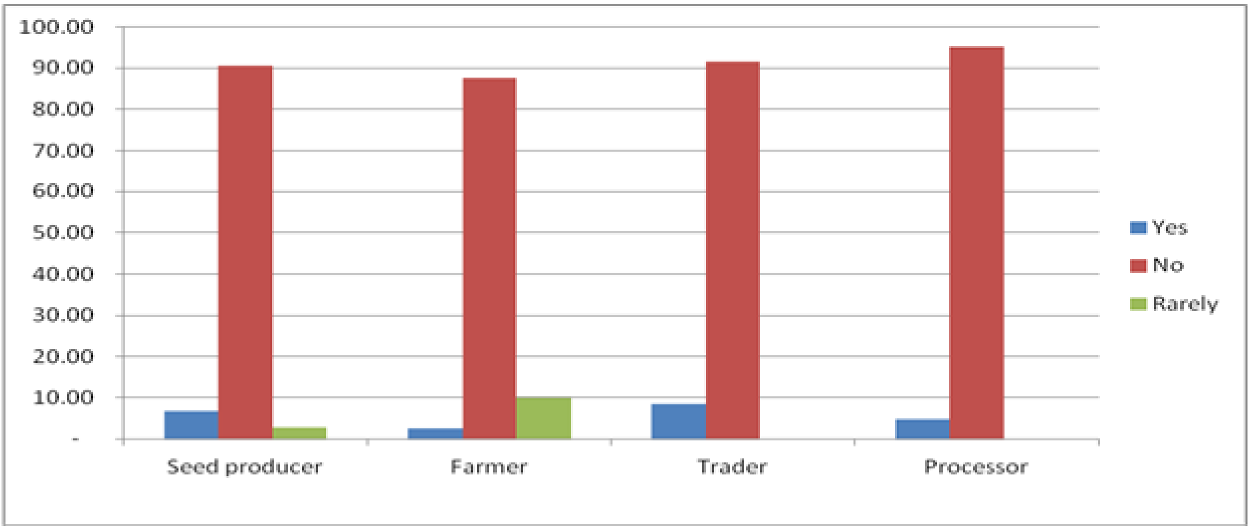

Figure 16. Snakehead culture actors working together to deal with the impacts of climate change in Vietnam.

Snakehead capture in Cambodia, One hundred percent (100%) of fishers, traders and processors interviewed in Cambodia reported that they were aware of climate change. The respondents reported that the main events that they consider as climate change in their area were changes in rainfall patterns, more severe storms, drought, and change in wind patterns. The climate change events of most concern to fishers were change in rainfall patterns, more severe storms and flooding; and to traders and processors were change in rainfall patterns and more severe storms (Figure 17). All of the respondents reported that they felt that the major changes to occur from climate change over the next ten years will be more severe storms and change in rainfall patterns.

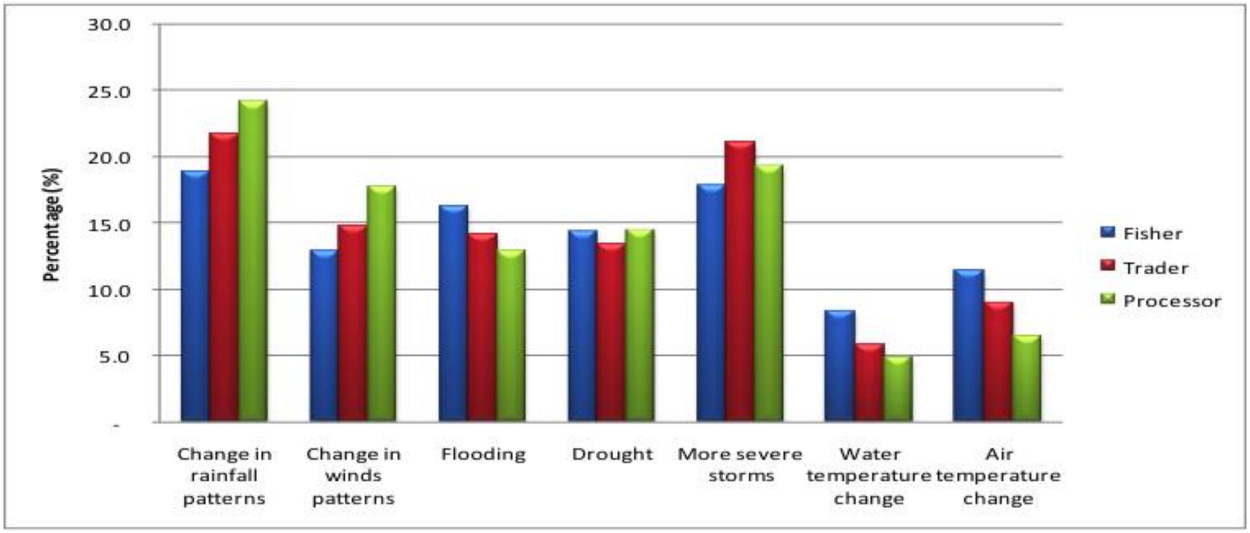

Figure 17. The percentage distribution of climate change events for actors in snakehead capture in Cambodia.

Fishers reported that the main impact of climate change on their business has been reduced fish catch/harvest/supply (Figure 18). More specific impact has been increased difficulty to go fishing due to the weather and climate. The responses were consistent across all provinces studied. Fishers reported that they expect the impacts of climate change in the next ten years will be a decrease in fish catch, increased difficulty to go fishing, and difficulty to earn income from fishing activity.

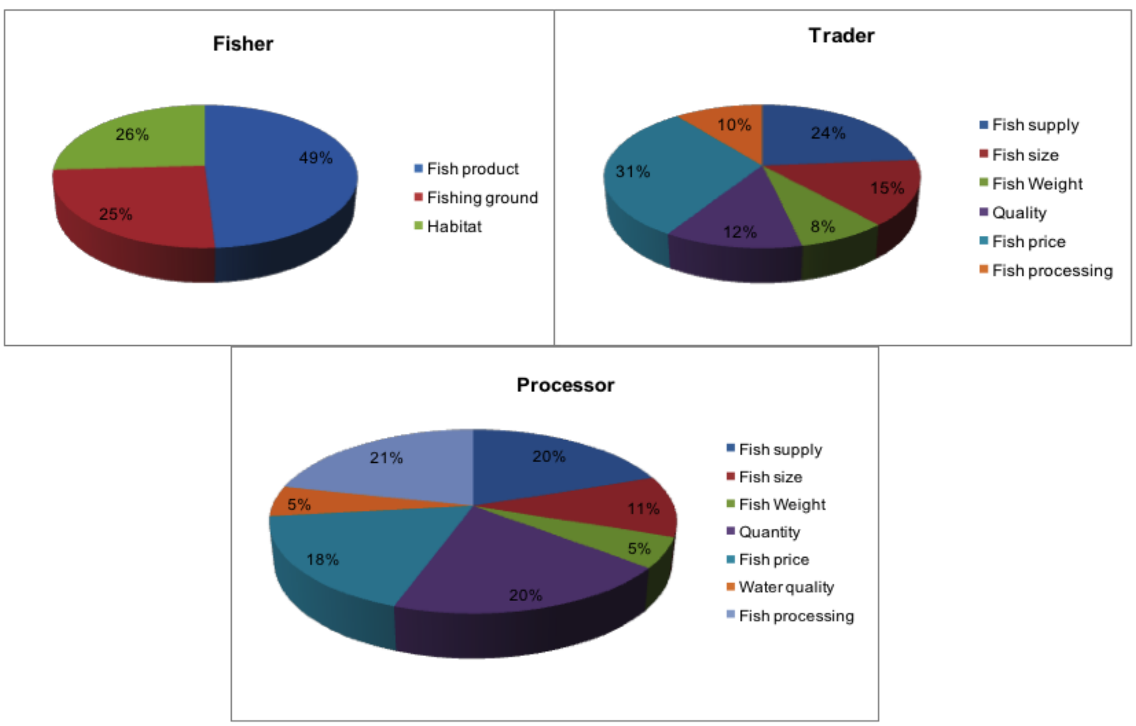

Figure 18. Main impacts of climate change on fisher, trader, and processor in Cambodia.

A vulnerability assessment of snakehead fishers identified storms as having the strongest impact and causing the greatest vulnerability. This was followed by drought, flooding, winds change, and rainfall change (Figure 19). Fishers feel more vulnerable as a result of storms as there is difficulty in going fishing and increased danger from fishing.

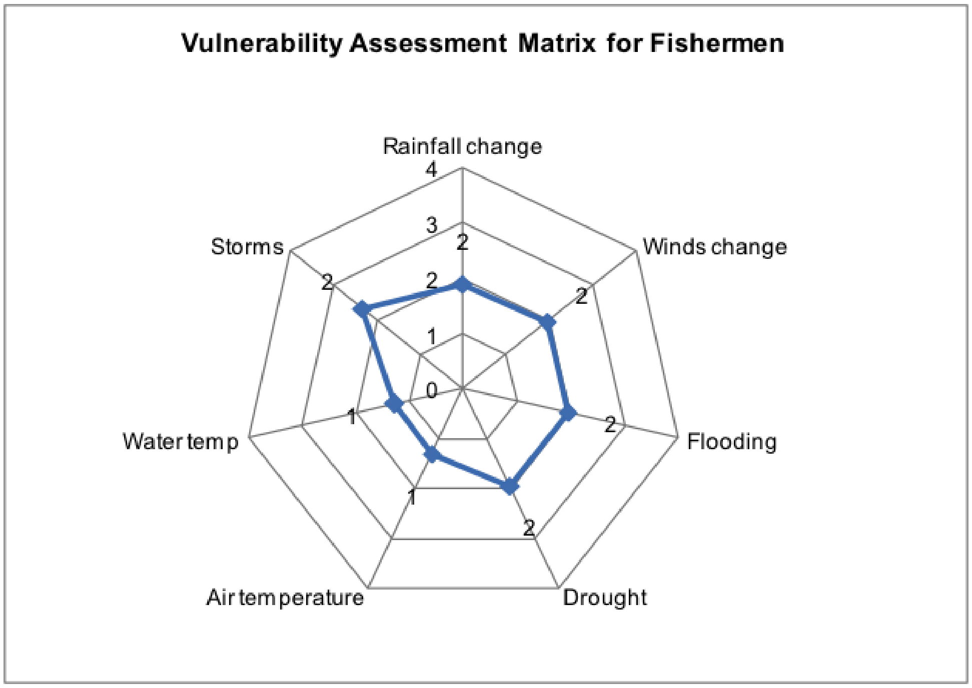

Figure 19. Vulnerability assessment matrix of fisher in Cambodia.

Traders reported that the main impacts of climate change on their business have been higher purchase price of fish and fish supply (Figure 18). More specific impacts have been a decrease in fish supply and do not have enough fish to sell. The responses were consistent across all provinces studied. Traders reported that they expect the impacts of climate change in the next ten years will be a decrease in the amount of fish available and the size of fish.

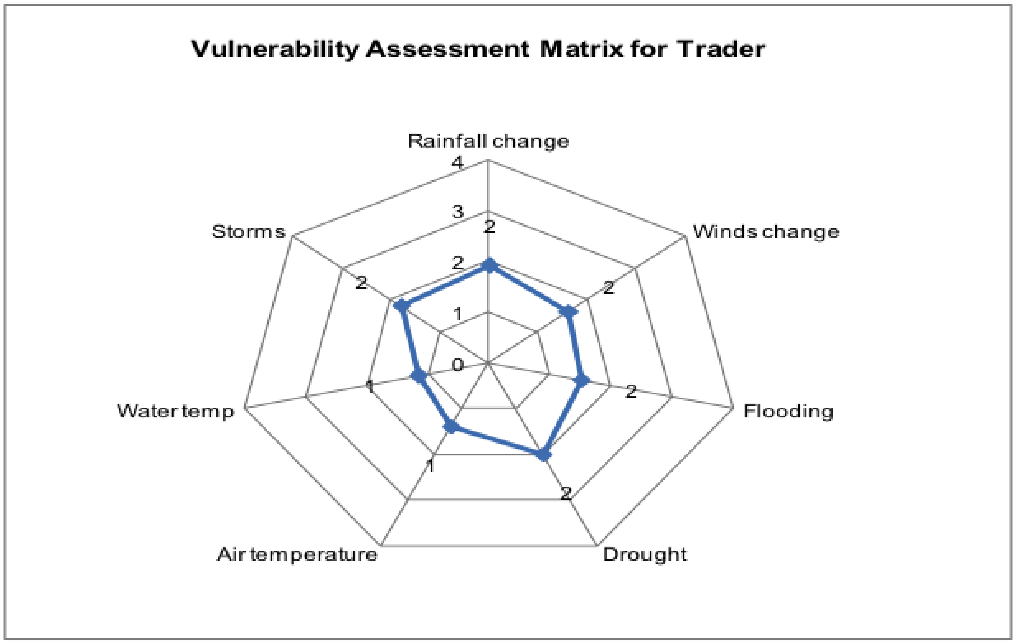

Figure 20. Vulnerability assessment matrix of trader in Cambodia.

A vulnerability assessment of snakehead traders identified drought and rainfall change as having the strongest impact and causing the greatest vulnerability (Figure 20). Traders felt that drought would reduce the fish supply and cause higher prices. Increased rainfall may cause difficulties for the trader to transport and sell fish.

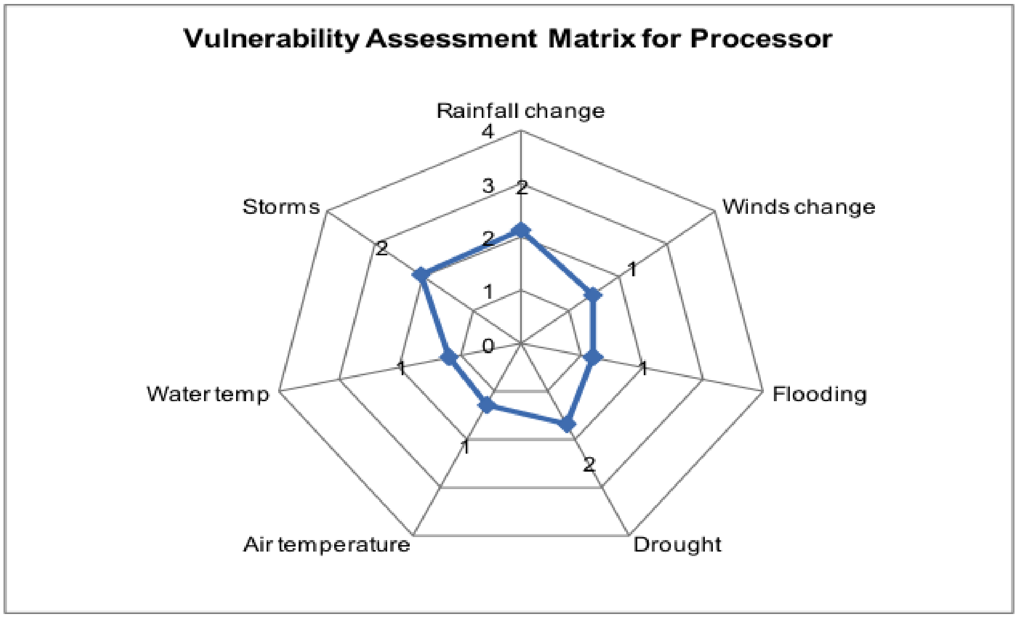

Figure 21. Vulnerability assessment matrix of processor in Cambodia

Processors reported that the main impacts of climate change on their business have been reduced fish processing, reduced fish supply, and higher purchase price for fish (Figure 18). More specific impact has been a lack of fish to process. The responses were consistent across all provinces studied. Processors reported that they expect the impacts of climate change in the next ten years will be a difficulty in processing, lack of big fish for processing, and a lack of fish for processing, especially to make *prahoc* (fish paste).

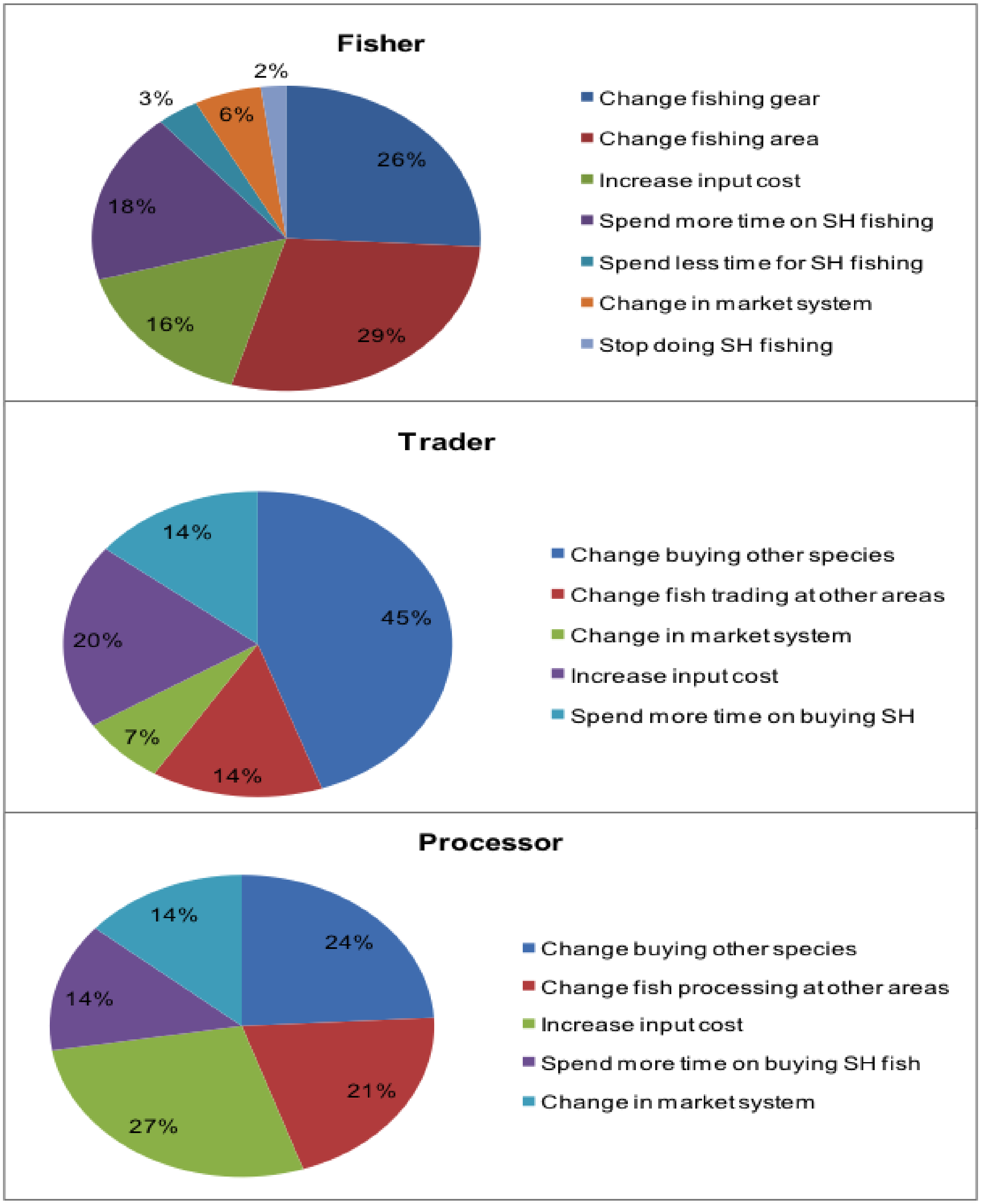

Figure 22. Adaptation strategy to deal with the climate change by fisher, trader, and processor in Cambodia.

A vulnerability assessment of snakehead processors identified changes in rainfall and storms as having the strongest impact and highest vulnerability (Figure 21). Processors felt that increased rainfall and storms would reduce the number of sunny days for processing fish products.

The fishers were asked how they plan to adapt to the impacts of climate change (Figure 22). The adaptation measures included change fishing gear, change fishing area, and spend more time fishing. When asked about other adaptation strategies, 50% of the fishers reported conserving or replanting forests. The traders planned to buy other fish species and increase input costs (for example, purchasing more fish or traveling to other areas to purchase fish) (Figure 22). When asked about other adaptation strategies, 62% of the traders reported conserving or replanting forests. The processors planned to increase input costs (for example, purchasing more fish or changing the type of processing that they do) and purchase other fish species (Figure 22). When asked about other adaptation strategies, 65% of the processors reported conserving or replanting forests.

While all respondents reported that other actors do not work together to deal with the impacts of climate change, more fishers (40%) reported working together than traders (22%) or processors (20%) (Figure 23).

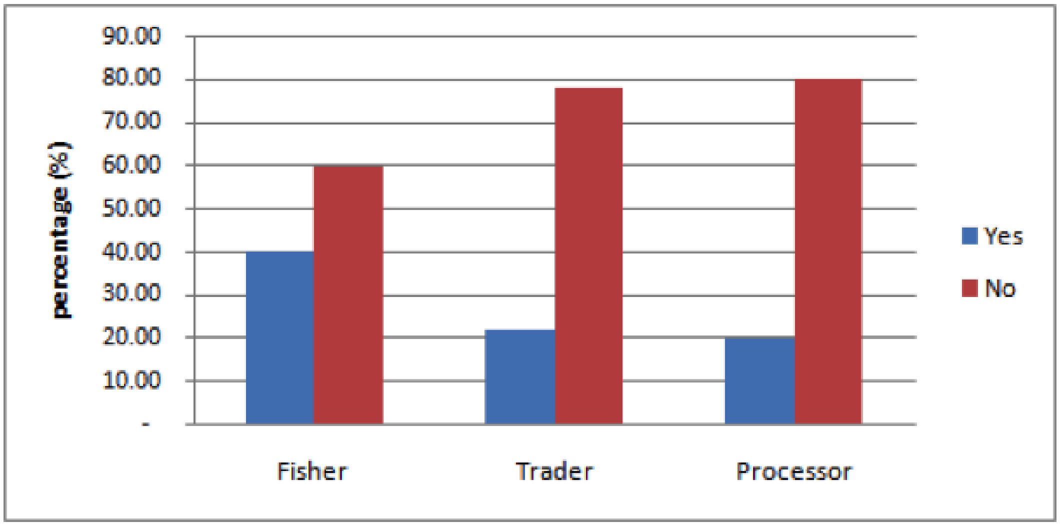

Figure 23. Snakehead capture actors working together to deal with the impacts of climate change in Cambodia.

Fishers reported that they felt that government assisted them in dealing with the impacts of climate change much more than traders or processors (Figure 24). The fishers reported that the government assisted them by providing basic needs (i.e., food) and by conserving forests. Those traders and processors who felt that government had assisted them reported that did so by conserving forests and providing basic needs to poor households (Figure 24).

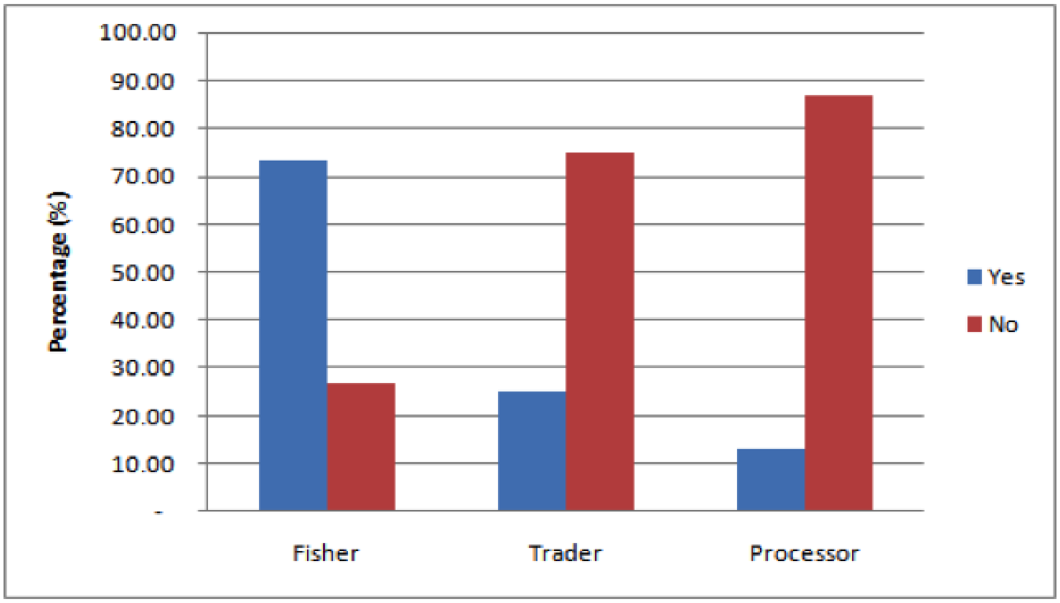

Figure 24. The government assisting actors with the impacts of climate change in Cambodia.

DISCUSSION

There was a high awareness of climate change among all of the actors in both snakehead capture and snakehead culture value chains in Cambodia and Vietnam. It was especially interesting to note that all of the actors in Cambodia reported awareness of climate change. Most of the actors in Cambodia and Vietnam reported concerns about changes in rainfall patterns, whether more drought or more rainfall. As would be expected, snakehead fishers in Cambodia are concerned about more severe storms as they must be out on the Tonle Sap Lake in boats. Snakehead farmers are concerned about increasing water and air temperature which will impact upon fish productivity. Traders and processors are concerned about more rainfall as it will impact upon their ability to transport the fish or process the fish.

Snakehead seed producers and farmers and snakehead fishers all reported the primary impact of climate change has been reduced production, whether as a result of disease or lower seed production or lower catch. Snakehead traders and processors in Cambodia and Vietnam report the impacts of climate change being higher purchase price for fish and less snakehead fish being available.

The vulnerability assessment identified a range of factors, as perceived by the snakehead value chain actors, to the effects of climate change on snakehead culture and capture. Snakehead seed producers and farmers in Vietnam were concerned about increases in water temperature on their production system. These farmers located in coastal provinces, as well as traders and processors in those areas, were concerned about increases in water salinity rates as a result of changes in rainfall and storms, which would impact upon snakehead production. In contrast, snakehead fishers in Cambodia were concerned about increases in storms which would impact their safety while fishing and their ability to go fishing. Traders and processors in Cambodia were concerned about changes in rainfall patterns and storms, bringing more rain, as well as drought; all of which would impact the availability of snakehead fish and their ability to transport fish.

Adaptation strategies were similar whether a snakehead farmer or fisher, that is, change the production system. Farmers in Vietnam plan to adjust their culture system or stop growing snakehead and culture another species. While fishers in Cambodia plan to change their fishing gear or target other fish species.

Similarly, snakehead traders and processors in Cambodia and Vietnam plan to make changes in their purchasing patterns by buying other species or in other areas, which may increase their operating costs.

Except for snakehead fishers in Cambodia, all of the other actors in the snakehead value chain tend to not work together to address the impacts of climate change. It is interesting to note that fishers, who have a reputation of being independent than farmers, work closer together. This may be a result of all of the work that has been done organizing fishers through community fisheries in the Tonle Sap Lake.

Except for snakehead fishers in Cambodia, all of the other actors in the snakehead value chain reported that government did not help them address the impacts of climate change. Snakehead fishers in Cambodia reported that they felt that government assisted them in dealing with the impacts of climate change through the provision of basic needs (i.e. food) and by conserving forests.

CONCLUSIONS

Snakehead are a preferred fish species for food in both Cambodia and Vietnam, and are consumed in both fresh and processed forms in the Lower Mekong Basin. In Cambodia, snakehead capture fisheries remain of importance in the capture fisheries sector, while snakehead aquaculture is important in Vietnam.

Snakehead production, whether capture or culture, is highly vulnerable to climate and non-climate (specifically water development such as hydropower dam development) related drivers of change. This includes increased temperatures; changes in rainfall patterns; changes in the hydrological regime (water levels, duration of flooding, timing of flooding); changes in run-off or sediment load/movement; increased instances of extreme weather events (storms, floods and droughts); and saline water intrusion (Keskinen et al. 2010; Hoanh et al. 2010; Västilä et al. 2010; Lauri et al. 2012). These drivers of change will be felt throughout the snakehead fish value chain and will pose significant challenges for fisheries and aquaculture production; food security and the nutrition and health of people, especially poor households; household income; livelihoods; markets and trade; and gender issues in the LMB of Cambodia and Vietnam. However, a complete understanding of the impacts of and vulnerability caused by each individual driver and a combination of drivers is only just beginning. Adaptation is urgently needed to foster the resilience of the snakehead fisheries and aquaculture sectors.

It is important to note that while the focus of this study was on snakehead capture and culture, similar impacts, vulnerability and adaptation strategies may be felt by fishers and farmers who target other fish species. For example, those fishers who target snakehead fish in Cambodia also target other fish species and those snakehead farmers in Vietnam also culture other species such as catfish (*Pangasius*).

Several actions need to be taken to address the impacts and vulnerability from climate change on snakehead culture and capture in Cambodia and Vietnam:

1. Governments in both Cambodia and Vietnam need to become more active in working with the various actors in the snakehead value chain to assist them in adapting and preparing for the impacts of climate change on their business. Only Vietnam has a strategy to address the impacts of climate change on aquaculture. Cambodia will need to develop such a strategy. Neither government has provided a budget to work with the industry actors to help adapt to climate change. The provinces in both countries will play an active role in any adaptation program. Much more outreach will need to be provided to the aquaculture industry in both countries.
2. The actors in the snakehead value chain will need to begin working together or be better organized to be able to share information and develop appropriate adaptation strategies to address the impacts of climate change on their business. In Vietnam, there are aquaculture associations

and organizations, but there are no such organizations in Cambodia (due to the small size of the aquaculture industry). Aquaculture industry actors in Cambodia, working with or without government, will need to be encouraged to organize. This will allow sharing of information among actors and allow governments to have points of contact for assistance.

3. The Government of Cambodia should consider reviewing the ban on snakehead aquaculture in order to provide an alternative livelihood to households as an adaptation strategy. The government of Cambodia put a ban on snakehead farming in September 2004 by Announcement No. 4004. The reasons for this were the potential negative impacts on wild fish populations from wasteful snakehead seed collection and on other fish species diversity, particularly the small-sized or low value fish used feed for snakehead aquaculture, and also the potential negative effects on poor people from decreased availability of small-sized/low value fish (So et al. 2007). The ban was also meant to force people to investigate other alternatives for their aquaculture and hopefully to create positive ecological effects (PRIAC 2006). In order to remove this ban, the same announcement mentioned that successful technologies for domestication (breeding, weaning and rearing/grow-out) of snakehead using formulated diets should be developed and applicable in on-station and on-farm levels in Cambodia. The government will lift the ban only when research develops a sustainable process to raise farmed snakehead without doing harm to the wild fishery on which so many people depend. There is currently a snakehead formulated feed, developed by this project, which will address one of the reasons for the ban. Current work by Can Tho University and IFREDI is on domestication of indigenous snakehead in Cambodia.

4. The aquaculture research facilities in Cambodia and Vietnam need to develop a program to better understand and address the impacts of climate change on snakehead seed production and grow-out. Neither IFREDI nor Can Tho University have a research strategy and program to address the impacts of climate change. This strategy needs to be developed along with a financial strategy to support the research program. This financial strategy should incorporate funding from government, donors, and the private sector.

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Value Chain Analysis of Farmed Nile Tilapia (*Oreochromis niloticus*) and African Catfish (*Clarias gariepinus*) in Tanzania

Marketing, Economic Risk Assessment, and Trade/Study/13MER02PU

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ABSTRACT

This study was conducted in four regions of Tanzania (Dar es Salaam, Coast, Mwanza, and Geita) to assess the value chain of pond-cultured Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). The study aimed at determining and mapping actors and identifying constraints and opportunities of various actors in the value chain. The study involved 113 fish farmers, 16 input suppliers, 74 fish marketers/retailers, 16 fish distributors/wholesalers and 41 restaurant owners/managers. The value chain actors for farmed Nile tilapia included input suppliers, fish farmers, fish traders and fish consumers. The input suppliers were private individuals (12.5%), farmers' groups (25%) and government institutions (62.5%) and supplied fingerlings, concentrate feeds, information and training on fish farming to farmers. The fish farmers owned 2.3 ± 0.3 ponds (mean ± se) with average size of 598.3 ± 56.4 m^2. All fish farmers cultured Nile tilapia, and a few (23%) of them also cultured African catfish. Average (± se) Nile tilapia yield was 4,928.4 ± 427.4 kg/ha/year and 68.1% of the fish produced were sold, mainly to retailers (26.5%), neighbour consumers (21.2%) and distributors (17.7%). For most farmers (85.8%), price of fish was based on market price. However, the selling price was sometimes negotiable. Fish traders included retailers, wholesalers, restaurant operators and food vendors. Fish retailers bought fresh fish, mainly Nile tilapia, not only from fish farmers but also from fishermen, and they sold to distributors/wholesalers, restaurants, food vendors and consumers. Before selling the fish, they added value by washing, dressing, frying, smoking and sun drying. Wholesalers sold fish to other traders, consumers and restaurants. Restaurants sold cooked or fried fish to consumers. For all traders, the price of fish was based on market price and cost plus pricing. Constraints for fish farmers included shortage of water for fish ponds, high costs of inputs, lack of proper knowledge on fish farming, shortage of fish feeds, low price of fish, slow growth of cultured fish and lack of reliable source of fingerlings. Problems encountered by fish traders included low capital, inadequate fish supply, lack of storage facilities and unfaithful suppliers who supply spoiled fish. Lack of contractual arrangement between input suppliers and fish farmers and fish farmers and fish traders was identified as the weakness among the various actors in the value chain. Opportunities for fish farmers included readily available markets for Nile tilapia in the villages and towns. For traders, opportunities included high demand for Nile tilapia, availability of tenders in hotels and rising income for the majority of the people and increase of the middle class group in the country.

INTRODUCTION

Aquaculture is one of the world's fastest growing food production sectors with great potential for supply of protein, income generation, poverty alleviation, and enhanced trade and economic benefits. Studies in Nepal (Bhujel et al. 2008) and Bangladesh (Jahan et al. 2010) have shown that fish farming significantly contributes toward food security and poverty alleviation in poor societies. In sub-Saharan Africa, aquaculture production has been promoted with the aim of improving food security; increasing domestic fish production and substituting imports of fish products; creating employment; promoting diversification and reduce risk; promoting economic development; and improving efficiency use of resources, especially water (Béné and Heck 2005, Satia 2011).

In Tanzania, fish farming is currently being emphasized as an alternative to capture fisheries due to decline in wild stock from natural water bodies. Aquaculture practice in Tanzania is mainly for subsistence purposes. In recent years, commercial aquaculture has started whereby commercial prawn farming is practiced in Mafia, Nile tilapia and African catfish in Mwanza and Trout (*Onchorynchus mykiss*) farming in Arusha. At the moment, aquaculture is dominated by freshwater fish farming in which small-scale farmers practice both extensive and semi-intensive fish farming. The emphasis of the national fisheries policy (URT 1997) is on a semi-intensive integrated mode of fish culture, focusing on Nile tilapia. The Nile tilapia is given first priority due to its better characteristics that include fast growth, short food chain, efficient conversion of food, high fecundity (which provides opportunity for distribution of fingerlings from farmer to farmer), tolerance to a wide range of environmental conditions, and good product quality (Hussain et al. 2000, Neves et al. 2008). Another species that is given priority is the African catfish (*Clarias gariepinus*). The African catfish is either cultured on pure stand or in polyculture with Nile tilapia. In the polyculture system the African catfish is used as a predatory fish species that eats the surplus fry, hence, controls undesirable tilapia recruitment in ponds and permits better growth of the adult tilapia population.

Value-chain analysis is the key entry point to poverty alleviation and achieving pro-poor outcomes. It is usually aimed at increasing the total amount and value of products that the poor can sell in the value chain (Hempel 2010). This, in turn, results in higher absolute incomes for the poor as well as for the other actors in the value chain. The other objective of value-chain analysis is to sustain the share of the poor in the sector or increase the margins per product, so that the poor do not only gain more absolute income but also relative income compared to the other actors in the value chain (Berg et al 2008). Furthermore, value chain is used as an analytical tool for understanding the policy environment that enables efficient allocation of resources within the domestic economy to maximize value, prevent post-harvest losses, and ensure effective management is in place to promote sustainable utilization of the resources. Value-chain analysis is done by mapping the actors participating in the production, distribution, marketing and sales of particular product (or products). The mapping involves assessment of the characteristics of actors, profits and costs structures, flow of goods throughout the chain, employment characteristics and the destination and volumes of domestic and foreign sales. Also it involves identifying the distribution of benefits of actors in the chain, the role of upgrading and governance within the chain.

In Tanzania, little is known about the value chain of cultured Nile tilapia and African catfish due to fact that no thorough study has been conducted on the subject matter, thus making the government put little effort to promote fish farming for poverty alleviation. This study was carried out to identify and map the main actors involved in Nile tilapia and African catfish value chains and their functions and analyze marketing margins of the different subsectors of Nile tilapia and African catfish value chain as the produces move from producers downstream the value chain. Also, the study was intended to determine the key constraints and problems affecting different actors in the value chain.

MATERIALS AND METHODS

Study location. The study was carried out in four regions of Tanzania: Geita, Mwanza, Coast, and Dar es Salaam. Geita and Mwanza regions are found in the Lake zone in the western part of the country while Coast and Dar es Salaam are located in the coastal zone in the eastern part of the country. In the Geita region, the study was conducted in Geita and Chato districts, while in Mwanza it was done in Ilelemela, Nyamagana, Misungwi, and Sengerema districts. In the Coast region, the study was done in Kibaha and Bagamoyo districts. In the Dar es Salaam region, three districts were involved, namely Kinondoni, Ilala, and Temeke.

Study subjects and sampling procedure. The study involved fish farmers, input suppliers, traders and distributors/wholesalers. The districts were purposefully selected, based on accessibility and presence of large number of fish farmers. In each district, lists of fish farmers and traders were taken as sampling frames from which respondents were picked randomly using a table of random numbers. The suppliers of fish production inputs and the fish distributors were purposely selected.

Data collection procedure. Cross-sectional surveys were conducted in all districts. During the survey, structured questionnaires were administered to individual fish farmers, input suppliers, traders and distributors/wholesalers. The structured questionnaires included both closed and open-ended questions. For fish farmers, the questionnaire was designed to seek information on households' socio-economic characteristics (age, gender and education level of household head, main occupation and source of income), number and size of ponds, fish species cultured, fish production yield, inputs sources and costs, proportion of harvested fish consumed at home and the proportion sold, income obtained from fish, marketing of fish produced, main customers, production constraints. A total of 113 small-scale fish farmers were individually interviewed. Out of the 113 fish farmers, 32, 28, 30 and 23 were from the Geita, Mwanza, Coast and Dar es Salaam regions, respectively. During the household surveys, the respondents were heads of households or spouses or adult members of the family (in the very rare cases when the household head was not available at home).

For input suppliers, the questionnaire was designed to collect information on type of organization, type of input supplied, price determination and mode of payment and problems faced. A total of 16 input suppliers were involved in the study. Among the input suppliers, four were from Mwanza, two from Geita, four from Dar es Salaam and six from the Coast region. For fish traders, distributors/wholesalers and restaurants the questionnaire was designed to collect information on households' socio-economic characteristics (age, gender and education level of household head, main occupation and source of income), type of business, fish species sold, source of fish, value addition activities done, customers, price determination and mode of payment, main competitors, services received, problems faced and available opportunities. In Geita, a total of 30 fish traders/retailers were involved in the study, while in the Coast region 24 fish traders/retailers were surveyed. In the Dar es Salaam region, 20 fish retailers were involved in the survey. Thus, the sample size for fish traders was 74 respondents from the three regions. For restaurants, a total of 41 respondents were individually interviewed, of whom 14 were from the Geita region, 7 from the Mwanza region, 10 from the Coast region and 10 from the Dar es Salaam region. For distributors, six were from Mwanza, six from Dar es Salaam and four from the Coast region, making the sample size for distributors to be 16 respondents.

Data analysis. Data from questionnaires were coded and recorded into the spreadsheets for statistical analysis. The Statistical Package for Social Science version 20 (SPSS 2011) computer software was used to generate descriptive statistics (means, standard deviations, frequencies and percentages).

RESULTS

Actors in the value chain. Most farmers and fish traders were involved in production and marketing of Nile tilapia (*Oreochromis niloticus*), hence the study focused on the value chain of Nile tilapia. The value-chain actors for farmed Nile tilapia both in the Lake and Coastal zones included input suppliers, fish farmers, fish traders and fish consumers. The input suppliers supplied fingerlings, fish feeds, information and training on fish production to fish farmers. The fish farmers cultured fish in ponds. All fish farmers (100%) cultured Nile tilapia (*Oreochromis niloticus*) and a few of them (23.0%) cultured African catfish (*Clarias gariepinus*) in addition to Nile tilapia (Table 1). The fish traders included retailers, wholesalers, restaurant operators and food vendors. Fish retailers bought fresh fish, mainly Nile tilapia, not only from fish farmers but also from fishermen and sold to distributors/wholesalers, restaurants, food vendors and consumers. Before selling the fish, they added value by washing, dressing, frying, smoking and sun drying. Wholesalers sold fish to other traders, consumers and restaurants.

Restaurants sold cooked or fried fish to consumers. Our findings concur with the observation made by Macfadyen et al. (2012) that the value chain of farmed fish in Egypt include input suppliers, retailers and food service providers. However, unlike the findings in this study the value chain in Egypt also includes supermarket retailers as well as export market (Macfadyen et al. 2012).

In the present study, African catfish were sold directly to consumers and were not sold in restaurants as consumers preferred Nile tilapia to African catfish. This is contrary to what has been reported in Uganda (Maurice et al. 2010) whereby the value chain of African catfish includes input suppliers (feed producers, seed producers, and equipment suppliers), farmers, middlemen and retailers. Similarly in Nigeria farmed catfish are sold by farmers to primary wholesalers who transport catfish to secondary wholesalers who, in turn, sell to retailers, restaurants, or consumers (Hempel 2010).

Input suppliers. Input suppliers included private individuals (12.5%), farmers' groups (25%) and government institutions (62.5%). All input suppliers supplied fingerlings to fish farmers, and in addition some supplied concentrate feeds (62.5%), information on fish production (37.5%) and training on fish farming (87.5%). The cost of inputs supplied was based on cost plus pricing method and the mode of payment was cash for all input suppliers. The study found that there were no formal contract between the input suppliers and the farmers and the inputs or services were supplied on demand basis.

Fish farmers. Most of the fish farmers were males (90.3%) and only a few were females (9.7%) with a mean age of 40.7± 0.9 years. The majority of the farmers were married (92.0%) and had primary school educations (62.8%). These farmers on average owned two ponds with mean size of 598 m^2 (Table 1). All farmers cultured Nile tilapia mainly under monoculture system. The majority of the farmers said that fish farming contributed either less than 25% (20.6% of farmers) or between 25 and 50% (46.4% of farmers) of the household income. Most fish farmers (77.9%) got knowledge for fish farming from other fish farmers and only few got the knowledge from fisheries extension officers (19.5%) or by reading extension materials (23.9%) and working on fish farms (25.7%) (Table 2). The majority of the farmers did not get financial assistance, but used their own money to start fish farming. The main sources of fingerlings for these farmers were other fish farmers (51.3%) and government institutions (31.9%). The government institutions included Kingolwira Fish Farming Centre and Fisheries Training Institutes. All farmers used manure to fertilize fish ponds and they obtained the manure from their own households (71.8%) and neighbours (24.7%). Similarly the source of fish feeds was their own households and neighbour farmers. The majority of the farmers used family labour to do all fish farming activities from pond making to fish harvesting.

Mean fish yield (Nile tilapia) per household was 4,928. 4 ± 427.4 kg/ha/year, and it was estimated that 68.1% of the fish produced were sold and the remaining were consumed at home (31.9%). Most of the fish were sold to fish vendors/retailers and neighbor consumers, and only small amount of fish were sold to wholesalers/distributors and restaurants (Table 3). For the majority of farmers, the fish were sold at the fish farm (65.5%) and at distribution points (45.1%). The mode of payment was via cash transaction, and the price of fish was based on the market price for most of the farmers (85.8%). However, the price was sometimes negotiable for all farmers. There were no formal contracts between the farmers and the buyers. On average fish farmers realized a gross margin of TZS 1,172,189.2 ± 38,679.7 per year.

Fish traders (retailers). The majority of fish retailers were males (89.2%), married and had a primary school level of education (73%). Most of these retailers sold Nile tilapia, and only a few sold African catfish. This is due to the fact the Nile tilapia is popular among consumers because of its good carcass characteristics. The results in Table 4 show that the fish retailers obtained fish mainly from fishermen and only few got fish from farmers. The retailers sold fish to consumers and wholesalers/processors. For most fish traders, the income from fish business accounted for about 81% to 100% of household income, implying that they mainly depend on fish trading for their livelihoods. The majority of fish traders reported that they do not provide financial assistance to fish farmers and themselves rarely get financial assistance from financial institution (Table 4). The financial institutions which provided short term loan to fish traders were mainly microfinance institutions and nongovernmental organizations (NGOs). The retailers added value by cleaning and dressing the fish before selling to customers (Table 5). According to the retailers the fish quality and low price were the main factors which customers considered when buying fish. The pricing method used by the retailers was market price and cost plus pricing. There were no formal contracts between the retailers and the customers. The main competitors were other fish traders.

Wholesalers/distributors. The results for wholesalers/distributors are shown in Table 6. About 69% of the wholesalers were males, and 31% were females. The mean age of the wholesalers was 39.4 ± 3.1 years, and most of them were married. Most of the wholesalers either had a primary school level of education or had no formal education. The wholesalers obtained fish from fish traders and farmers and they sold mainly Nile tilapia to fish vendors and consumers. The price of fish was based on market price, but some (68.8%) of the wholesalers used cost plus pricing method, and the method of payment was based on cash transactions. For the majority of the wholesalers, there were no formal contracts between the wholesalers and the customers. With regard to financial assistance, only few wholesalers report that they get loan from banks (18.8%) and microfinance institutions (25%).

Restaurants. The socio-economic characteristics and marketing practice for restaurants are shown in Table 7. The majority of owners of restaurants were males (63.4%), married (70.7%) and had a mean age of 35.4 ± 1.2 years. Most of them had either primary (34.1%) or secondary school (48.8%) level of education. All restaurants sold cooked or fried Nile tilapia to consumers, and no restaurant was found selling African catfish. African catfish was even not included in the menu. The main source of fish were fish traders and only few restaurants obtained fish from fish farmers (Table 7). This indicates that most restaurants served wild Nile tilapia and very few restaurants served both wild and farmed Nile tilapia. Only few restaurants had contracts with the fish suppliers, but the majority did not have any formal contracts. The price of fish was based on the market price and cost plus pricing for most of the restaurants. Value addition in the restaurants included cleaning, dressing, frying and drying. Customers were attracted by good quality of the fish, convenience of the place and habit of the customers.

Problems and opportunities for different actors in the value chain. The main actors in the value chain were input suppliers, fish farmers, retailers, wholesalers/distributors and restaurants. The problems facing fish farmers, traders and restaurants are shown in Tables 8, 9 and 10, respectively. The main constraints affecting fish farming were shortage of water supply for fish ponds, high cost of inputs, lack of proper knowledge on fish farming, lack of fish feeds, low price of fish and slow growth of the cultured species (Table 8). Most farmers said that there is no reliable source of good quality fish feed. The problems that affected fish traders were lack of appropriate infrastructure for fish handling and storage, low capital and inadequate supply of fish (Table 9). The constraints for restaurants included fish scarcity, low capital and unfaithful suppliers who supply spoiled fish (Table 10).

The main weakness for various actors in the value chain was mainly lack of contractual arrangement between input suppliers and fish farmers and fish farmers and fish traders. This made the transactions to be unreliable and expensive. Another weakness was that fish farmers considered fish farming as a secondary economic activity and, hence, invested little in terms of time, labor and money. Furthermore, most value chain actors were highly dependent on self-financing even though they have low capital. This made the level of investment of fish farming and business to be low and, hence, low productivity. Opportunities for fish farmers included readily available markets for fish in the villages and nearby towns. For traders opportunities included high demand for Nile tilapia, availability of tenders in hotels and rising income for the majority of the people and increase of the middle class group in the country.

CONCLUSION

- Fish farming contributes significantly to household income of farmers and traders and has a great potential to contribute to food security and poverty reduction among the poor households;
- Nile tilapia (*Oreochromis niloticus*) is preferred to African catfish (*Clarias gariepinus*) by consumers in the markets, and this has resulted in more fish farmers and traders being involved in Nile tilapia business compared to African catfish business;
- Value-chain actors for farmed Nile tilapia include input suppliers (fingerlings and feeds), fish farmers, fish retailers/vendors, wholesalers/distributors, restaurants and fish consumers;
- The proportion of farmed Nile tilapia in the markets is very small, and most fish traders sell wild tilapia; and
- The market for Nile tilapia is readily available in villages, towns and cities, and this provides opportunity for increasing production.

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TABLES

Table 1. Socio-economic characteristics of fish farmers.

Variable	**Region**				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Gender of household head					
Males (%)	90.6	89.3	90.0	91.3	90.3
Females (%)	9.4	10.7	10.0	8.7	9.7
Age of household head (mean ± se)	41.7 ± 1.5	42.0 ±1.7	39.5 ± 1.7	39.1 ± 2.1	40.7 ± 0.9
Marital Status					
Single(%)	0.0	10.7	6.7	13.0	7.1
Married(%)	100	85.7	93.3	87.0	92.0
Divorced(%)	0.0	3.6	0.0	0.0	0.9
Education level					
Adult education(%)	3.1	0.0	13.3	17.4	8.0
Primary school(%)	78.1	85.7	56.7	21.7	62.8
Secondary school(%)	15.6	14.3	23.3	52.2	24.8
University graduate(%)	3.1	0.0	6.7	8.6	4.4
Land ownership					
Own land with title deed (%)	34.4	35.7	76.7	95.5	58.0
Own land under customary law (%)	34.4	14.3	16.7	4.5	18.8
Squatting (%)	31.2	50.0	6.7	0.0	23.2
Fish species cultured					
Nile tilapia	100	100	100	100	100
African catfish	6.2	3.6	43.3	43.5	23.0
Number of ponds (mean ± se)	2.1 ± 0.3	1.8 ± 0.2	2.6 ± 0.5	3.0 ± 1.2	2.3 ± 0.3
Pond size (mean ± se) (m^2)	615.3 ± 114.9	556.3 ± 76.1	683.8 ± 56.5	514.4 ± 45.86	598.3 ± 56.4
Fish farming method					
Monoculture	100.0	100.00	93.3	100.00	98.2
Polyculture	0.0	0.0	6.7	0.0	1.8
Number of years in fish farming					
1 - 2	78.1	78.6	66.7	87.0	77.0
3 - 4	21.9	21.4	26.7	13.0	21.2
5 - 7	0.0	0.0	6.7	0.0	1.8
Proportion of income from fish farming					
≤ 0.25	8.3	13.0	27.6	33.3	20.6
0.26 - 0.5	75.0	56.5	31.0	23.8	46.4
> 0.5	8.3	13.0	10.3	9.5	10.3

Table 2. Sources of inputs for fish farmers.

Variable	Region				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Source of knowledge for fish farming					
Worked on a private fish farm	15.6	25.0	23.3	8.7	18.6
Worked on a government fish farm	9.4	3.6	13.3	0.0	7.1
Attended training	3.1	0.0	3.3	8.7	3.5
Learned from neighbours	81.2	75.0	70.0	87.0	77.9
Advised by Fisheries Extension Officer	25.0	21.4	20.0	8.7	19.5
Read fish farming extension materials	15.6	17.9	30.0	34.8	23.9
Source of funds for fish farming					
Own	100	96.4	90.0	91.3	94.7
Borrowed from friends	6.2	3.6	0.0	0.0	2.7
Borrowed from microfinance institutions	0.0	3.6	6.7	4.3	3.5
Sponsored by government	0.0	7.1	0.0	0.0	1.8
Sponsored by NGOs	0.0	0.0	3.1	0.0	0.9
Source of fingerlings					
Own	21.9	3.6	23.3	17.4	16.8
Government institutions	50.0	50.0	20.0	0.0	31.9
Other fish farmers	28.1	46.4	56.7	82.6	51.3
Source of fertilizers					
Own	64.7	60.9	76.0	85.0	71.8
Government	11.8	0.0	0.0	5.0	3.5
Neighbour farmers	23.5	39.1	24.0	10.0	24.7
Source of feeds					
Own	50.0	40.7	89.7	52.2	58.7
Government	20.0	14.8	0.0	0.0	9.2
Neighbour farmers	30.0	44.4	10.3	47.8	32.1
Source of labour					
Family labour	92.9	100.00	100.00	95.0	97.3
Hired labour	7.1	0.0	0.0	5.0	2.7
Source of water					
Spring	68.8	82.1	70.0	60.9	70.8
Underground	6.2	0.0	23.3	52.2	18.6
River	6.2	3.6	6.7	0.0	4.4
Reservoir/dam	6.2	0.0	16.7	17.4	9.7
Lake	18.8	17.9	0.0	0.0	0.0

Table 3. Nile tilapia yield and marketing system of fish produced by small-scale farmers.

Variable	**Region**				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Fish yield (mean ± se) kg/ha/year)	4,706.5 ± 647.1	5,006.3 ± 756.3	4,088.8 ± 566.7	5,750.0 ± 1130.9	4,928.4 ± 427.4
Proportion of fish consumed at home (%)	37.0 ± 4.6	36.6 ± 4.9	27.9 ± 5.0	24.6 ± 2.7	32.0 ± 2.3
Proportion of fish sold (%)	63.0 ± 7.4	63.4 ± 8.5	72.1 ± 7.2	75.4 ± 6.7	68.0 ± 3.8
Place where fish are sold					
Farm gate (%)	53.1	57.1	73.3	82.6	65.5
Market (%)	9.4	14.3	0.0	0.0	6.2
Distribution point (%)	50.0	50.0	40.0	39.1	45.1
Customer delivery (%)	34.4	25.0	33.3	34.8	31.9
Proportion of fish sold to neighbours (%)	8.0 ± 1.6	7.1 ± 1.8	39.2 ± 6.4	36.1 ± 5.2	21.8 ± 2.5
Proportion of fish sold to distributors (%)	21.1 ± 5.4	28.2 ± 7.0	13.7 ± 5.3	5.65 ± 3.1	17.7 ± 2.8
Proportion of fish sold to restaurants (%)	4.0 ± 1.2	0.8 ± 0.4	12.8 ± 3.1	24.6 ± 5.1	9.7 ± 1.6
Proportion of fish sold to vendors (%)	35.7 ± 6.6	31.8 ± 7.1	17.7 ± 4.1	20.7 ± 4.4	26.9 ± 3.0
Payment method (cash)	100	100	100	100	100
Pricing method					
Market price (%)	76.0	78.3	92.6	95.2	85.4
Cost plus (%)	64.0	43.5	26.9	42.9	44.2
Markup (%)	8.0	4.3	0.0	14.3	6.2
Targeted return (%)	4.0	0.0	0.0	4.8	2.1
Profit maximization (%)	0.0	0.0	0.0	0.0	0.0
Negotiable (%)	100	100	100	100	100
Have contract with customers					
Yes (%)	3.1	17.9	3.3	4.3	7.1
No (%)	96.9	82.1	96.7	95.7	92.9

Table 4. Socio-economic characteristics of fish traders/retailers.

Variable	**Region**			
	Coast	**Dar es Salaam**	**Geita**	**Overall**
Gender				
Males (%)	83.3	100	86.7	89.2
Females (%)	16.7	0.0	13.3	10.8
Marital status				
Single (%)	50.0	80.0	6.7	40.5
Married (%)	50.0	20.0	86.7	56.8
Widow (%)	0.0	0.0	6.7	2.7
Education level				
Primary school (%)	83.3	70.0	66.7	73.0
Secondary school (%)	16.7	30.0	26.7	24.3
Informal education (%)	0.0	0.0	6.7	2.7
Assistance provide to fish suppliers				
Short term financing (%)	0.0	0.0	26.7	10.8
Fish farming information (%)	0.0	0.0	13.3	5.4
None	100	100	60.0	83.3
Suppliers of Nile tilapia				
Fish farmers (%)	16.7	0.0	33.3	18.9
Fishermen (%)	83.3	100	66.7	81.1
Suppliers of African catfish				
Fish farmers (%)	33.3	0.0	40.0	27.0
Fishermen (%)	66.7	100	60	73.0
Contractual arrangement with suppliers				
Yes (%)	16.7	0.0	26.7	16.2
No (%)	83.3	100	73.3	83.8
Contribution of fish business to household income				
0 - 20 (%)	0.0	0.0	13.3	5.4
21 - 40 (%)	33.3	0.0	6.7	13.5
41 - 60 (%)	8.3	60.0	6.7	21.6
61 - 80 (%)	0.0	20.0	0.0	5.4
81 - 100 (%)	58.3	20.0	73.3	54.1
Customers for fish sold				
Consumers (%)	100	80.0	80.0	86.5
Wholesalers/processors (%)	58.3	60.0	86.7	70.3
Contractual arrangement with customers				
Yes (%)	0	0	33.3	13.5
No (%)	100	100	66.7	86.5
Assistance received				
Short term financing from NGOs (%)	0.0	0.0	6.7	2.7
Short term financing from Banks (%)	0.0	0.0	6.7	2.7
Short term financing from microfinance (%)	0.0	0.0	33.3	13.5

Table 5. Value addition activities and marketing practices done by fish retailers/traders.

Variable	**Region**			
	Coast	**Dar es Salaam**	**Geita**	**Overall**
What attracts customers				
Good fish quality (%)	83.3	40.0	60.0	62.2
Low price of fish (%)	25.0	0.0	66.7	35.1
Convenience of the place (%)	25.0	0.0	0.0	8.1
Habit of customer (%)	50.0	30.0	0.0	27.0
Value addition method				
Cleaning (%)	100	100	100	100
Dressing (%)	25.0	0.0	40.0	24.3
Smoking (%)	8.3	20.0	0.0	8.1
Frying (%)	8.3	0	0	2.7
Drying (%)	33.3	0	0	10.8
Packing (%)	8.3	0	13.3	8.1
Price determination mechanism				
Market price (%)	58.3	100	86.7	81.1
Cost plus (%)	33.3	40.0	73.3	51.4
Targeted return (%)	8.3	20.0	13.3	13.5
Profit maximization (%)	0.0	0.0	0.0	0.0
Break even analysis (%)	0.0	0.0	0.0	0.0
Negotiable (%)	0.0	0.0	0.0	0.0
Main competitors				
Other fish traders (%)	83.3	60.0	100	83.3
Wholesalers (%)	16.7	20.0	0.0	10.8
None (%)	0.0	20.0	0.0	5.4

Table 6. Socio-economic characteristics and marketing practices of fish distributors/wholesalers.

Variable	Region			
	Mwanza	**Dar es Salaam**	**Coast**	**Overall**
Gender				
Males (%)	16.7	100	100	68.8
Females (%)	83.3	0.0	0.0	31.3
Age (mean ± se)	39.6 ± 3.5	35.0 ± 10.0	47.0 ± 0.0	39.4 ± 3.1
Marital status				
Single (%)	0.0	50.0	0.0	18.8
Married (%)	66.7	50.0	100	68.8
Divorced (%)	33.3	0.0	0.0	12.5
Highest education level				
Primary school (%)	83.3	0.0	0.0	31.3
Secondary school (%)	16.7	0.0	0.0	6.3
University (%)	0.0	0.0	0.0	0.0
Adult education (%)	0.0	100	100	62.5
Fish species sold				
Nile tilapia (%)	100	100	100	100
Source of fish sold				
Fish farmers (%)	16.7	100	0.0	43.8
Fish traders (%)	83.3	0.0	100	56.3
Customers				
Fish traders/retailers (%)	100	50.0	100	81.3
Consumers (%)	0.0	50.0	0.0	18.8
Services received				
Short term financing from microfinance institution (%)	66.7	0.0	0.0	25.0
Loan from banks (%)	0.0	50.0	0.0	18.8
None (%)	33.3	50.0	100.0	56.3
Contractual arrangement with customers				
Yes (%)	33.3	0.0	0.0	12.5
No (%)	66.7	100.0	100	87.5
Nature of payment (cash) (%)	100	100	100	100
Price determination mechanism				
Market price (%)	100	100	100	100
Cost plus (%)	16.7	100	100	68.8
Markup (%)	0.0	0.0	0.0	0.0
Targeted return (%)	0.0	0.0	0.0	0.0
Profit maximization(%)	0.0	0.0	0.0	0.0
Break even analysis (%)	0.0	0.0	0.0	0.0
Negotiable (%)	0.0	0.0	0.0	0.0

Table 7. Socio-economic characteristics and marketing practices of restaurants owners.

Variable	Region				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Gender					
Males (%)	50.0	71.4	60.0	80.0	63.4
Females (%)	50.0	26.6	40.0	20.0	36.6
Age of household head (mean ± se)	37.1 ± 1.9	35.9 ± 3.1	32.9 ± 2.8	35.3 ± 2.6	35.4 ± 1.2
Marital Status					
Single (%)	14.3	28.6	40.0	30.0	26.8
Married (%)	85.7	71.4	50.0	70.0	70.7
Divorced (%)	0.0	0.0	10.0	0.0	2.4
Education level					
Adult education (%)	14.3	0.0	10.0	30.0	14.6
Primary school (%)	35.7	28.6	40.0	30.0	34.1
Secondary school (%)	42.9	71.4	50.0	40.0	48.8
University graduate (%)	7.1	0.0	0.0	0.0	2.4
Fish species sold					
Nile tilapia (%)	100	100	100	100	100
Type of fish sold					
Wild caught fish (%)	100	85.7	90.0	100.0	95.1
Farmed fish (%)	0.0	0.0	0.0	0.0	0.0
Both	0.0	14.3	10.0	0.0	4.9
Suppliers of fish					
Fish farmers (%)	14.3	14.3	22.2	0.0	12.5
Fish traders (%)	85.7	85.7	55.6	80.0	77.5
Fish shop/cold store (%)	0.0	0.0	22.2	20.0	10.0
Contract with fish suppliers					
Yes (%)	42.9	14.3	0.0	0.0	17.9
No (%)	57.1	85.7	100	100	82.1
Type of value addition					
Cleaning (%)	78.6	85.7	60.0	60.0	70.7
Dressing (%)	42.9	28.6	30.0	20.0	31.7
Smoking (%)	0.0	0.0	10.0	10.0	4.9
Frying (%)	100	100	100	100	100
Drying (%)	28.6	14.3	10.0	40.0	24.4
Cutting (%)	35.7	0.0	0.0	30.0	19.5
Packaging (%)	21.4	14.3	0.0	0.0	9.8
Things which attract customers					
Good fish quality (%)	78.6	100	100	80.0	87.8
Low price (%)	14.3	14.3	0.0	0.0	7.3
Convenience (%)	28.6	14.3	40.0	40.0	31.7
Habit (%)	35.7	57.1	50.0	50.0	46.3
Price determination mechanism					
Market price (%)	57.1	71.1	70.0	70.0	65.9
Cost plus (%)	64.3	85.7	60.0	6.0	65.9
Markup (%)	21.4	0.0	10.0	30.0	17.1
Targeted return (%)	0.0	0.0	0.0	0.0	0.0
Profit maximization (%)	28.6	14.3	0.0	0.0	12.2
Negotiable (%)	0.0	14.3	0.0	0.0	2.4

Table 8. Problems faced by small-scale fish farmers.

Variable	Region				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Shortage of water (%)	21.9	25.0	53.3	73.9	41.6
Lack of fingerlings (%)	25.0	14.3	20.0	4.3	16.8
Lack of fertilizers (%)	15.6	10.7	13.3	13.0	13.3
Shortage of feeds (%)	31.2	25.0	26.7	21.7	26.5
High cost of inputs (%)	31.2	28.6	50.0	47.8	38.9
Low price of fish (%)	15.6	28.6	30.0	17.4	23.0
Slow growth of cultured fish (%)	15.6	39.3	13.3	21.7	22.1
Lack of knowledge on fish farming (%)	50.0	50.0	20.0	17.4	35.4
Theft (%)	9.4	0.0	23.3	8.7	10.6

Table 9. Problems faced and opportunities for fish traders.

Variable	Region			
	Coast	**Dar es Salaam**	**Geita**	**Overall**
Constraints for fish retailers				
Lack of transport (%)	0.0	0.0	20.0	8.1
Low capital (%)	50.0	20.0	13.3	27.0
Inappropriate policies/regulations (%)	16.7	0.0	6.7	8.1
Lack of appropriate infrastructure (%)	25.0	80.0	26.7	40.5
Inadequate fish supply (%)	8.3	0.0	26.7	13.5
Lack of knowledge on fish farming (%)	0.0	0.0	6.7	2.7
Problems faced by distributors/wholesalers				
Late delivery of fish (%)	33.3	0.0	100	37.5
Inadequate fish supply (%)	33.3	50.0	0.0	31.3
Buying spoiled fish (%)	16.7	50.0	0.0	25.0
Opportunities for fish traders				
Availability of tender in hotels (%)	41.7	40.0	20.0	32.4
Export market (%)	41.7	0.0	6.7	16.2
New traders (%)	0.0	20.0	6.7	8.1
Increase in capital (%)	58.3	50.0	13.3	37.8
Improvement in markets (%)	83.3	100	26.7	64.9

Table 10. Problems and opportunities of restaurants.

Variable	Region				
	Geita	**Mwanza**	**Coast**	**Dar es Salaam**	**Overall**
Problems					
Fish scarcity	28.6	28.6	40.0	20.0	29.3
Shortage of power	7.1	14.3	0.0	10.0	7.3
High price of fish	7.1	28.6	0.0	0.0	7.3
Buying spoiled fish	14.3	0.0	20.0	20.0	14.6
Low capital	21.4	14.3	10.0	10.0	14.6
Shortage of customers	7.1	14.3	0.0	10.0	7.3

Household Fish Ponds in Nepal: Their Impact on Fish Consumption and Health of Women and Children

Marketing, Economic, Risk Assessment, and Trade/Study/13MER06UM

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Abstract

This study focused on the value of household ponds by comparing fish consumption and indicators of health for children and women in households with fishponds to those without access to ponds. Specific objectives of the study were to determine the frequency and amounts of fish eaten by children ages 1-5, as well as women, from households with or without fish ponds; and to evaluate the health characteristics of children from households with or without fish ponds. In Kathar, Chitwan and Kawasoti, Nawalparasi, 51 and 55 households, respectively, each including children between the ages of one and five years and owning at least one fish pond were recruited for participation through door-to-door visits. Similarly, in Majhui, Chitwan and Pragatinagaar, Nawalparasi, 54 and 55 households, respectively, each including children between the ages of one and five years and not owning fish ponds were recruited.

Mothers from locations that had access to fish ponds consumed 132% more fish than those without ponds, a significant increase in consumption. They also reported 126% higher rates of fish consumption by their children. Owners of household ponds also consumed fish more frequently, particularly Small Indigenous Species (SIS) (97% more frequently in households with ponds). However, height at weight regressions and body mass index data were not significantly different between children from households with or without ponds. Health of children evaluated using details on stunting and wasting indicated that there were no significant differences between households with or without ponds. Overall, children from our study groups averaged 19% underweight, 18% stunted, and 12% wasted. These values are quite low compared to 2013 estimates for the entire country for stunted (40.5%) and underweight (28.8%), but not for wasted (10.9%) children.

Introduction

The government of Nepal has recognized that chronic malnutrition is a major problem in the country. The most common forms of malnutrition include undernutrition (insufficient energy) and deficiencies of vitamins and minerals, including vitamin A, iodine, and iron. About 41% of children less than five years of age are stunted (below two standard deviations of median height for age; UNICEF 2012a), and 48% are anemic (MoHP 2006). Also, 36% of women, aged 15-49 are anemic (MoHP 2006). Realizing this, the government of Nepal signed the Declaration of Commitment for Accelerated Improvement in Maternal and Child Nutrition and launched the Multi-sectoral Nutrition Plan (MSNP) on 17 September 2012 (UNICEF 2012b). Much of our research and outreach in Nepal has focused on providing fish culture alternatives to improve the nutrition and health of poor farmers, but we have not yet done much to assess the success of increased fish production on human health.

Fish has been recognized as a nutritionally beneficial food source around the world. Fish provide high-quality protein and important micronutrients, such as vitamin A, vitamin D, and iodine, and they can also be a source of phosphorus, fluoride, and calcium if bones are consumed (Speedy 2003). Additionally, the benefits of consuming fish for Omega-3 fatty acids have recently been widely documented (Oken and

Belfort 2010, Mahaffey et al. 2011). While certain fishes can provide all of these health benefits, there currently exists a difference in the perceived nutritional gains in developed versus developing countries: in the former, individuals, the media, and researchers are primarily concerned with omega-3 fatty acids (Domingo et al. 2007, Oken and Belfort 2010), while in the latter, the primary concerns are protein and micronutrients (Aiga et al. 2009, Parajuli et al. 2012). In Nepal, the benefits of fish consumption have been linked with such outcomes as improving protein intake (Bhujel et al. 2008) and increasing vitamin A and zinc ingestion (Parajuli et al. 2012). Approximately half of all fish produced in Nepal during 1994-95 was done so through aquaculture (FAO 2012). It is believed that the majority of fish currently consumed in Nepal is produced through aquaculture practices, since nearly all fish sold in markets in Kathmandu and surrounding areas are raised in ponds.

During summer 2012, we conducted our first study on the influence of household ponds on the health and nutrition of children in the household (Stepan 2013). This study focused on small household ponds in Kathar and Kawasowoti, with a control population in Bhandara. The concept of small household ponds was originally extended to local residents to improve the nutrition of poor families in Nepal. These ponds have been deemed so successful by local residents that the number of ponds has increased from approximately 100 in the early stages to over 1,000, with the additional ponds built by local owner groups. All of the adopting communities are in the Terai region and are comprised mainly of Tharu people. The earlier study showed that children from homes with household ponds consumed about five times more fish than children in households without ponds. While it was clear fish consumption did increase dramatically in households with ponds, it was less clear this consumption resulted in increases in the height at age or weight at age for children from those households, or in the health of mothers or pregnant women. This was due in part to problems with the timing and intensity of our sampling; in addition, it was affected by the similar socioeconomic status of all participants. However, the survey did help us detect some consistent patterns and design better surveys for the future. One purpose of this study is to conduct such an expanded survey.

One issue related to the expected health improvements from people eating fish would be what other sources of protein are available to them. Most Nepalese families eat a largely vegetarian diet, focused on rice and some vegetables, with fish or meat added when available (Stepan 2013). The Terai region of Nepal is its main agricultural area, with much production of rice, as well as some livestock. Health improvements might not be measureable if households without ponds eat meat instead of fish. Our earlier survey had some flaws, mostly in the timing of sampling (in summer, eight months since the last fish harvest), as well as in finding sufficient families with young children (under age 5) whose growth trajectories would be reflected by recent consumption history. It was our intent in this study to improve on these limitations by also measuring the amount of meat consumption and by sampling more families to include adequate numbers of children under age 5.

Women play an integral role in the aquaculture and fisheries sectors throughout the world. Even though women's roles and responsibilities are changing in some countries, there are constraints that limit female participation in aquaculture (Egna et. al. 2012). A few such constraints women face in aquaculture and fisheries are: time availability and allocation, land ownership, and access to water, credit, training, and labor. Lack of training opportunities can trap women in vulnerable and poorly paid positions with no prospects of advancement (FAO 1998). However, the situation in Nepal with household ponds differs considerably from this norm. In most of the poorer Nepalese households, women tend and manage gardens and ponds, while men seek work at outside locations (Bhujel et al. 2008). Therefore, household ponds enhance the income, nutrition, and status of women and provide them with alternatives for their families.

OBJECTIVES

This study is intended to focus on the value of household ponds by comparing fish consumption and indicators of health for children and women in households with fish ponds to those without access to ponds. Specific objectives of the study were:

- To determine the frequency and amounts of fish eaten by children ages one through five, as well as women, from households with or without fish ponds; and
- To evaluate the health characteristics of children from households with or without fish ponds.

MATERIALS AND METHODS

A total of 13 undergraduate students from the Agriculture and Forestry University, Nepal were involved in survey work. The surveyors were trained on the methods of data collection and height/weight measurement before implementation. Survey protocols were submitted to the University of Michigan and received Institutional Review Board approval (HUM00093052).

A list of participating households was determined with the help of local village leaders, who also guided surveyors to the homes during the surveys. Before surveying, an informal meeting was organized with the local village leaders to discuss the purpose and methodology of the survey. They informed participating households and determined a suitable survey date and time.

In Kathar, Chitwan and Kawasoti, Nawalparasi, 51 and 55 households, respectively, each including children between the ages of one and five years and owning at least one fish pond were recruited for participation through door-to-door visits. Similarly, in Majhui, Chitwan and Pragatinagaar, Nawalparasi, 54 and 55 households, respectively, each including children between the ages of one and five years and not owning fish ponds were recruited for participation through door-to door-visits.

After obtaining informed consent, mothers — the traditional care-givers and food preparers in Nepali culture — were specifically targeted to respond to survey questions. Interviews were conducted in the local language with the aid of a skilled Tharu/Nepali translator and cultural "broker," whose duties included ensuring that cultural sensitivities were considered at all times. In order to compensate survey respondents for their time, each family that participated was given US$5. All data for this study were collected from 10 October to 10 November 2015.

Questions were asked regarding fish pond information, age, sex, duration of breastfeeding, introduction of first complementary food, history of child illness, socioeconomic, parental education level, number of children in the household, and regular dietary intake (Appendix 1).

Child measurement data were collected immediately following the interviews. In cases when children were not available, return visits were made to the household on the same day. For weights, a digital balance was used. The balance was carried from house to house and was placed on a hard, level surface. Children were weighed individually. Parents were asked to remove their children's shoes and any heavy clothing before weighing. If a child was incapable of standing on the balance, the child's mother was asked to stand on the balance while holding the child. She was then weighed without the child, and the child's weight was determined by subtraction. A child's height was determined by a portable measuring scale. The parent was asked to remove the child's shoes, bring the child to the plane surface near a straight wall, and to kneel in front so the child remained comfortable and cooperative. A total of 225 children were weighed and measured. Stunting in children was estimated by comparing height at age with countrywide values, and a child was considered stunted if their height was more than two standard deviations below the country median (UNICEF 2015). Underweight values were determined similarly, except using values of weight at age. Wasting in children was estimated by comparing weight at height with countrywide values, and a child was considered stunted if the value was more than two standard deviations below the country median. We determined the number of wasted, underweight, and stunted children in each of our populations and compared those using Chi-square tests.

RESULTS AND DISCUSSION

Mothers from locations that had access to fish ponds consumed 132% more fish than those without ponds, a significant increase in consumption (Figure 1, $p<0.05$). They also reported significantly higher rates of fish consumption (126% higher) by their children (Figure 2, $p<0.05$). They also consumed fish more frequently (Figures 3 and 4), particularly SIS. Again, these differences were also statistically significant, with overall consumption frequency being 97% higher in households with ponds. However, height at weight regressions and body mass index data were not significantly different between children from households with or without ponds.

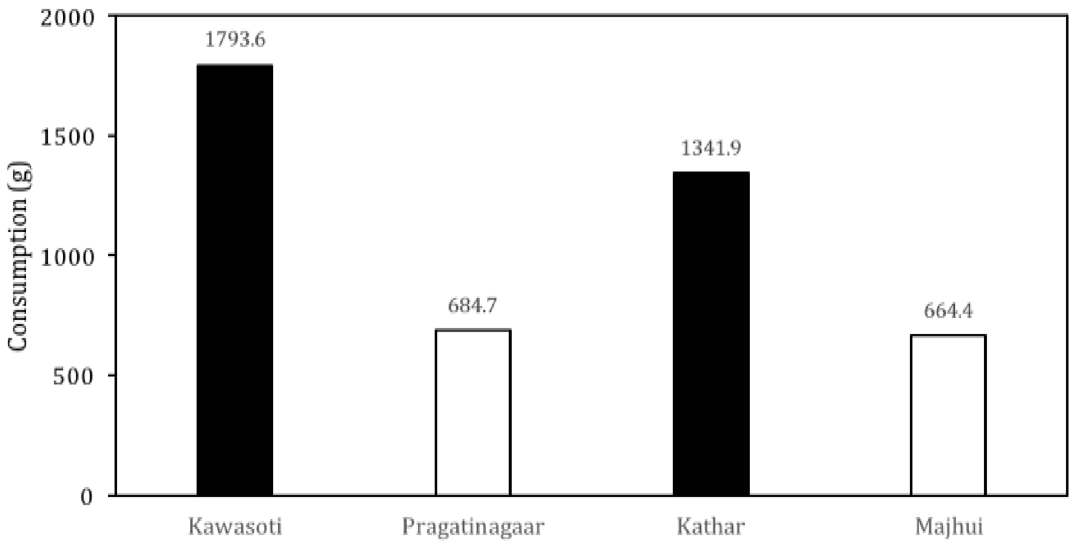

Figure 1. Monthly estimates of fish consumption by mothers interviewed from households with ponds (solid bars) and without ponds (open bars) in four locations in Nepal.

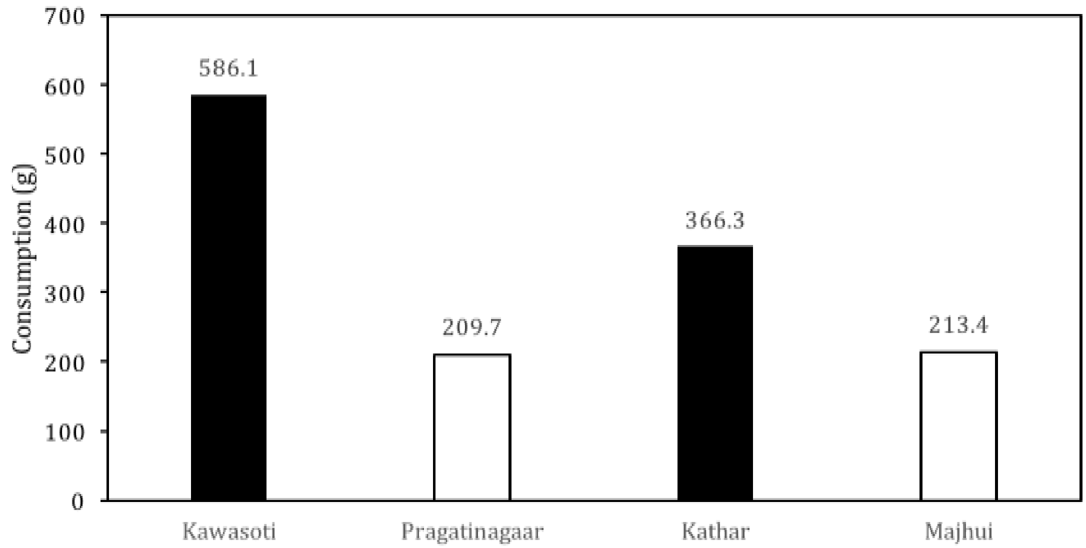

Figure 2. Monthly consumption estimates by children estimated for households with or without ponds.

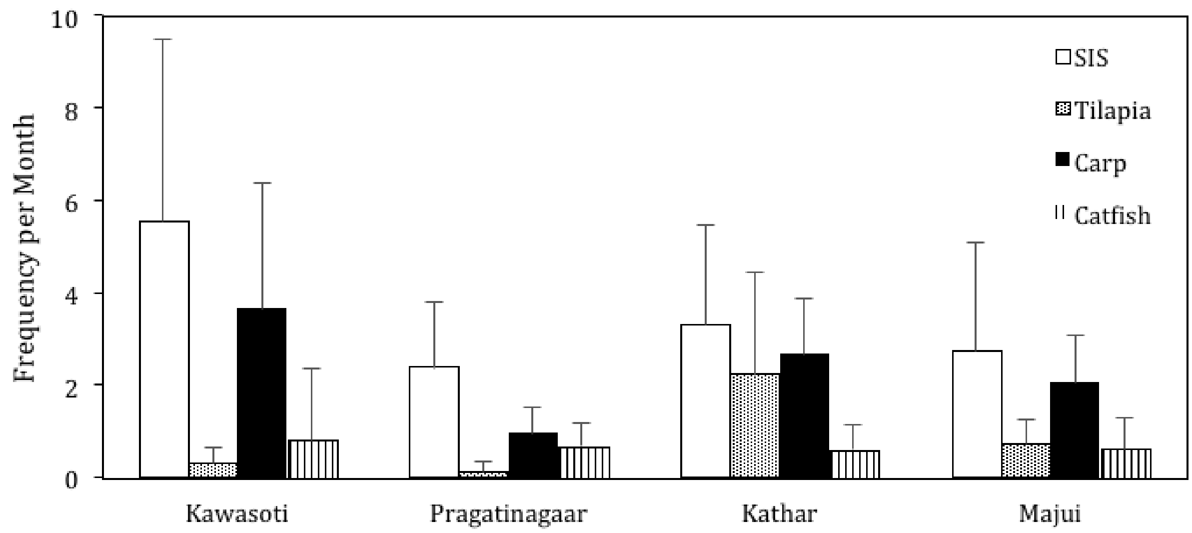

Figure 3. Reported frequencies (mean ± SE) of mothers consuming fish from four species groups for households with or without ponds.

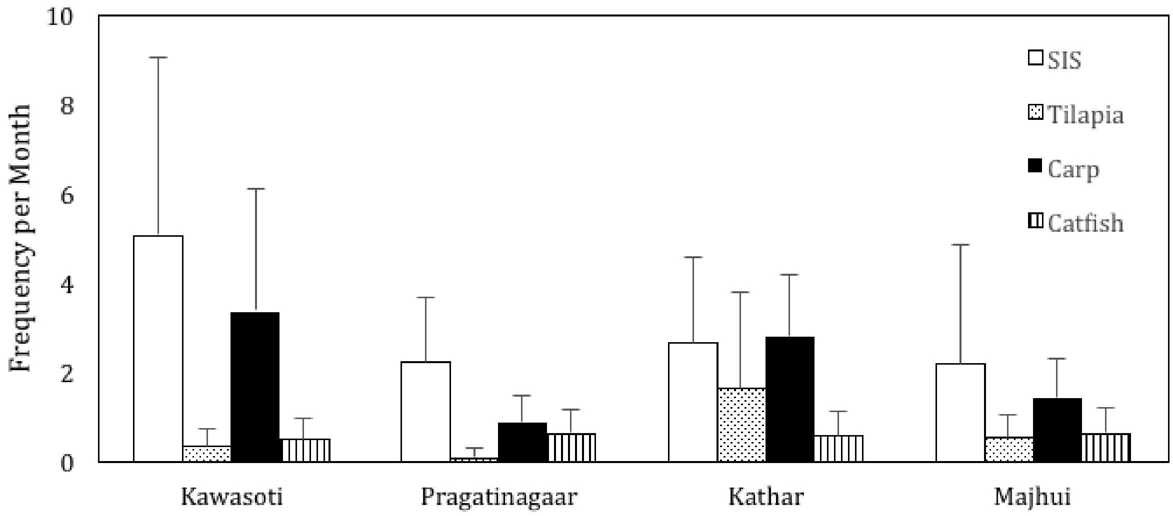

Figure 4. Reported frequencies (mean ± SE) of children consuming fish from four species groups for households with or without ponds.

Health of children evaluated, using details on stunting and wasting, indicated that there were no significant differences between households with or without ponds (Chi-square, $p>0.05$; Table 1). Overall, children from our study groups averaged 19% underweight, 18% stunted, and 12% wasted. These values are quite low compared to 2013 estimates for the entire country for stunted (40.5%) and underweight (28.8%), but not for wasted (10.9%) children (UNICEF 2015).

Table 1. Frequency and overall percentage for children under five in the study populations that were stunted, underweight, and wasted.

	Underweight	Stunted	Wasted
Kawasoti	26.7% (16/60)	20% (12/60)	16.9% (10/59)
Kathar	19.6% (10/51)	21.6% (11/51)	8.3% (4/48)
Total	**23.4% (26/111)**	**20.7% (23/111)**	**13.1% (14/107)**
Pragatinagaar	12.7% (7/55)	20.7% (12/58)	3.5% (2/57)
Majhui	16.4% (9/55)	12.7% (7/55)	20% (11/55)
Total	**14.5% (16/110)**	**16.8% (19/113)**	**11.6% (13/112)**

CONCLUSIONS

Overall, women and children from households with ponds ate more mass of fish and ate fish more frequently than comparable groups from households without ponds. However, the overall health of children from these homes did not differ among study group, but in general was considerably better than health based on country-wide statistics.

QUANTIFIED ANTICIPATED BENEFITS

This study provides a robust database on the nutrition of children in rural Nepal families and the role of fish consumption in their health. We surveyed 225 families, and, as a result, all of these families gained a better understanding of nutrition and the role of protein in the health of their children. Families with household ponds ate 130% more fish than people from households without ponds. The results of this survey help inform aquaculture extension programs in the country, as they clearly indicate that ownership of small household ponds is truly aiding in the nutrition of these families, and is growing in the country.

ACKNOWLEDGMENTS

Surveys were conducted by 13 undergraduate students, and we acknowledge the help of Anjana Khanal, Anusha Lamichhane, Bhuwan Devkota, Sarita Neupane, Kiran Khadka, Manish Devkota, Nita Dhakal, Pratikshya Neupane, Sajani Thapa, Sandesh Khanal, Santosh Lamichhane, Subodh Pokhrel, and Sujata Timalsina. Six local village leaders assisted in gaining acceptance for the surveys, and we thank Renuka Choudhary, Shanti Choudhary, Ishori Singh Mahato, Kabita Mahato, Bisram Mahato, Sita Tamang, Indra Thanet, and Shiva Adhikari for their assistance.

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APPENDIX

Questions asked in the fish consumption survey. Questions were translated into Nepali and asked by a trained surveyor with knowledge of local dialects.

Pond Production Assessment

Do you own or manage a fish pond? _____ (if no, skip to fish consumption questions)
What is the size of your pond? _________
Where do you get fish to stock your pond? ____________________________________
Do you feed fish in your ponds? _______
    How often? ____
    With what? ____
What do you do with the fish you grow? (enter percentage of those that apply)
    Sell ____   Trade ____   Give away ____   Eat in household ____
If you sell fish, who manages the sale? (check all that apply)
    Myself ____   A fish purveyor ____   A community market ____
How much money does your family make a year from aquaculture? ___________

Maternal Fish Consumption

Do you eat fish?
How do you get the fish you eat? (check all that apply)
Our own pond____   Community pond____   Buy or trade____   Do not eat fish____
When you eat meat or fish, estimate the average portion size for fish you eat at typical meals.
__ 25 g __ 50 g __ 75 g __ 100 g __ 200 g __ 300 g __ 400 g
Note: One portion = 100 g of grilled fish = the size of a deck of cards; two portions = a regular 200 g can of tuna.

During a month, how many meals did you eat the following?

Fish spp.	Never	Once	2–3 times	1 time/ week	2 times/ week	3–4times/ week	5–6 times/ week	Once/ day	Twice or more/day
SIS									
Tilapia									
Carp									
Catfish									
Mutton/ Buff									
Pork									
Chicken									

Socioeconomic Status

How much money does your family make in one month? __________

Does your household have: (Y/N)

Electricity ____ a radio ____ a television ____ a mobile telephone ____

A nonmobile telephone____ a refrigerator____ a table ____

A chair ____ a bed ____ a sofa____ a cupboard ____ a computer____

A clock ____ a fan _____ a dhiki/janto _____

In the past 12 months, did you worry that your household would not have enough food?

Often _________ Seldom _________ Never __________

Educational Status

What was the last grade level completed in school?

Mother _________ Father __________

Child Dietary Considerations

Yesterday, during the day or at night, did your child eat or drink any of the following: (Y/N/DK)

Plain water ____ Juice or juice drinks ____ Soup ____

Milk ___ (if yes, how many times?) ____ Infant formula, like Lactogen ___ (if yes, how many times?) ___

Any other liquids ____ Yogurt ____ (if yes, how many times?) ____

Any fortified baby food, like Cerelac, Nestrum, Champion, etc. ____

Roti, rice, maize, millet, noodles, porridge, or other foods made from grains ____

Pumpkin, carrots, squash, or sweet potatoes that are yellow or orange inside ____

White potatoes, white yams, colocasia, or any other foods made from roots ____

Any dark green leafy vegetables, like spinach, amaranth leaves, mustard leaves ____

Ripe mangoes, papayas, bananas, or others ____

Any other fruits or vegetables ____

Liver, kidney, heart, or other organ meats ____

Any meat, such as pork, buff, lamb, goat, chicken, or duck ____

Eggs ____

Fresh or dried fish or shellfish ____

Any foods made from beans, peas, lentils, or nuts ____

Cheese or other food made from milk ____

Any other solid, semi-solid, or soft food (jaulo, lito, sarbottam pitho, etc.) ___

Does your child eat fish?

Often ____ Seldom____ Never____

At what age did your child first eat fish? _____
When your child eats fish, estimate the average portion size of fish he/she typically eats. ______
Note: One portion = 100 g of grilled fish = the size of a deck of cards; two portions = a regular 200 g can of tuna.

During a month, how many meals did your child eat the following fish?
__ 25 g __ 50 g __ 75 g __ 100 g __ 200 g __ 300 g __ 400 g

Fish spp.	Never	Once	2-3 times	1 time/ week	2 times/ week	3-4times/ week	5-6 times/ week	Once/ day	Twice or more/day
SIS									
Tilapia									
Carp									
Catfish									
Mutton/ Buff									
Pork									
Chicken									

Child Health
Did you breastfeed your child? __________
How long was your child breastfed? ___________
At what age was your child first fed complementary food? ___________
Has your child had a diarrhea related illness within the past two weeks? _________
Has your child had a respiratory illness within the past two weeks? __________
How many times do you take your child to the hospital in a year? ______
How much money do you spend for your child’s medical treatment in a year? ________
How many children do you have? _________

Measurement Data

ID #___________	**ID #___________**	**ID #___________**
Age ___________	**Age ___________**	**Age ___________**
Sex ___________	**Sex ___________**	**Sex ___________**
Ht___________ (cm)	**Ht___________ (cm)**	**Ht___________ (cm)**
Wt___________ (kg)	**Wt___________ (kg)**	**Wt___________ (kg)**

Household Fish Ponds in Nepal: Their Constraints Determined by Value Chain Analysis

Marketing, Economic, Risk Assessment, and Trade/Study/13MER06UM

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ABSTRACT

Household ponds enhance the income, nutrition, and status of women and provide them with alternatives for their families. This study focused on the value of household ponds by completing a value chain analysis of household ponds by determining sources of fish grown in ponds, as well as their use in the household and market. Specific objectives of the study were to conduct an analysis of household pond production, harvesting, processing, distribution, markets, and sales in Southern Nepal; and to organize data into a value chain diagram and to use the diagram to draw insight on possible improvements in the aquaculture sector. We surveyed 100 households that included household ponds for fish consumption and use. Our household surveys evaluated the production details (source of fry, end use of fish) for household pond owners as part of the VCA. Once we identified likely sources or markets for fish produced in household ponds, we surveyed those participants as well to complete the value chain details. Value chain mapping was then done with data collected on uses and sources. All fish farmers interviewed did not intentionally stock their ponds with SIS, but allowed fish to colonize from canal waters. All farmers interviewed reported harvesting small indigenous species (SIS), and they were all aware of their higher nutritional content and market price compared to carp. Farmers reported harvesting between 4–12 kg of SIS/yr. When corrected to SIS/ha, this would equal approximately 180–800 kg. SIS are not often sold in markets but consumed at home. When they are sold, however, prices are higher/kg than that for carp; US$4/kg compared to carp at USD $2.00-$3.60. All farmers interviewed reported selling their carp for Rs 200 (US$2). Among Household Farmers, 77% of all fish produced was consumed by the farmer and the farmer's family, while the remaining 23% was sold to neighboring households. Farmers occasionally sold fish to sales agents on bicycles and did not have information regarding the location of the ultimate sale of fish purchased by individuals on bicycles, but unanimously reported that all such transactions resulted in sales at the local market.

INTRODUCTION

Although aquaculture has been practiced in Asia for thousands of years (FAO 2012), it is fairly new in Nepal. It was not until the 1940s that the country began raising fish, and an additional 40 years passed before any significant progress was made in the field (FAO 2012). Considering Nepal's late start in aquaculture practices, it is no surprise the country is yet to contribute substantially to the huge volume of Asian aquaculture production (Asia produced 92.5% of the world's total aquaculture in 2008) or benefit largely from the economic improvements aquaculture has created. However, Nepal has recently shown a marked increase in aquaculture production (Figure 1). Carp polyculture has been developed as the most popular system in the country, and we have completed a value chain analysis (VCA) of this system (Stepan et al. 2013), so our next evaluation was a study of small indigenous species (SIS) in household ponds. These ponds function mainly for family consumption rather than sales, but the end use of the fish produced, as well as the methods for fingerling acquisition and other transfers of fish, have not been studied. Household ponds are very small scale, using carps, small indigenous species, and local inputs for fertilizer and fodder. They also do not exchange water, so they represent an environmentally friendly form of aquaculture to be extended.

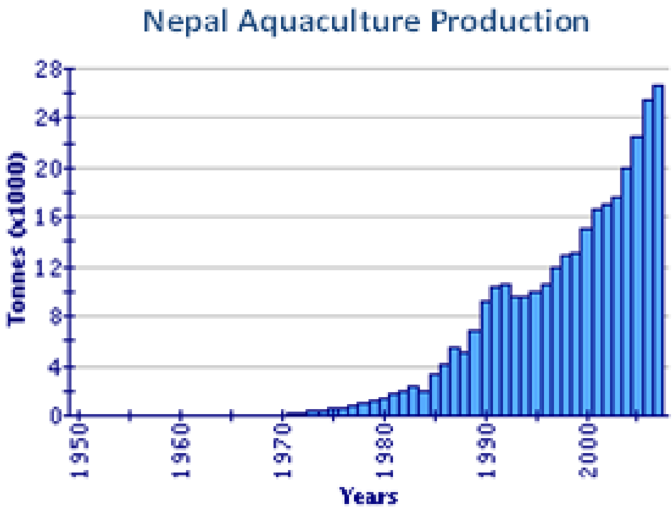

Figure 1. Reported aquaculture production in Nepal since 1950. Figure copied from FAO.org.

The general concept of a value chain is to link all steps of production, processing, and distribution of a product together and then to analyze each step as it relates to those that precede and follow it. In doing so, the value chain describes all of the activities responsible for bringing a product from creation to ultimate disposal (Hempel 2010). Given the early stages of aquaculture development in Nepal, a value chain would be best applied to evaluating limitations in the potential growth of the sector. Taking this into consideration, the following topics have been highlighted as research areas:

- Fingerling production – Is there adequate fingerling production to accommodate the demand for SIS in Nepal? Are fingerlings wild caught?
- Seasonality – Rural lowland communities in Nepal are able to raise carp only in the monsoon season when water is plentiful. How does this restraint affect SIS production?
- Transportation – How far can fish be safely transported?
- Market concerns – What is the nature of the demand for SIS in Nepal?

Women play an integral role in the aquaculture and fisheries sectors all over the world. Even though women's roles and responsibilities are changing in some countries, there are constraints that limit female participation in aquaculture (Egna et al. 2012). Some constraints women face in aquaculture and fisheries are: time availability and allocation, land ownership, and access to water, credit, training, and labor. Lack of training opportunities can trap women in vulnerable and poorly paid positions with no prospects of advancement (FAO 1998). However, the situation with household ponds in Nepal differs considerably from this norm. In most of the poorer Nepalese households, women tend and manage gardens and ponds, while men seek work at outside locations (Bhujel et al. 2008). Household ponds enhance the income, nutrition, and status of women and provide them with alternatives for their families. This study focused on the value of household ponds by completing a value chain analysis of household ponds.

OBJECTIVES

This study focused on the value of household ponds by determining sources of fish grown in ponds, as well as their use in the household and market. Specific objectives of the study were:

- To conduct an analysis of household pond production, harvesting, processing, distribution, markets, and sales in Southern Nepal; and
- To organize data into a value chain diagram and to use the diagram to draw insight on possible improvements in the aquaculture sector.

MATERIALS AND METHODS

We surveyed 100 households that included household ponds for fish consumption and use during our nutrition study. Our household surveys evaluated the production details (source of fry, end use of fish) for household pond owners as part of the VCA. Once we identified likely sources or markets for fish produced in household ponds, we surveyed those participants as well to complete the value chain details. Value chain mapping was then done with data collected on uses and sources. Following the previous steps, opportunities for improvement and specific constraints of the household pond value chain were determined.

Information was also gathered by interviewing three individual farmers, the Kathar Women's Aquaculture Cooperative, a private hatchery, a government hatchery, and a vendor at a local fish market in Bharatpur, Chitwan. Questions included SIS prevalence and interest, carp and SIS market price and production, sources of aquaculture information and training, fish production, and pond preparation costs including purchase of fingerlings, feed, and fertilizer. For Value chain mapping, percentages of marketable fish moved (consumed, sold, etc.) by farmers were determined by averaging the responses given by each farmer regarding the flow of products. Percentages of the movement of fingerlings from hatcheries or collection businesses could not be determined because SIS were seldom stocked in ponds, they simply occurred there from natural colonization.

RESULTS AND DISCUSSION

Figure 2 summarizes the value chain derived from our interviews. All fish farmers interviewed did not intentionally stock their ponds with SIS, but allowed fish to colonize from canal waters.

All farmers interviewed reported harvesting SIS, although they did not purposely stock them and they were all aware of their higher nutritional content and market price compared to carp. SIS entered farmer ponds naturally, and farmers reported harvesting between 4–12 kg of SIS/yr. When corrected to SIS/ha, this would equal approximately 180–800 kg. SIS are not often sold in markets but consumed at home. When they are sold, however, prices are higher/kg than that for carp; US$4/kg compared to carp at US$2–$3.60. All farmers interviewed reported selling their carp for Rs 200 (US$2).

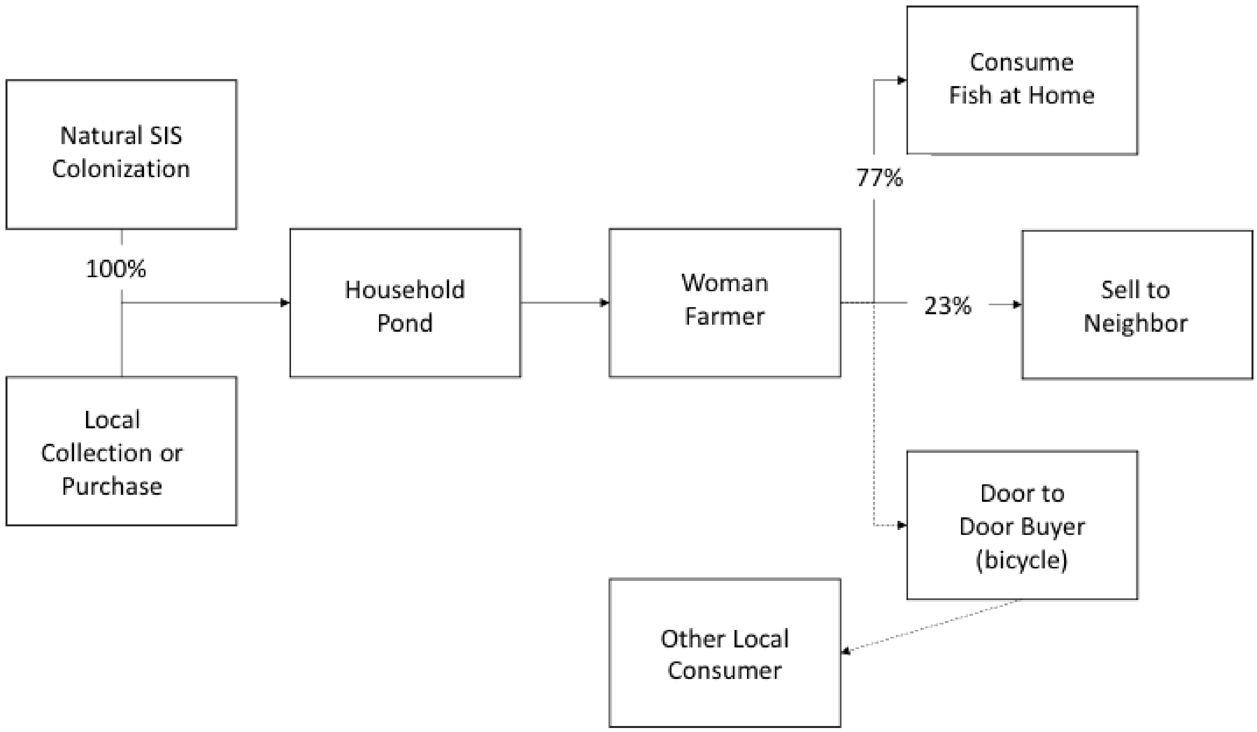

Figure 2. Value chain map of carp-SIS household pond systems in Nepal. Dashed lines represent activities known to occur for which data was not obtained. Dashed lines represent market flows still not measured.

Motivation for household farmers choosing to partake in pond aquaculture include non-monetary incentives, such as increasing nutritional well-being for themselves and their families and being able to provide protein for visiting family members and other guests. Indeed, most fish were consumed at home with a reported sale of only 15%–30% of harvest by weight, giving a realized average net profit of $620.61 to $1,241.22 per ha annually, but a large increase in household fish consumption. Findings in this experiment were similar to previous studies in that SIS are often earmarked for household consumption over sales (Kadir et al. 2006; Roos et al. 2007); although in the case of household ponds, even carp were mainly targeted for consumption rather than sale. Furthermore, findings support the notion that small-scale aquaculture promotes household consumption of fish (Kawarazuka 2010). Thus, economics should not be the only factor considered when assessing aquaculture benefits to a region or group of people.

Farmer reports of approximate SIS harvests highlight the high abundance, yet variability, of natural SIS abundance within ponds. However, if reported farmer SIS production numbers are accurate, SIS are already prolific in ponds, and, given experimental SIS harvest data from experiments conducted this year, stocking does not add enough production to justify the additional cost.

Among Household Farmers, 77% of all fish produced was consumed by the farmer and the farmer's family, while the remaining 23% was sold to neighboring households. Farmers occasionally sold fish to sales agents on bicycles and did not have information regarding the location of the ultimate sale of fish purchased by individuals on bicycles, but unanimously reported that all such transactions resulted in sales at the local market.

Dotted lines in Figure 2 represent a series of transactions that occur in household aquaculture, but have not yet been quantified. While some mention was made of the use of Door-to-Door Buyers to sell surplus fish that were then distributed locally using bicycle transport, none of the farmers indicated that they did this regularly or at any significant level.

CONCLUSIONS

Many aquaculture ponds in Nepal were constructed through international development projects focused on providing fish — an important source of high quality animal protein — to low-income families with limited diets. It is therefore no surprise the majority of fish farmers in this analysis raise fish in small ponds and keep most of what they harvest for home consumption. Such small-scale subsistence aquaculture has been viewed as a success in the region, not only because it has succeeded in providing fish to families, but it has also led to empowerment of women and increased income generation (Bhujel et al. 2008).

QUANTIFIED ANTICIPATED BENEFITS

The completion of a VCA for household ponds provides better understanding of their strengths and weaknesses. Through this understanding, all of those involved in the sector, from fingerling collectors to fish farmers to those possibly involved with fish sales, will be informed of management strategies to improve their service. This will lead to increased supply of high-quality fish protein to communities with limited food resources, and the overall growth of the aquaculture sector. In the case of household ponds, few fish grown reach a market outside of the local neighborhood, and most fish grown are consumed in the home. Little can be done in the value chain at present to enhance efficiency of production in household ponds.

ACKNOWLEDGMENTS

Surveys were conducted by 13 undergraduate students, and we acknowledge the help of Anjana Khanal, Anusha Lamichhane, Bhuwan Devkota, Sarita Neupane, Kiran Khadka, Manish Devkota, Nita Dhakal, Pratikshya Neupane, Sajani Thapa, Sandesh Khanal, Santosh Lamichhane, Subodh Pokhrel, and Sujata Timalsina. Six local village leaders assisted in gaining acceptance for the surveys, and we thank Renuka Choudhary, Shanti Choudhary, Ishori Singh Mahato, Kabita Mahato, Bisram Mahato, Sita Tamang, Indra Thanet, and Shiva Adhikari for their assistance.

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Assessment of Market Opportunities for Small-Scale Fishers and Farmers in Central Uganda

Study/Marketing, Economic Risk Assessment, and Trade/Study/13MER05AU

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ABSTRACT

This study was designed to generate information to support the development of marketing strategies for fishers and aquaculturalists producing product for the reseller markets in Uganda. The specific objectives were to: 1) identify the appropriate market segments and pricing mechanisms used by small-scale fish farmers in central Uganda; 2) analyze the commodity flows and price formation in the different fish reseller market channels; 3) evaluate the performance of the marketing system by calculating gross and net margins for selected fish species; and 4) assess the critical factors affecting market performance and propose policy recommendations for enhancing market performance. The study area was defined to include selected districts in central and eastern Uganda including: Buyende, Jinja, Nakasongola, Mukono, Kampala, Wakiso, Buikwe, and Luweero. With both metric and non-metric data collected, the analysis included descriptive as well as inferential statistics. The results revealed that: (1) mark-up pricing, competitors prices and price haggling were the most used pricing strategies by fish farmers; (2) the direction of causal relationships was observed from the retail to the wholesale and ex-vessel markets, indicating that retailers are the price leaders in the Uganda catfish supply chain; (3) by using gross margin and marketing margin to examine market performance, it was revealed that participants in the wholesale market channel realized higher absolute margins compared to participants in the retail market channel; and (4) the most pressing concerns were common to both retailers and wholesalers, including high fish supply cost, low sales price, low fish supplies, and arrests for selling immature fish. In brief, study findings can be used by relevant authorities to harmonize marketing strategies and to develop guidelines through which price distortions can be removed to promote free market practices.

INTRODUCTION

There is need to place special emphasis on market research derives from the strategic challenges that the aquaculture industry faces in Sub-Saharan Africa. In Uganda, one of the constraints to the growth of the aquaculture industry is lack of organized effort to assist small- and medium-scale producers in developing marketing strategies and programs designed to serve existing and newly emerging markets.

Experience has shown that markets can fail the poor, especially poorest and marginalized groups, including women. Many of the recent initiatives to link small-scale farmers to markets have largely focused on export markets as these are seen as important sources of economic growth (Johnson 2005, Hellin and Higman 2002, GoU 2003). However, many of these approaches tend to be top down and lack an effective process of community learning and empowerment. The decisions on what products and enterprises to develop, what markets to target are often prescribed by government agencies, private companies or development organizations. These organizations then conduct a commodity market chain analysis and organize production to meet identified market demand, often external export markets. These approaches have produced mixed results.

While many studies have documented impressive results of linking farmers to export markets, it has been argued that small-scale farmers have rarely benefited from these initiatives, as niche markets tend to be highly competitive and specialized, with rigorous quality standards which can be challenging for many small-scale farmers (Diao and Hezel 2004). There are real risks that such market opportunities may be seized by a few large-scale commercial farmers to the expanse of small-scale farmers.

With much emphasis on exports, the study of the domestic market for fish and fishery products has not received the attention it deserves. Particularly, domestic markets still represent a large and growing market that ought to offer real opportunities to small-scale farmers. Also, domestic marketing affect the performance of the fish-exporting sector given that all fish products, before being exported, have to pass through some stages in the domestic market. Efforts to ameliorate information on domestic fish marketing and on identifying constraints and opportunities for the improvement of production and marketing arrangements are thus paramount.

OBJECTIONS

The main driver for this study was to generate background information for the development of marketing strategies for fishers and aquaculturalists producing product for the reseller market. The project had four overriding objectives:

- Identify the appropriate market segments and pricing mechanisms used by small-scale fish farmers in central Uganda;
- Analyze the commodity flows and price formation in the different fish reseller market channels;
- Evaluate the performance of the marketing system by calculating gross and net margins for selected fish species; and
- Assess the critical factors affecting market performance and to propose policy recommendations for enhancing market performance.

METHODS

The study was conducted in selected districts in central and eastern Uganda: Buyende, Jinja, Nakasongola, Mukono, Kampala, Wakiso, Buikwe, and Luweero. Both secondary and primary data were used to develop a detailed understanding of the price phenomenon in the fisheries reseller markets. For the primary data, three distinct, complementary, questionnaires were designed for researching the fish food processing reseller market (see instruments in the appendix). The first questionnaire was designed for wholesalers, the second for retail buyers, while the third was designed for food service providers. The data were collected from both capture and aquaculture establishments.

Wholesalers were identified and selected from the respective district fisheries office records and where possible by referral. Restaurants and retail samples were also determined by visiting major fish markets in the selected districts. The questionnaires were designed to ascertain the respondents' interest in purchasing aquaculture products as well as potential for value-added opportunities. The questions required respondents to identify marketing issues and features that are important to meeting their product needs and market demand. Questions on volume and value of aquaculture products currently used by the respondents were included.

The data were analyzed to determine the potential demand for aquaculture products, buyer requirements, and organizational buyer preferences for products and service. This was done for all three reseller markets (wholesalers, retail buyers and food service) with comparisons made where appropriate. With both metric and nonmetric data collected, the analysis includes descriptive as well as inferential statistics.

RESULTS

Examined market segments and pricing mechanisms used by small-scale fish farmers. The first study objective was to generate background information for addressing marketing strategies and pricing mechanisms for farmed fish in the study area. A market strategy combines the farm's set of marketing mix variables and the arrangements for their application and identifies the firm's marketing goals and explains how they will be achieved, ideally within a stated timeframe. The strategy determines the choice of target market segments, market positioning, and the allocation of resources along each marketing mix factor. The lack of appropriate marketing strategies, skills and knowledge in marketing has further complicated the situation leaving many fish farmers in the study region struggling to grow market share. Thus this study was designed to accomplish two related activities: (a) to determine the market segment of farmed fish in central Uganda, and (b) to determine the marketing strategies of farmed fish in central Uganda.

Three districts (Mukono, Wakiso and Mpigi) from central Uganda were purposely selected, and a snow ball sampling technique was used to select a sample of 126 fish farmers that had harvest fish in the last fish cycle. Data were collected using a structured questionnaire on farmers' socio economic and socio demographic characteristics, production practices, marketing aspects, and constraints. A summary of the survey results is presented below (Please refer to the appendix for the detailed results).

Socio-economic characteristics of fish farmers in selected districts. Fish farmers were generally middle aged (42.7 years), literate, with 2 ponds per farm on average, and an experience of 7 years (Table 1).

Table 1. Showing socio-economic characteristics of fish farmers in Mukono, Mpigi and Wakiso districts.

Characteristic	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
	Mean	Mean	Mean	Mean
Age (years)	49.4	50.4	46.9	48. 7
Household size	4.7	6.2	5.8	5.36
Education (years)	11.3	13.2	13.1	12.2
Number of ponds	3.0	4.3	3.5	3.39
Number of ponds harvested in the last cycle	1.7	2.2	2.3	1.95
Experience in fish farming (years)	7.1	7.4	6.5	6.93

Fish marketing. The majority, 93.4%, reported selling fish while 6.6% did not, mainly because of low production (62.5%), home consumption (12.5%) and lacked market (25%).

Selling context. More than half of the respondents (56.90%) reported selling fish products as individuals, not as a group (Table 2).

Table 2. Context for selling fish.

Context	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Individual	56.90	73.68	71.43	64.29
Group	39.66	21.05	22.86	31.25
Both	3.45	5.26	5.71	4.46

Fish farmers expressed different reasons why they used individual/group approaches in selling fish. Reasons why group method was preferred are given in Table 3.

Table 3. Reasons for preferring group marketing for selling fish.

Reason for preference	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Good payment	43.48	0	0	28.57
Buyers come to the farm	4.35	75	37.5	20
No competition	13.04	0	12.5	11.42
Convenient	13.04	25	12.5	14.29
Pay in cash	21.74	0	37.5	22.86
Group project	4.35	0	0	2.86

However, some farmers used individual marketing system as shown in Table 4.

Table 4. Reasons for preferring individual marketing for selling fish.

Reason for preference	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Good payment	6.25	0	21.74	10.29
Buyers come at the farm	15.63	15.38	26.09	19.12
No competition	50	0	13.04	27.94
Convenient	9.38	15.38	17.39	13.23
Lack of farmer group	12.5	61.54	13.04	27.94
Pay in cash	6.25	0	4.35	4.41
Difficulty in marketing	0	7.69	4.35	2.94

To market fish farmers seek pricing strategies that enable them to earn high profit margins. These are summarized in Table 5.

Table 5. Pricing strategy used by fish farmers in Mukono, Mpigi and Wakiso districts.

Pricing strategy	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Price penetration	11.48	42.86	37.5	25.41
Price skimming	4.93	19.05	15	10.66
Lead pricing	3.28	19.05	5	4.10
Break even pricing	13.11	4.76	2.50	8.20
Geographical pricing	3.28	4.76	2.50	3.28
Perceived pricing	6.56	14.29	22.50	13.11
Volume pricing	11.48	38.10	20	18.85
Single pricing	54.10	52.38	35	47.54
Loss leader pricing	0	19.5	7.5	5.7
Discounts offer	1.64	38.10	20	13.93

Source of market information. Lack of market information results in limited capacity for fish farmers to respond to market signals and leads to weak bargaining power. Respondents mentioned various sources of market information utilized in selling fish (Table 6).

Table 6. Sources of market information.

Source of market information	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Fellow farmers	40.4	31.6	32.3	36.4
Fisheries (Entebbe)	8.8	31.6	6.5	12.1
Pond constructors	5.3	26.3	29.0	15.9
Market traders	29.8	5.3	22.6	23.4
No source	5.3	5.3	3.2	4.7
Radio	8.8	0.0	6.5	6.5
Television	8.8	1.8	0.0	0.9

Niche markets. Respondents indicated selling most of the fish at farm gates or at the fish ponds. About 37% of the farmers were aware of better market outlets: 40% in Mukono, 36.4% Mpigi and 30% in Wakiso.

Reasons why they were not able to access better market outlets. Low fish production was sited mostly at 60% followed by no BMU permit 20% and high transport costs 6.7% and lack of proper market information at 13.3%. Marketing strategies on how to improve fish marketing are outlined in Table 7. Promotion of awareness of better markets (21%) and production of required size featured as the most important marketing strategies for fish marketing in central Uganda.

Table 7. Strategies for improving fish marketing in the study area*.

Suggestions	Mukono % (n = 61)	Mpigi % (n = 21)	Wakiso % (n = 40)	Total % (n = 122)
Invest in iced vehicles	11.1	0.0	0.0	5.6
Provision of enough capital	5.6	0.0	0.0	2.5
Form strong fish farming groups	5.6	0.0	11.5	6.2
Promote awareness of better markets	25.0	26.3	11.5	21.0
Ease of access of permits	11.1	25.0	0.0	16.7
Production of required fish size	11.1	21.1	30.8	19.8

* % do not add up to 100% because of multiple responses

Commodity flow and price formation in catfish reseller markets. The widening gap between farm, wholesale and retail prices in various agricultural markets has motivated many empirical analyses of price transmission (Meyer and Cramon-Taubadel 2004; Pozo, Schroeder and Bachmeier 2013; Simioni et al. 2013). The concern in many of the studies is whether prices adjust symmetrically or asymmetrically. This is not surprising given that asymmetric price responses are of concern to producers of agricultural commodities who often claim that retail prices rise faster and fuller than farm price increases, but that retail price declines are not likely to be either as full or transmitted as fast as declines in farm prices (Gauthier and Zapata 2006).

The implication is that retailers possess and exercise greater market power as evidenced by asymmetric price responses. Though many of these studies report asymmetric and imperfect pass through of prices, the evidence is mixed and varies widely across commodities and geographic locations.

Furthermore, most of these studies focused on large-scale market chains in developed countries. As observed by Garcia and Salayo (2009), studies on market integration of fisheries and fishery products in developing countries are still lacking. The aim here was to address this need by investigating the price transmission, threshold behavior and asymmetric adjustment in the Ugandan fisheries sector. Uganda constitutes a particularly interesting case.

Although the operation of the local marketing system has been the subject of previous studies (Kirema-Mukasa and Reynolds 1991; SEDAWOG 1999), the distribution of fish and fish products in Uganda has improved over the last fifteen years, with increased channels involving middle agents that supply fish to factories involved in industrial fish processing and export, and traders that supply fish to rural and urban markets (Keizire 2006). By focusing on the African catfish (Clarias gariepinus) supply chain, the study was set out to understand how changes in ex-vessel and wholesale prices affect retail price and vice versa.

Using secondary data, the analysis looked at the wild-harvest African catfish (whole fresh) market along the production (ex-vessel), wholesale and retail channels. The ex-vessel prices from January 2006 to August 2013 were collected at landing sites (Kikondo, Buikwe district; Masese, Jinja district; and Ggaba, Kampala district) on Lake Victoria, while corresponding retail and wholesale price data were gathered from several fish markets (Nateete, Busega, Luzira, Mukono, Kalerwe, Nakawa, and Owino) in the Central region.

All prices, expressed in Uganda Shillings (UG Shs.) per kilogram, were deflated using consumer price index (CPI) deflator to account for inflation in the period covered. The CPI data for food stuff in central Uganda were drawn from Uganda Bureau of Statistics; using 2005/2006 as the base year (UBoS 2013).

The methodology used involved both traditional and threshold autoregressive approaches to determine whether price movements share a common long-run relationship, whether response of price shocks are symmetric or asymmetric, and the time path needed for shocks to be transmitted. The results revealed that prices in the Uganda catfish value chain are tied together by a long-run relationship, and that ex-vessel and wholesale price adjustments to retail price changes are symmetric while ex-vessel price adjustments to wholesale price changes are asymmetric. The direction of causal relationships was observed from the retail to the wholesale and ex-vessel markets, indicating that retailers are the price leaders in the Uganda catfish supply chain.

In explaining similar results, Sapkota et al. (2012) for instance, emphasized the lack of sufficient numbers of wholesalers capable of influencing the transmission of prices to retailers. Their explanation applies to most fish supply chains in developing countries such as Uganda, where until very recently, there was no large scale wholesale demand from institutional buyers such as supermarkets. This suggests that catfish wholesale prices may be influenced by retail prices, due to less organized behavior at the wholesale market level as compared to the retail market level. Other plausible explanations for the observed retail price leadership over wholesale and ex-vessel prices include the dispersed landing points, poor transportation, perishability of the product and lack of timely information about downstream markets (Sapkota et al. 2012).

Furthermore, the asymmetric price transmission behavior in the reseller markets was analyzed according to Ender and Siklos (2001) momentum-threshold autoregressive approach. The observed positive asymmetric price transmission behavior for the ex-vessel-wholesale price pair indicated that ex-vessel prices respond more to declining wholesale prices than to rising wholesale prices. Further analysis with the asymmetric error-correction model (AECM) revealed that price adjustment to the long-run equilibrium was not instantaneous and that both ex-vessel and wholesale prices adjust from below the threshold to restore the long-run relationship. The causality relationship was found to run from the wholesale market to the ex-vessel market level.

Overall, these findings have important implications for the catfish subsector in particular, and the Uganda fisheries sector in general. Firstly, the evidence of non-linear price adjustment in the ex-vessel-wholesale market channels suggests the existence of some barriers to free trade (Serra et al. 2006). Such barriers might include high transaction costs and imperfect information. As a start, this finding could be used by policy makers to harmonize marketing strategies in the catfish supply chain, and to develop policies through which price distortions can be removed to promote free market practices.

The important objective for such policies should be improving access to credit, market information, transportation, and grading. Particularly, poor infrastructure, namely transport and communication services, gives rise to large marketing margins because of the high costs of delivering products to destinations. They may also hinder the transmission of price signals because of non-competitive behavior amongst traders. On the other hand, infrastructural development can play an important role in supporting the integration of catfish markets, facilitating competition, encouraging investment, and allowing a more efficient allocation of resources and enhancing market oriented production (Van Campenhout 2012).

Secondly, the analysis of market integration and market chain equips policy implementers with information on the transmission of incentives in the supply chain and this is relevant to the success of other policies concerned with market liberalization, price stabilization and food security. Practices like promoting fisher associations, demarcating landing points for product pooling and improvements in shelf-life increasing technologies would improve the stability of prices for this perishable product.

Calculating gross and net margins. The focus here was to examine market performance of small-scale fish traders selected randomly from a cross-section of nine fish markets in four districts in central Uganda. The data were collected in four districts (Kampala, Mpigi, Mukono, and Wakiso). Respondents were drawn from a cross-section of wholesale and retail fish traders operating in nine markets (Kasubi, Busega, Mpigi, Mukono, Bwaise, Kawempe, Nsangi, Nansana, and Wekembe). Data were collected through a structured questionnaire which was designed to solicit information on traders' socio-economic characteristics, marketing characteristics, operating costs and returns, and problems associated with fish marketing in the study area. Percentages were used to describe the socio-economic characteristics, market characteristic and problems associated with fish marketing while gross profit and marketing performance models were used to determine profitability, marketing margin, and operational efficiency, respectively. Although data collection was limited to marketing areas in central Uganda, the areas covered are places where most people are concentrated and marketing activity is most intense in the country.

The major costs revealed by traders in our sample are depicted in Figure 1, which shows there are four major cost categories observed for the two dominant marketing channels (retail and wholesale). For instance, marketing costs are higher in the retail channel (USh 284.73/kg) compared to the wholesale marketing channel (USh235.52/kg), which is not surprising considering that retailers usually sell in small quantity at a point in time, hence prolonging the time spent and expenditures on the various marketing functions. Particularly, storage costs represent a substantial amount of the cost in both wholesale (USh155/kg) and retail (USh146/kg) marketing channels, followed by transportation of fish from the landing sites to the markets at USh110/kg in the retail channel and loading/offloading at USh51/kg in the wholesale channel. The least cost component of the marketing chain for fish retailers was packaging (USh8/kg) while transportation (USh13/kg) was shown to be the least cost in the wholesale channel.

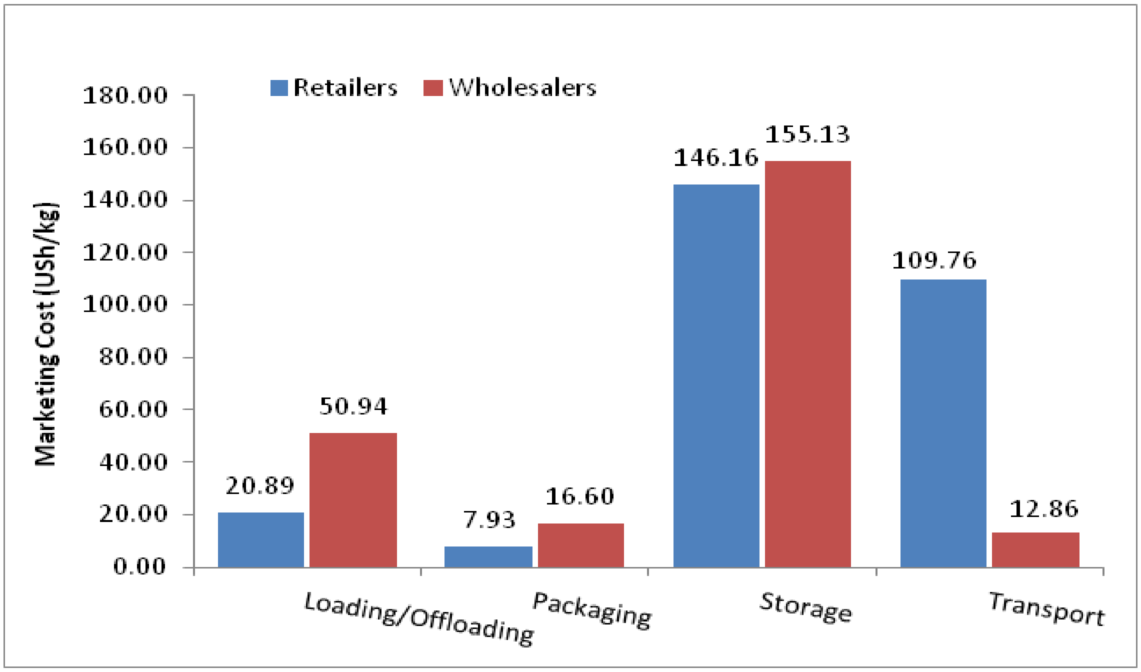

Figure 1: Cost of marketing fish in central Uganda (USh/kg).

Following previous studies (Olukosi and Isitor 1990; Gaya, Mohammed and Bawa 2007), market margin analysis was used to determine the deference between the price paid by consumers and that received by fish traders as:

$$(1)\quad \text{Market Margin} = \left[\frac{\text{Consumer Price} - \text{Supply Price}}{\text{Consumer Price}}\right] * 100$$

Also, market efficiency was computed using the value added concept as:

$$(2)\quad \text{Market Efficience} = \left[\frac{\text{Value added through marketing}}{\text{Cost of marketing services}}\right] * 100$$

In equation 2, the value added through marketing was estimated by subtracting the total cost price of fish as it follows through the market from the total selling price. The cost of marketing services was obtained from the total cost of providing marketing functions such as transportation, storage, packaging, loading/offloading and license charges.

The results in the table 8 show that profits made in both market channels (wholesalers and retailers) were positive, however, wholesalers realized higher absolute margins compared to retailers. As indicated, gross margin per kilogram (kg) of fish sold by wholesalers and retailers were USh358.40 and USh234.73 respectively, with overall market returns for the total sample estimated at USh262.96/kg. The marketing margins were estimated at 19.32 and 16.67 percent for the wholesalers and retailers respectively, with overall marketing margin for the total sample of 17.23 percent. Similarly, the market operational efficiency was 279.27 percent for the entire market in the study area.

Table 8. Estimated gross margin, marketing and efficiency margins.

Market Channel	Gross Margin (USh/kg)	Market Margin %	Market Efficiency %
Wholesale	358.4	19.3	187.1
Retailer	234.7	16.7	319.3
Total Market	263.0	17.3	279.3

Previous studies have highlighted several factors constraining the development of processing and trading food and agricultural products in Uganda including limited access to resources, insufficient credit facilities, inadequate transport means, bad roads, poor processing and marketing facilities to name a few. To ascertain the extent to which these among other factors are of concern to fish traders in the study area, the questionnaire asked traders to indicate what they perceive to be the major concerns in the fish marketing business.

A tally of their responses is summarized in Table 9, representing the proportions of the total sample that identified a particular issue to be of major concern. As shown in the table, the most pressing concerns are common to both retailers and wholesalers, including high fish supply cost (21.62%), low sales price (16.22%), low fish supplies (12.16%), and arrests for selling immature fish (18.92%). When looked at within the marketing channels, the results reveals that high supply cost (22.2%), low fish prices (18.5%), and arrests for selling immature fish (16.7%) are the major concerns highlighted by the retailers in the sample. On the other hand, unreliable fish supply (20%) in addition to high supply cost (20%) and arrests for selling immature fish (25%) ranked higher among wholesalers.

Table 9. Major problems faced by fish traders in central Uganda.

Problem	Retailers %	Wholesalers %	Overall Market %
Corrupt officials	11.1	0.0	8.1
High supply cost	22.2	20.0	21.6
Transportation	5.6	10.0	6.7
Limited capital	5.6	0.0	4.1
Low prices	18.	10.0	16.2
Low and unreliable supply	9.3	20.0	12.2
Post-harvest loses	11.1	5.0	9.2
High taxes/license fees	0.0	10.0	2.7
Arrests for selling immature fish	16.7	25.0	18.9

The major concerns highlighted by fish traders in the study area are not surprising given the reported increased decline of fish stock in Lake Victoria due to over exploitation and illegal fishing activities. Indeed, the practice of fishing, trading and consuming immature fish is hampering Uganda's hitherto lucrative fishing sector. To ensure continued business the existing laws for the protection of immature fish should be better enforced by increasing the personnel and material resources of the fisheries department and by combating corruption among the fisheries officers, an area that was also mentioned by the traders.

Finally, although not ranked high by traders other factors including inadequate market facilities, such as lack of ice plants, containers with aerating devices, processing facilities and protected (cold) storage facilities also limit the development of trading enterprises. Strategies to overcome these among other constraints for fish marketing would benefit both traders and consumers in the study area.

CONCLUSION

Policy. The findings have some economic and policy implications for the fisheries industry. Foremost, better and statistically tested knowledge on the transmission of price information in the markets can be used to justify domestic policies and infer whether the law of one price holds at the domestic fish production level. Particularly, the evidence of non-linear price adjustment in the market channels suggest the existence of some barriers to free trade. Such barriers might include high transaction costs and imperfect information as observed in similar studies.

In terms of marketing strategy (Objective 1), one finding from the study clearly points the way for Clarias producers. In a more detailed study, it was found that the causal direction of price transmission was from retail to the wholesale and ex-vessel markets. The results suggest that retailers are the price leaders in the Uganda catfish supply chain and that producers might use negotiated price and supply relationships to protect themselves from price swings and thin markets.

Among the important policy objectives, relevant authorities should focus on improving access to credit, market information, transportation, and grading. Particularly, poor infrastructure, namely transport and communication services, gives rise to large marketing margins because of the high costs of delivering fish and fish products to destinations. They may also hinder the transmission of price signals because of noncompetitive behavior amongst traders. Conversely, infrastructural development can play an important role in supporting the integration of fish markets, facilitating competition, encouraging investment, and allowing a more efficient allocation of resources and enhancing market oriented production.

Overall, the analysis of market integration and market chain as curried out in this study should equips policy implementers with information on the transmission of incentives in the market chain and this is relevant to the success of other policies concerned with market liberalization, price stabilization and food security. Practices like promoting fisher associations, demarcating landing points for product pooling, and improvements in shelf-life increasing technologies would improve the stability of prices for this perishable product. In brief, the study findings can be used by relevant authorities to harmonize marketing strategies and to develop guidelines through which price distortions can be removed to promote free market practices.

Development impact. Through the National Development Plan (NDP 2015 to 2020), fish has been chosen as one of the 12 agricultural commodities that will transform “Uganda from a Peasant (80%) to a Modern and Prosperous Country within 30 years.” During this period the government will enhance agricultural production and productivity through commercialization, mechanization, and increased value addition. Therefore, this study is already aligned to the NDP and Vision 2040. Only fish and cattle are selected as animal protein sources to transform livelihoods through provision of employment and poverty reduction.

QUANTIFIED ANTICIPATED BENEFITS

- The main target groups were small-scale farmers. The findings revealed the potential for commercial fish farming at small-scale enterprises and availability of local markets;
- Participating fish farmers directly benefited from this work. They were informed of the results of the study through workshops and received recommendations on the best marketing strategies and the direction of price flow within the different market channels;
- The sector provides employment to fishermen, fisher mongers and those employed in fish processing. Therefore, enhancing the profitability of the sector has an important direct and indirect impact on poverty reduction efforts in the region. The direct benefits arise from direct dependence on the fisheries, especially the lake communities. Indirect benefits arise from secondary employment through services that are provided in support of fisheries;
- The project will strengthen the capacity of Uganda’s extension system through the dissemination

of the findings and identifying the needs for possible follow-up activities in the field of fisheries products marketing;

- Analysis of processed (food) markets for aquaculture (primarily African catfish and tilapia) products identified alternative production and marketing strategies for producers and processors that lead to increased economic returns;
- Increase sales and incomes for fish farmers;
- Fish production becomes more market oriented and reduces post-harvest losses;
- Reduced marketing and other transaction costs for farmers; and
- Improved market linkages and farm sales for farmed fish.

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TOPIC AREA:
WATERSHED AND INTEGRATED COASTAL ZONE MANAGEMENT

❖

Estimating Carrying Capacity for Aquaculture in Cambodia

Watershed and Integrated Coastal Zone Management/Study/13WIZ01UC

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ABSTRACT

We conducted a pilot project on Aquaculture Carrying Capacity (ACC) in Cambodia. The objective of the study was to plan for sustainable aquaculture development in Cambodia by training Cambodian scientists, staff of the Inland Fisheries Research and Development Institute (IFReDI) in the use of models to estimate the amount of aquaculture waste and therefore to estimate ACC. Stung Chinit Reservoir, located in Kampong Thom province, was selected as the pilot study site. The results showed that the best scenario with acceptable phosphorus concentration ([P]) at 200 mg/m^3, farmers could produce 895 tons of snakehead in the dry season or 467 tons in the wet season. Setting acceptable [P] at 200 mg/m^3 and just varying FCR demonstrates that an FCR of 2.0 allows only 790 tons of snakehead production during the dry season and 412 tons during the wet season, whereas lowering the FCR to 1.0 will allow 1918 tons of snakehead production during the dry season and 1000 tons during the wet season. Holding FCR constant at 1.8 and setting acceptable [P] at 150 mg/cubic meter means that aquaculture will not be allowed in Stung Chinit. On the other hand, setting acceptable [P] at 350 mg/m^3 means that 2138 tons will allowed during the dry season and 14,448 tons during the wet season. Using P mass-balance modeling to project acceptable snakehead production levels in Stung Chinit Reservoir provides the policy makers, and especially farmers, to see the impacts of different scenarios on potential snakehead production in Cambodian reservoirs and in Southeast Asia region.

INTRODUCTION

Cambodia has plans to expand freshwater aquaculture, including in reservoirs (Fisheries Administration, 2011). Lakes and reservoirs represent commonly owned or used water bodies and are therefore subject to the “tragedy of the commons”, in which too many users can destroy the quality of the resource (Hardin, 1968). It is not unusual in Southeast Asia to see reservoirs in which aquaculture has grown beyond reasonable limits, with subsequent declines in water quality (e.g., the Cirata and Jatiluhur reservoirs in Indonesia, with tens of thousands of fish cages).

Aquaculture carrying capacity (ACC) refers to the limits to aquaculture in a common water body, as defined by the environment’s ability to assimilate aquaculture wastes. McKindsey et al. (2006) reviewed the topic and discussed different entities that one might consider protecting (the farms themselves, the entire ecosystem, human society) in the calculation of ACC. Various kinds of models exist for calculating ACC, depending on what is to be protected and how much data one has available to use in the models.

For freshwater bodies with relatively little data available, mass-balance modeling of phosphorus (P) is often used, since P is normally the limiting nutrient for freshwater primary production. The basic P mass-balance model is rooted in the work of Vollenweider (1968) and Dillon and Rigler (1974), relating P levels and primary production in studies of eutrophication. That is, eutrophic waters eventually result in lowered dissolved oxygen (DO) levels due to decomposition of organic material. The aquaculture of fish in cages is usually based on feeding of some diets (chopped trash fish or formulated feed pellets) that add substantially to the organic load of the water.

OBJECTIVES

The objective of this activity was to plan for sustainable aquaculture development in Cambodia by training Cambodian scientists, regulators/managers, and officers in the use of models to estimate the amount of aquaculture waste that an ecosystem can assimilate.

METHODS

The Lead PI provided training workshops and seminars at IFReDI to educate the staffs of relevant regulatory agencies on the problems behind unregulated aquaculture development and the uses of modeling to estimate aquaculture carrying capacity. He further worked with selected IFReDI scientists to learn simple mass- balance models for calculation of aquaculture carrying capacity.

Stung Chinit Reservoir, located in Kampong Thom province, was selected as the pilot study site. It has a surface area of 2,530 ha, and can store up to 38 million m^3 of water. The reservoir is used for irrigation of 22,000 ha during the rainy season and 5,000 ha during the dry season.

IFReDI staff received training in P mass-balance modeling and collected information about Stung Chinit reservoir to be used in the modeling. As described by Beveridge (1996), the modeling procedure is quite simple and requires relatively little input data. One needs to know the volume of the water body, area (A) and average depth (z) of the water body, the turnover rate (number of volume replacements per year, ρ), initial P concentration before aquaculture $[P]_i$, and some acceptable final P concentration $[P]_f$, and the fraction of P that is lost to the sediments (R). In addition, one needs to know about the fish being proposed for rearing: species, P content of their feed, feed conversion ratio (FCR, which is a measure of how much feed must be provided to achieve desired growth of the fish), and the amount of P retained by the fish at harvest. The critical quantity is $\Delta P = [P]_f - [P]_i$, which is the amount of new phosphorus that aquaculture can add to the system and still allow the system to be at or below the acceptable P level.

Clearly, if $[P]_i$ is already greater than $[P]_f$ (due to nutrient runoff, etc), then no aquaculture can be allowed.

Average volume of Stung Chinit reservoir is 35.6 million m^3. During the dry season (November to April) flow in the Stung Chinit River is 460 million m^3 (for the whole season), whereas during wet season (May to October) flow is 1586 million m^3 for that season. [P] in the reservoir in 2008 (the last year for which we have an annual data set) averaged 92 mg/m^3 in the dry season (range = 40-150) and 195 mg/m^3 in the wet season (range = 50-520). The area of the reservoir is 16,720,000 m^2 in the wet season and 5,140,000 m^2 in the dry season, and the average depth is 1.5 m. In the absence of specific data, we are assuming that R = 0.5. With this information, one can use the relationship described by Beveridge (1996) $\Delta P = [L_{fish}(1-R_{fish})]/z\rho$, where L_{fish} is the amount of P that can be contributed by fish aquaculture, by rearranging it to solve for $L_{fish} = [\Delta P z\rho]/(1 - R_{fish})$.

One can then calculate the number of tons of fish that be produced to achieve L_{fish}. That is accomplished by multiplying the P content in a ton of feed times the FCR (to determine how much P is provided to the aquaculture operation, P_{feed}) and subtracting from that the amount of P that is retained in a ton of fish, P_{fish} (and therefore removed from the system). In other words, the amount of P lost to the environment, $P_{env} = P_{feed} - P_{fish}$, expressed as P loss per ton of fish produced.

RESULTS

In the current best scenario with acceptable [P] at 200 mg/m^3, farmers could produce 895 tons of snakehead (dry season) or 467 tons (wet season). Since the growth cycle for snakehead lasts for more than one season, the annual production will be limited to 467 tons. Setting acceptable [P] at 200 mg/m^3 and just varying FCR demonstrates that an FCR of 2.0 allows only 790 tons of snakehead production during the dry season and 412 tons during the wet season, whereas lowering the FCR to 1.0 would allow 1918 tons of snakehead production during the dry season and 1000 tons during the wet season (Figure 1). Holding FCR constant at 1.8 and setting acceptable [P] at 150 mg/m^3 means that aquaculture will not be allowed in Stung Chinit. On the other hand, setting acceptable [P] at 350 mg/m^3 means that 2138 tons will be allowed during the dry season and 14,448 tons during the wet season (Figure 2).

DISCUSSION

One of the interesting things about this exercise is that there are some things that fish farmers and feed manufacturers cannot control (volume, area, depth, flow rate of the water body) and some things that they can (FCR, P content of feed). In addition, stakeholders of the water can decide on the acceptable level of P for that water body. For example, if stakeholders desire oligotrophic (clear, very low nutrient water) for tourism, then aquaculture production is unlikely, but if they really want to promote aquaculture, the higher levels of P would be permissible. Beveridge (1996) suggested that P levels up to about 250 mg/m^3 are permissible for tropical culture of tilapia, carp and milkfish, although lower levels of 50-75 mg/m^3 would be more protective of fisheries production.

We followed the above approach to calculate ACC for fish culture in Stung Chinit. Since this effort was part of a project to bring about the reintroduction of snakehead culture in Cambodia, we used that as our model species, although one could clearly model other species as well. We began by calculating ACC with the best current data available and an assumed acceptable [P] of 200 mg/m^3. However, as part of the exercise, we also calculated ACC under different scenarios of FCR and $[P]_f$. We were faced with the additional challenge that Stung Chinit has very different flow rates and $[P]_i$ values for the wet and dry seasons, but snakehead require about one year to grow to market size, thereby encompassing both wet and dry seasons. We therefore decided a priori that we would calculate ACC separately for wet and dry seasons, but that we would finally choose the lower of the two values for tons of fish production, so that production would be protected in the worst-case scenario.

For our current best scenario with acceptable [P] at 200 mg/m^3, farmers could produce 895 tons of snakehead (dry season) or 467 tons (wet season). Thus, the annual production would be limited to 467 tons, the lower of the two values. As we examine other scenarios, we see that FCR is a powerful regulator of allowable tons of fish production. Setting acceptable [P] at 200 mg/m^3 and just varying FCR demonstrates that an FCR of 2.0 allows only 790 tons of snakehead production during the dry season and 412 tons during the wet season (so we choose 412 tons for year-round production to be safe), whereas lowering the FCR to 1.0 would allow 1918 tons of snakehead production during the dry season and 1000 tons during the wet season (so again we choose 1000 tons to be safe) (Fig. 1). Similarly, holding FCR constant at 1.8, setting acceptable [P] at 150 mg/m^3 would mean that aquaculture would not be allowed in Stung Chinit (481 tons during the dry season but a negative number during the wet season), whereas setting acceptable [P] at 350 mg/m^3 would mean that 2138 tons would be allowed during the dry season and 14,448 tons during the wet season (so 2138 tons to be safe) (Fig. 2). It is interesting that the wet season production levels are always lower than the dry season production levels and therefore determine the year-round production at all FCR levels, but that, when FCR is held constant and acceptable P varies, the wet season production levels are higher and the dry season production levels determine the year-round production.

Some final issues must be considered regarding the introduction of aquaculture to Stung Chinit. First, we must be sure that the P levels do not violate Cambodian national standards for water quality. Those standards appear to allow P levels from 50-1000 mg/m^3, so that should not be a problem. Because the water leaving the dam is only used for irrigation of agriculture, elevated nutrient levels will be considered something positive. Second, we do not want to endanger the fish community that already exists in Stung Chinit and contributes to fishery catches. Monthly measured P values in Stung Chinit in 2008 ranged from 40-150 mg/m^3 during the dry season and from 50-520 mg/m^3 during the wet season. It is therefore likely that the fish community is already adapted to a wide range of P conditions in the reservoir and can cope with somewhat elevated average P values due to aquaculture. Finally, Stung Chinit averages only 1.5 m in depth, but has some deep areas that reach 10 m in depth. Whatever tonnage of fish production is allowed in Stung Chinit must also be consistent with good aquaculture practices of siting cages in deeper water. Thus, sufficient deep water areas must be shown to be available as part of the decision to allow aquaculture operations.

CONCLUSION

Using P mass-balance modeling to project acceptable snakehead production levels in Stung Chinit Reservoir provides us, policy makers, and especially farmers to see the impacts of different scenarios on potential snakehead production. It can serve as a template for modeling allowable levels of aquaculture in other Cambodian reservoirs and perhaps throughout the Southeast Asia region.

QUANTIFIED ANTICIPATED BENEFITS

One Master's student has been involved in this investigation. Four IFReDI researchers have received training in P mass-balance modeling and collected information about Stung Chinit reservoir to be used in the modeling. Two-thousand IFReDI/FiA staff, scientists, researchers, and government officers have an improved understanding of environmental carrying capacity through sharing research result findings such as policy brief, technical report, and meetings and workshops; and about 100 scientists and researchers can apply models to the calculation of carrying capacity for specific bodies of water.

ACKNOWLEDGEMENTS

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FIGURES

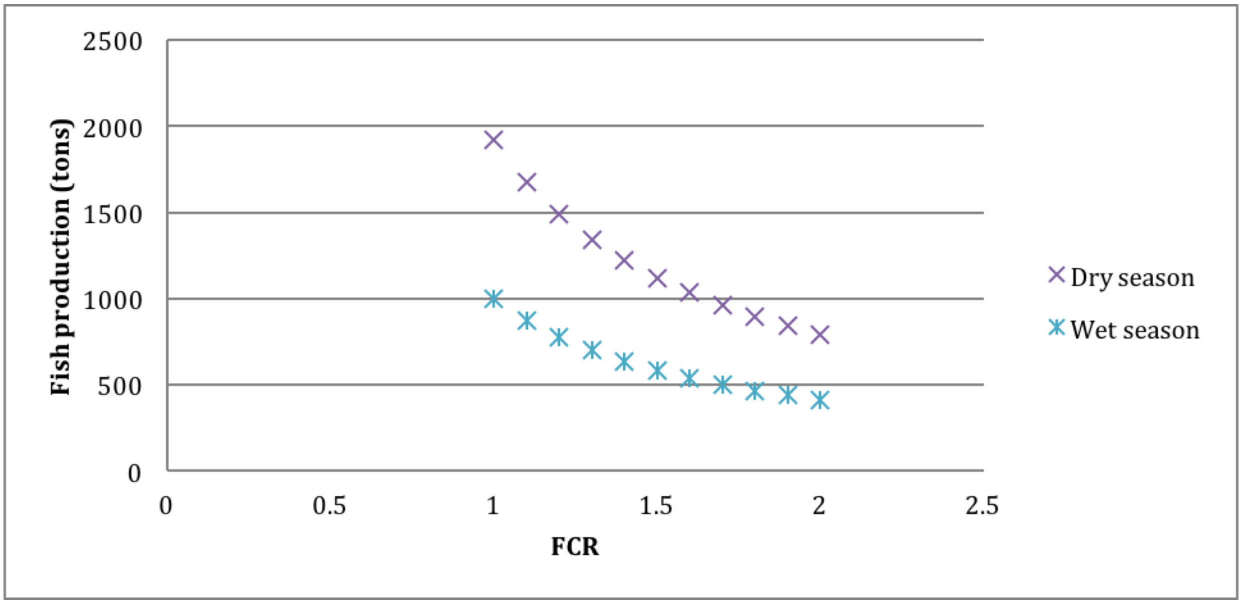

Figure 1. Effect of FCR on aquaculture carrying capacity in Stung Chinit Reservoir.

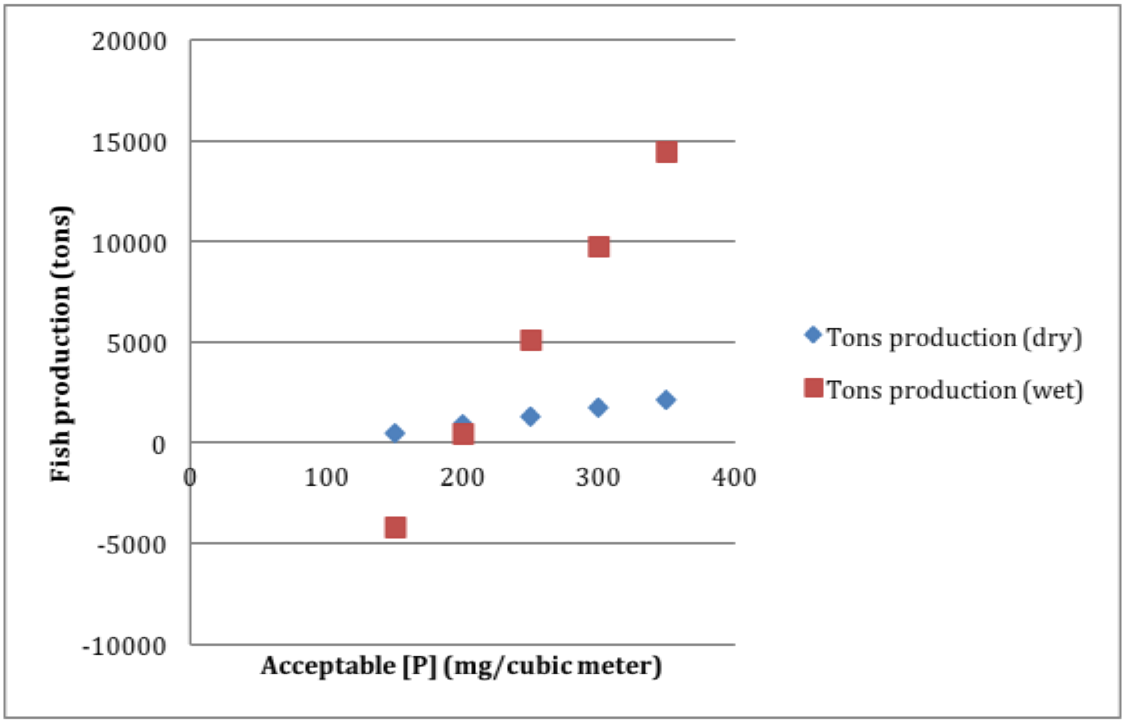

Figure 2. Effect of phosphorus acceptability criterion on aquaculture carrying capacity in Stung Chinit Reservoir.

TOPIC AREA:
MITIGATING NEGATIVE ENVIRONMENTAL IMPACTS

❖

Novel Approach for the Semi-Intensive Polyculture of Indigenous Air-Breathing Fish With Carps for Increasing Income and Dietary Nutrition While Reducing Negative Environmental Impacts

Mitigating Negative Environmental Impacts/Experiment/13MNE01NC

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ABSTRACT

Air-breathing fishes provide a significant advantage for pond culture, as they tend to be resilient to harsh conditions, particularly during periods of low-oxygen, which can occur with high temperatures, drought or poor water quality. Currently, production of shing (*Heteropneustes fossilis*, stinging catfish) and koi (*Anabas testudineus,* climbing perch) is limited to monoculture systems with intensive use of commercial-grade feeds (30%–35% crude protein). As feed can comprise up to 60% of total production costs, the current practices for these fish limit participation by small homesteads and therefore comprise a significant impediment to further expansion of this industry. Further, the use of high-levels of feed inputs has led to a persistent deterioration of pond water quality. Studies were carried out to determine: 1) if addition of Indian major carps (rohu, *Labeo rohita*, and catla, *Catla catla*) alone can provide cost benefits for growout of shing and if reducing feed by 50% from levels typically used by the industry to grow shing might provide further cost savings in shing-carp polyculture, and 2) what the effect of carp stocking density is on koi production using the best strategy established for shing-carp polyculture. The studies were carried out for 165 days in ponds at Bangladesh Agricultural University. The first experiment consisted of four treatments (T1, T2, T3, and T4) with four replications each. The stocking density was 5 shing/m^2, 0.8 rohu/ m^2 and 0.2 catla/m^2. All three fish species were stocked in all ponds except in the T1 group, representing the monoculture of shing as control. Ponds under T1 and T2 were fed at rates typically used in shing culture (20%– 5% body weight/day), while T3 received feed at 75% and T4 at 50% of full ration daily. Ponds were fertilized weekly in T3 and T4. Growth and production of fishes did not vary significantly in the different treatments. The survival rate of fish did not differ and ranged from 47% to 53% for shing and > 89% for carps. The net productions of fish in T1, T2, T3 and T4 were 623±155, 3069±774, 3280±853 and 3171±805 kg/ha, respectively. Net return was -103,827, 294,485, 442,711 and 542,215 BDT/ha and benefit cost ratio (BCR, total returns/total costs) was 0.82, 1.55, 1.93 and 2.37 in T1, T2, T3 and T4, respectively. T4 showed the best overall feed conversion ratio (FCR), BCR and fish yield followed by T3. The results show that feed and production efficiency is best in shing-carp polyculture under the 50% reduced feeding regimen.

Study 2 consisted of three treatments (T1, T2, and T3). Koi were stocked at the same density in all groups (5/m^2) and feed was applied at a 50% rate based on koi biomass. T1 was stocked with 0.8 rohu/m^2 and 0.2 catla/m^2, T2 with 1.0 rohu/m^2, and T3 with 1.0 catla/m^2. All ponds were fertilized weekly. There was no difference in weight gain or specific growth rate for any species between treatments or for survival rate

for koi. The survival rate for rohu in T1 was significantly higher than T2 and for catla in T1 than in T3. Both gross and net production parameters were significantly higher for koi in T3 than in T1 or T2. Catla grown at a stocking rate of 1.0 fish/m^2 (T3) resulted in production parameters that were significantly higher than when stocked at 0.2 fish/m^2 (T1). There was no significant difference in production of rohu between treatments. There was no significant difference in FCR or BCR between treatments. In conclusion, the cost effectiveness of shing growout can be substantially improved by addition of carps to pond culture systems. Moreover, reducing feed inputs by half provides additional benefits to shing-carp polyculture with a 85% increase on returns. Based on these studies, farmers have the potential to enhance their income opportunities by incorporating carps and reducing feed inputs in the growout of shing catfish. Our studies also suggest that koi grow well with carps and production may be best with catla alone. Future studies are required to directly compare koi monoculture and koi-carp polyculture and the impacts of feed and fertilization inputs.

INTRODUCTION

Carps are the dominant finfish cultivated in Bangladesh, with multiple species farmed together in polyculture. Studies suggest that cultivation of other finfish varieties, particularly indigenous species with high mineral content, will be important steps for increasing the yield and diversity of aquaculture products for consumption in Bangladesh and in reducing some types of dietary malnutrition, such as iron-deficient anemia (Dey et al. 2008, Micronutrient Initiative/UNICEF 2004). Indigenous air-breathing fishes, such as shing catfish (*Heteropneustes fossilis*) and koi (climbing perch, *Anabas testudineus*) have been successfully cultivated in Bangladesh in recent years and command a high market value (DOF 2012, Kohinoor et al. 2011). Both are currently in great demand by consumers for their taste and nutritional value (Hasan et al. 2007, Vadra 2012, Vadra and Sultana 2012). Shing catfish is particularly high in both iron (226 mg 100 g^{-1}) and calcium relative to other freshwater fishes, and has been recommended in the diets of the sick and convalescent (Saha and Guha 1939, Singh and Goswami 1989). This investigation seeks to promote production of finfish with high nutritional value (shing catfish and koi), while improving both economic profitability and environmental water quality through implementation of better management practices.

Air-breathing fishes provide a significant advantage for pond culture, as they tend to be resilient to harsh conditions, particularly during periods of low-oxygen, which can occur with high temperatures and drought. Currently, production of shing and koi is limited to monoculture systems with intensive use of commercial-grade feeds (30%–35% crude protein). As feed can comprise up to 60% of total production costs, the current practices for these fish limit participation by small homesteads and therefore comprise a significant impediment to further expansion of this industry. Further, the use of high-levels of feed inputs has led to a persistent deterioration of pond water quality (eutrophication; cf. Chakraborty and Mirza 2008, Chakraborty and Nur 2012) and periodic mass mortalities and disease outbreaks. As most ponds are located near homesteads and villages, poor water quality and foul odors related to greater nutrient-loading impacts both local health and socio-economic tensions within the community (personal communication, Nural Amin, local farmer in Tarakanda, Mymensigh, July 2012). Through field visits to Mymensingh, this research team (Wahab and Borski) observed firsthand that most air-breathing fish farms are often overfed, therefore some of the problems associated with farming of air-breathing fishes can be alleviated through better management and implementation of semi-intensive culture practices. These problems may be mitigated through polyculture, where excess nutrients and algae can be utilized by other species (e.g., carp). This investigation will evaluate whether carps can be incorporated into the culture of indigenous air-breathing fishes, shing catfish and koi. As carps feed primarily upon primary production (phytoplankton/algae, Wahab et al. 2002), their incorporation may significantly reduce negative impacts associated with the farming of air-breathing fishes, while also allowing for greater production yields and the availability of additional fish for home consumption.

An additional mechanism for mitigating excess nutrient inputs is to limit the amount of feed applied in shing and koi culture. We have previously shown that equivalent production yields of tilapia can be achieved with 50% less feed either provided as a full ration on alternate days or as a lower daily rate (Bolivar et al. 2006, Borski et al. 2011). Similarly, alternate day feeding significantly improves feed conversion and reduces costs in the grow-out of milkfish in ponds and seacages (DeJesus-Ayson and Borski 2012). Feed-restriction has not been evaluated in shing catfish or koi production, however previous work in catfish (US and Asian varieties) suggests shing may also undergo periods of compensatory growth (SRAC 1989, Zhu et al. 2005). In particular, sutchi catfish (*Pangasianodon hypophthalmus*) raised on alternate-day feed regimens (50% feed reduction) had little differences in production yield compared to fish fed daily, yet net profits were increased 99% through the reductions in feed and labor costs (Amin et al. 2012). This investigation evaluated whether reduced-feeding protocols can be successfully applied to the polyculture of shing catfish/carp or koi/carp. Reductions in feed and overhead costs, combined with mixed-trophic level nutrient utilization, may make semi-intensive culture of shing catfish and koi more feasible for greater adoption among farmers while also mitigating environmental impacts associated with nutrient loading.

OBJECTIVES

- Assess reduced-feeding strategies for combined polyculture of two major carps (rohu, *Labeo rohita*, and catla, *Catla catla*) with shing catfish or koi in semi-intensive pond culture. Culture of carp with these fishes would represent a new polyculture technology in Bangladesh.
- Identify the feed-reduction strategy and carp stocking ratios needed for equivalent or better production yields through increased nutrient utilization efficiency.
- Evaluate overall performance and economic returns of the improved management strategy and transfer of findings to local farmers through an extension workshop.

MATERIALS AND METHODS

Study 1 — Assess reduced-feeding strategies for combined polyculture of two major carps (rohu and catla) with shing catfish. An experiment was carried out in 2013 prior to the start of this project to assess the semi-intensive polyculture of indigenous air-breathing fish shing catfish, with carps as a potential method for increasing income and reducing negative environmental impacts of shing catfish monoculture. rohu, catla and shing were stocked (rohu, 0.8 fish/m^2 ; catla, 0.2 fish/m^2 ; shing, 5 fish/m^2) in 9–100 m^2 ponds (1.5 m depth) in a completely randomized design allocated to three treatments: full daily feeding (T1), half daily feeding ration (T2), and alternative day full daily feeding (T3) under weekly fertilization rate for all treatments (N:P = 4:1). The combined net production for the three species was 3,300 kg/ha for T1, 2,136 kg/ha for T2, and 2,440 kg/ha for T3. Despite the higher net production of fish in T1, the benefit-to-cost ratio (returns ÷ investment) was better for T2 (3.34) and T3 (2.97) than for T1 (2.55). This is largely due to the lower costs of feed associated with 50% feed reduction strategies. Thus, despite lower production levels, daily feeding at half ration levels was the most cost effective strategy. The above novel approach demonstrates that carp can be polycultured with shing through utilization of natural food organisms along with reduced feed inputsedThis work was presented at the Aquaculture America meeting in February 2014 (Wahab et al. 2014).

Additional studies are required to directly evaluate shing-carp polyculture versus the current practice of shing monoculture to determine if the former allows for greater income generation for Bangladeshi farmers. Based on results from the first study, a revised research protocol was implemented. We eliminated alternate day feeding (benefit-cost ratio is less than that of 50% daily feeding) and replaced it with a 75% daily ration group that may result in growth that better approximates that observed under standard 100% feed ration and that yields improved growth over the 50% daily ration group, while still providing additional benefits of reduced feed inputs and the culture of Indian carps. The experimental design for this study is shown in Table 1.

This design contrasts the current practice of intensive shing catfish monoculture (T1) against treatments incorporating carps (T2), or semi-intensive culture with 75% and 50% reductions in daily ration (T3, T4). The treatment groups were randomly assigned to ponds (N =15, 100 m^2, 1.5 m depth). Prior to flooding and stocking, the ponds were dried, re-excavated, and limed (25 g $CaCO_3/m^2$). They were fertilized initially at 28 kg N and 5.6 kg P/ha prior to stocking. During the production period (165 days), T3 and T4 ponds were fertilized at a rate of 28 kg N/ha/week and 5.6 kg P/ha/week. Full rations of floating commercial feed (30% crude protein) was provided using a standard feeding rate currently employed by farmers (20% bw/day, 0–30 days; 15%, 31–60 days; 10%, 61–90 days; 5%, > 90 days). The reduced-feeding groups received either 75% or 50% less feed. Feed amounts were recorded for feed conversion and cost-benefit analysis performed at the end of study. All ponds were sub-sampled every 15 days for collection of weight and length. Rohu and catla were captured by seine net and bottom dwelling shing by cylindrical bamboo traps.

Fingerlings of rohu (~20 g), catla (~25 g) were collected from a local supplier and shing fingerlings (~2 g) from Authentic Matshya Hatchery, Mymensingh, Bangladesh. Fifty fingerlings of rohu, 20 fingerlings of catla and 50 fingerlings of shing were randomly sampled for measuring of length and weight prior to stocking.

Water quality was monitored daily (dO_2, pH, transparency by Secchi -disk depth), while additional parameters, e.g., ammonia, nitrites, nitrates, total phosphate, total alkalinity, and chlorophyll *a* were measured fortnightly by the Water Quality and Pond Dynamics Laboratory at BAU. Production yields (market weight, kg; length, g), estimated market returns, feed input costs (feed, fertilizers, fingerlings), and labor costs were gathered for all treatment groups at the end of study for marginal cost-benefit analysis.

The following equations were used to determine the growth parameters:

Weight gain (g) = Mean final weight − Mean initial weight

SGR (% bw d^{-1}) = [{Ln (final weight) – Ln (initial weight)} ÷ Culture period in days] × 100.

Survival (%) = (number of fish harvested ÷ number of fish stocked) ×100

Gross production = Number of fish harvested × Final weight of fish

Net production = Number of fish harvested x Weight gain of fish

All treatments were tested for significant differences in growth (mean length, weight X time), growth efficiency (specific growth rate, feed conversion ratio), and water quality using Analysis of Variance ($p < 0.05$).

Study 2 — Effect of stocking density for koi/carp polyculture using the feeding-fertilization strategy developed for shing catfish. The 50% reduced ration with pond fertilization was identified to yield the best returns for shing catfish (T4, Study 1). We tested whether this management could be implemented for polyculture production of air-breathing koi with Indian carps (rohu and catla). As production of only one carp may prove useful under reduced-feeding, we also tested different stocking levels for these two carps. The experimental design used is shown in Table 2.

The treatment groups were randomly assigned to ponds (N = 12, 100 m^2, 1.5 m depth).
All treatment groups were fed a commercial diet (30% crude protein) at half the ration typically used by farmers (e.g. 20%–5% bw/day). Therefore, koi were fed at the beginning of the trial at 10% bw/day for 30 days, 7.5% bw/day for days 31–60, 5% for days 61–90, and 2.5% thereafter. Only the biomass of koi was

used for calculating feed inputs. The preparation of ponds, fertilization rates, and sample collection (growth data, water quality parameters) were performed as described in Study 1. As outlined in Study 1, the final production yields (market weight, kg; length, g), estimated market return, feed and labor costs were determined at the end of the study for an additional cost-benefit analysis. Treatments were tested for significant differences in growth (mean length, weight X time), growth efficiency (specific growth rate, feed conversion ratio), and water quality using analysis of variance (ANOVA) ($p < 0.5$).

The marginal cost-benefit for Experiments 1 and 2 (BAU) were addressed to determine whether semi-intensive polyculture of shing catfish and koi farming with Indian carps is economically more profitable and can reduce costs so smaller scale farmholders might adopt the practice. Water quality analyses determined the potential environmental benefits of the new semi-intensive polyculture technology on shing/koi culture. Results were presented to representatives from local extension agencies for further consideration and promotion to rural farmers. Perceived benefits from this analysis, including increased fish production, greater cost savings, market profitability, and feasibility for semi-intensive culture, along with promoting greater consumption of fish with high nutrient content (e.g., shing and koi), were extended to rural farmers through presentations at a local farmer's day event. The research outcomes were also disseminated through production of an extension factsheet in the local language for wider outreach to farmers, extension agencies of the government, and nongovernmental organizations (NGOs).

RESULTS AND DISCUSSION

Study 1 — Assess reduced-feeding strategies for combined polyculture of two major carps (rohu and catla) with shing catfish. This study evaluated the potential benefits of polyculture of shing with Indian major carps and of reduced feeding strategies on fish production. Water quality parameters are listed in Table 3. There were no differences in water quality among any of the treatments except for ammonia and nitrates, which were higher in the two treatments utilizing fertilizer to boost primary production of plankton (T3 and T4).

Four different groups of organisms were identified in the benthic samples collected in this study (Table 4). These included Chirnomid larvae, Oligocheta, mollusks, and unidentified organisms. The number of total benthic organisms were highest in treatments 3 and 4 (ponds that were fertilized weekly).

During the study period, five groups of phytoplankton were identified: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, and Rhodophyceae. In addition, four groups of zooplankton were identified in the experimental ponds: Cladocera, Copepoda, Rotifera, and Crustacea (Table 5). The total phytoplankton counts were highest in treatment 1 and total zooplankton counts were highest in treatment 3.

Table 6 summarizes the growth and production performance for Study 1. There was no difference in growth (weight and length) between any of the treatments for each species, shing catfish (Figure 1), rohu (Figure 2), or catla (Figure 3). There was also no difference in specific growth rate (SGR) or survival between the treatments (summarized in Table 6). Kohinoor et al. (2012) reported a harvesting weight of 49.50 g ± 4.52 g to 69.42 g ± 6.20 g and survival rate as 71% ± 2.64% to 87% ± 3.6% in a six month study of shing catfish monoculture. Chakraborty and Nur (2012) reported a mean harvesting weight of shing catfish varied between 30.24 g ± 3.91 g to 50.14 g ± 3.22 g in monoculture or in polyculture with koi (*A. testudineus*) and a survival rate of 64.70% ± 4.88% to 87.55% ± 2.02%. Stocking densities in these intensive culture systems ranged from 7.5 to 25 fish/m^2. The lower harvesting weight observed here is likely attributed to the spawning of the shing, which coincided with the slower rate of growth that occurred at around 90 days into the study.

There was no difference in gross or net production between treatments within species (Table 6). Total net fish production was higher in the polyculture treatments 2, 3, or 4 than in shing monoculture. Production values for carp polyculture of between 1,800 and 2,000 kg/ha have been previously reported (Mazid and Hossain 1999, Sharma and Thakur 1998) which are lower than those reported in this study (2,450–2,680 kg/ha). The feed conversion ratio (FCR) calculated for shing in treatment 1 was quite high due in part to survival rates of 50% and wastage of feed, exacerbated by lack of growth and reproductive activity found in the later 60 days of the study. It is possible that fish may have crawled and escaped from the ponds, particularly with heavy rains. Future studies should incorporate a barrier around the pond to prevent this potential occurance. Additionally, harvest of shing at an earlier period (100–120 days) when body weights tended to peak may have benefit both to reducing the FCR and improving returns on investment.

When we considered the economic return among treatment groups with a decreasing level of investment from treatment 1 to 4, this study found that the gross return for treatment 1 was significantly lower (negative) when compared to the other three treatments (Table 7). The highest economic returns were from the lowest feed input treatment groups (Figure 4). Benefit cost ratios were also highest in shing fed at 75% and 50% reduced ration in treatment 3 (BCR = 1.93) and 4 (BCR = 2.37), respectively. Moreover, a net positive BCR of 1.55 was seen when carps alone were introduce to shing culture

This study indicates that reduced feed rationing along with pond fertilization does not affect the growth or production of shing catfish, rohu, or catla in polyculture. Rohu and catla primarily feed on planktonic organisms, therefore application of feed does not contribute significantly to their growth, hence they can be supplemented with shing production systems without additional costly feed inputs. Taken together, these studies suggest: 1) that shing can be polycultured with major Indian carps with little impact on survival or growth of the species, 2) addition of carps to shing culture increases the net production of fish and provides greater returns on investment that shing monoculture, and 3) combined pond fertilization and application of 50% less feed further improves economic returns by > 50% of shing-carp polyculture with no impact on fish production.

Study 2 — Effect of stocking density for koi/carp polyculture using the feeding-fertilization strategy developed for shing catfish. This study was designed to assess to determine whether air-breathing koi (Study 1) can be polycultured with Indian carps (rohu and catla). We also tested if there might be benefits to koi-carp polyculture when stocking rohu or catla alone or both in at a 4:1 rohu:catla ratio. Based on the feeding protocol that yielded the best results in shing-carp polyculture in Study 1, fish were fed at half the recommended ration (e.g. 20%–2.5% bw/day). Application of feed was based only on biomass of koi. All ponds were fertilized to provide primary productivity for fishes, namely carps. We found no difference in water quality among any of the treatments assessed in this study (Table 8).

Four different groups of organisms were identified in the benthic samples collected in this study (Table 9). These included Chirnomid larvae, Oligocheta, mollusks, and unidentified organisms. The number of total benthic organisms were highest in treatment 3 (koi raised with catla alone).

During the study period, six groups of phytoplankton were identified: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Xanthophyceae, and Rhodophyceae. In addition, five groups of zooplankton were identified: Cladocera, Copepoda, Rotifera, Crustacea, and Protozoa were identified in the experimental ponds (Table 10). Although total phytoplankton counts were highest in treatment 2 and total zooplankton counts were highest in Treatment 3, there were no significant difference in plankton counts among the treatment groups.

Table 11 summarizes the growth and production performance for Study 2. There was no difference in growth (weight) between any of the treatments for each species, koi, rohu, or catla. When cage cultured, koi raised at 150 fish/m^3 had the greatest mean harvesting weight of 118.60 g ± 2.535 g (Habib et al. 2015). Koi harvesting weights have been reported between 86.02 g ± 1.02 g to 90.00 g ± 2.00 g (Helal

2014). Mean harvesting weight in the present study was substantially higher (129–148 g; Figure 5, Table 11) which may relate to differences in feed, fertilizers, and stocking density used among the studies.

The survival rate of koi did not vary significantly between treatment (64.36% ± 9.92% to 77.36% ± 11.74%; Figure 6; Table 11). Ahmed et al. (2015) reported the highest survivability of koi was 87% when stocked at a rate of 150 fry/dec (3.75 fry/m^2) but was 69% when stocked at a rate of 350 fry/dec (8.75 fry/m^2). Here, ponds were stocked at a rate of 5 koi/m^2, and survival rates fell within the range observed in these other studies. Catla and rohu survival declined when each was cultured alone compared to when they were cultured together with koi ($p < 0.01$; Figure 6). Variation in stocking density may affect survival rates and final production of carps, although there were no significant differences in specific growth rate for each species among the treatments (Figure 6).

Gross and net production of koi was significantly higher when koi were grown with catla (treatment 3) than with rohu only (treatment 2) or with both catla and rohu (Treatment 1; Table 11, Figure 7). Both parameters were greater for catla when the fish was grown alone at 1.0/m^2 with koi that when grown at a stocking density of 0.2/m^2 with rohu and koi. No differences in gross or net production was found with rohu whether cultured alone with koi or in combination with catla and koi. The combined gross production in this study did not vary between treatments but the combined net production was highest in treatment 3 (the combined culture of koi and catla) than in treatment 2 (the combined culture of koi and rohu, Figure 10d). The overall feed conversion ratio (FCR) based on biomass of all fishes did not significantly vary between treatment (Figure 8). The benefit cost ratio (BCR) was highest for treatment 1 (1.95) followed by treatment 3 (1.87) and treatment 2 (1.86). However, there was no significant difference in BCR between any treatment (Table 12).

Taken together, these results indicate that koi can be polycultured with carps and that this system produces significant returns on investment of around 450,000 BDT/ha when fish are fed at a rate of 10% bw/day–2.5% bw/day and ponds are fertilized weekly. While the best polyculture production may occur when koi are solely cultured with catla, koi can also be cultured with either rohu alone or both rohu and catla at a 4:1 ratio.

CONCLUSION

Air-breathing fishes provide a significant advantage for pond culture, as they tend to be resilient to harsh conditions, particularly during periods of low-oxygen, which can occur with high temperatures, poor water quality and other conditions. Currently, production of the air breathing fishes, shing and koi are limited to monoculture systems with intensive use of commercial-grade feeds (30%–35% crude protein) at rates of application from 20% down to 5% body weight/day. As feed can comprise up > 80 % of total production costs, as demonstrated here, the current practices for these fish limit participation by small homesteads and therefore comprise a significant impediment to further expansion of this industry. The research presented here suggests that addition of major Indian carps (rohu and catla) to shing catfish enhances total fish yields, increases return on investment with little impact on growth of shing. Reducing the daily rate of feeding by 50% provides an additional 80% profit. Farmers, therefore, have the potential to enhance their income opportunities by incorporating carps and reducing feed inputs in the growout of shing catfish while providing a more sustainable product. Our studies also suggest that koi grow well with carps and production may be best with catla alone. Future studies are required to directly compare koi monoculture and koi-carp polyculture and the impacts of feed and fertilization inputs. Two extension brochures were produced and a farmers day workshop was provided to disseminate the new polyculture technologies. Several M.S. graduate students also received research training to build capacity in the Bangladesh fisheries and aqaculture sectors.

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TABLES AND FIGURES

Table 1. Experimental design for Study 1.

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Rohu (*L. rohita*)	0	80 (0.8/m^2)	80 (0.8/m^2)	80 (0.8/m^2)
Catla (*C. Catla*)	0	20 (0.2/m^2)	20 (0.2/m^2)	20 (0.2/m^2)
Shing (*H. fossilis*)	200 (5.0/ m^2)	200 (5.0/ m^2)	200 (5.0/ m^2)	200 (5.0/ m^2)
Fertilization	0	0	4:1 (N: P)	4:1 (N: P)
Feeding Protocol	100% ration	100% ration	75% ration	50% ration
Replicates (*n*)	3	4	4	4

Table 2. Experimental design for Study 2.

	Treatment 1	***1.1.1*** *Treatment 2*	*Treatment 3*
Rohu (*L. rohita*)	80 (0.8/m^2)	100 (1.0/m^2)	none
Catla (*C. Catla*)	20 (0.2/m^2)	none	100 (1.0/m^2)
Koi (*A. testudineus*)	500 (5.0/m^2)	500 (5.0/m^2)	500 (5.0/m^2)
Fertilization/Feeding	50% daily ration	50% daily ration	50% daily ration
Replicates (*n*)	4	4	4

Table 3. Water quality parameters from Study 1. Values are mean ± SD. Values with different letters are significantly different ($P < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Temperature (°C)	30.31±1.59	30.33±1.43	30.18±1.42	30.26±1.44
Transparency (cm)	24.42±14.44	25.31±11.33	25.43±10.90	27.10±10.62
Total Alkalinity (mg/L)	86.61±32.90	95.89±36.96	89.27±37.48	93.57±36.56

pH	7.49±0.46	7.54±0.49	7.51±0.48	7.53±0.50
Dissolved Oxygen (mg/L)	6.31±0.81	6.19±0.85	6.18±0.84	6.30±0.83
Nitrate (mg/L)	0.08±0.0[c]	0.08±0.07[c]	0.25±0.26[a]	0.16±0.17[b]
Nitrite (mg/L)	0.08±0.15	0.08±0.13	0.13±0.17	0.10±0.15
Ammonia (mg/L)	0.26±0.23[a]	0.17±0.14[a]	0.32±0.43[ab]	0.48±0.66[b]
Phosphate (mg/L)	0.68±0.43	0.75±0.49	0.82±0.54	0.66±0.48
Chlorophyll-a (mg/L)	323.67±266.18	243.54±216.44	249.64±223.71	194.63±36.56

Table 4. Benthic organisms identified in Study 1. Values are mean abundance (×10^3 cells/L) ± SD.

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Oligochaeta	125.43±90.07	113.33±46.91	137.77±37.75	90.37±28.39
Chironomidae	356.54±93.03	783.70±114.35	978.51±137.04	1057.03±287.55
Mollusca	61.23±31.07	48.88±23.47	40±15.05075	69.62±18.83
Unidentified	26.66±5.04	80±18.28	82.96±17.17	42.22±14.22
Total Benthos	569.87±172.95	1,025.92±140.03	1,239.25±134.91	1,259.25±294.45

Table 5. Plankton populations identified in Study 1. Values are mean abundance (×10^3 cells/L) ± SD.

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Chlorophyceae	71.27±4.67	71.25±3.03	80.72±4.14	82.90±3.89
Cyanophyceae	108.09±13.34	51.01±3.43	75.76± 8.08	57.92±4.44
Bacillariophyceae	27.90±1.77	27.90±1.64	31.58±1.87	30.90±1.65
Euglenophyceae	16.41±2.73	22.70±2.99	30.21±5.84	41.10±5.44
Rhodophyceae	3.53±0.64	4.63±0.69	4.98±0.75	5.16±0.66
Total phytoplankton	232.75±14.8	178.78±7.11	224.70±12.07	217.72±10.76
Rotifera	13.06±1.40	13±1.41	18.89±2.29	16.69±1.60
Crustacea	1.35±0.34	1.05±0.24	0.92±0.24	1.14±0.25
Cladocera	0.48±0.24	0.80±0.27	0.65±0.24	0.90±0.23
Copepoda	0.94±0.27	0.43±0.13	0.58±0.17	0.87±0.19
Total Zooplankton	16.07±1.79	16.00±1.59	21.38±2.24	20.21±1.91
Total Plankton	248.82±1.52	194.78±7.55	246.08±1.28	237.95±1.11

Table 6. Growth performance outcomes for Study 1. Values are mean ± SD. Values with different letters are significantly different ($P < 0.05$). NA = not applicable.

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Shing (*Heteropneustes fossilis*)				
Stocking Weight (g)	1.13 ± 0.98	1.13 ± 0.98	1.13 ± 0.98	1.13 ± 0.98
Harvesting Weight (g)	24.73±3.45	20.62±3.50	22.70±2.34	24.44±5.09
Weight Gain (g)	23.60±3.45	19.49±3.50	21.57±2.34	23.31±5.09
Initial Length (cm)	5.53±1.67	5.53±1.67	5.53±1.67	5.53±1.67
Final Length (cm)	16.08±2.10	15.28±2.12	15.59±2.18	15.99±2.77
Net Length (cm)	10.55±2.10	9.75±2.12	10.06±2.18	10.46±2.77
Survival Rate (%)	53.00±6.36	47.50±5.02	52.00±2.44	53.35±2.00
Specific Growth Rate, SGR (%)	1.83±0.08	1.72±0.10	1.78±0.06	1.82±0.13
Gross Production (kg/ha)	652.21±158.42	483.65±100.90	583.71±70.80	644.23±134.30
Net Production (kg/ha)	622.63±155.25	457.14±99.46	554.68±69.99	614.44±134.09
Rohu (*Labeo rohita*)				
Stocking Weight (g)	NA	21.76± 7.76	21.76± 7.76	21.76± 7.76
Harvesting Weight (g)	NA	304.81±106.6	309.63±103.26	279.92±119.29
Weight Gain (g)	NA	283.05±106.61	287.87±103.26	258.16±119.29
Initial Length (cm)	NA	12.48±1.40	12.48±1.40	12.48±1.40
Final Length (cm)	NA	28.95±2.54	29.58±2.08	28.02±3.34
Net Length (cm)	NA	16.47±2.54	17.1±2.08	15.54±3.34
Survival Rate (%)	NA	90.63±8.92	89.38±8.75	92.19±3.73
Specific Growth Rate, SGR (%)	NA	1.54±0.22	1.55±0.21	1.48±0.27
Gross Production (kg/ha)	NA	2126.67±561.52	2218.06±874.12	2062.45±941.87
Net Production (kg/ha)	NA	1970.80±575.10	2064.34±863.13	1903.90±936.21
Catla (*Catla catla*)				
Stocking Weight (g)	NA	27.30± 8.23	27.30 ± 8.23	27.30 ± 8.23
Harvesting Weight (g)	NA	368.60±117.88	402.08±57.89	389.40±119.54
Weight Gain (g)	NA	341.30±117.88	374.78±57.89	362.10±119.54
Initial Length (cm)	NA	13.05±1.36	13.05±1.36	13.05±1.36
Final Length (cm)	NA	29.63±2.24	30.46±1.58	29.69±3.48
Net Length (cm)	NA	16.58±2.24	17.41±1.58	16.64±3.48
Survival Rate (%)	NA	96.25±3.50	88.75±10.15	91.25±4.79
Specific Growth Rate, SGR (%)	NA	1.53±0.20	1.60±0.09	1.56±0.18
Gross Production (kg/ha)	NA	692.84±196.38	708.89±163.02	701.48±220.48
Net Production (kg/ha)	NA	640.91±197.96	661.01±157.20	652.26±220.21
Combined				
Feed Conversion Ratio, FCR	15.23±3.26^{b}	2.35±0.61^{a}	1.74±0.48^{a}	1.37±0.49^{a}
Gross Production (kg/ha)	652.21±158.42^{a}	3303.16±825.23^{b}	3510.66±904.85^{b}	3408.16±853.72^{b}
Net Production (kg/ha)	622.63±155.25^{a}	3068.85±774.45^{b}	3280.04±852.98^{b}	3170.60±805.46^{b}

Table 7. Economic analyses from Study 1. Values are mean ± SD. Values with different letters are significantly different (*P* < 0.05). NA = not applicable.

	Treatment 1	*Treatment 2*	*Treatment 3*	*Treatment 4*
Financial Input (BDT/ha)				
Lime	2,470	2,470	2,470	2,470
Urea	1,033[a]	1,033[a]	20,659[b]	20,659[b]
TSP	729[a]	729[a]	14,582[b]	14,582[b]
Shing	61,750	61,750	61,750	61,750
Rohu	NA	39,520	39,520	39,520
Catla	NA	19,760	19,760	19,760
Feed	517,003[d]	398,449[c]	309,733[b]	228,050[a]
Labor and Others	10,000	10,000	10,000	10,000
Total Cost	592,986[d]	533,712[b]	478,475[c]	396,792[a]
Financial Return (BDT/ha)				
Shing	489,159	362,738	437,783	483,169
Rohu	NA	361,534	377,070	350,617
Catla	NA	103,925	106,334	105,222
Total Return	489,159[a]	828,197[b]	921,187[b]	939,008[b]
Net Return	-103,827[a]	294,485[b]	442,711[b]	542,215[b]
BCR	0.82[a]	1.55[b]	1.93[bc]	2.37[c]

Note: Sale price of shing catfish, rohu and catla were 750, 170 and 150 BDT/kg, respectively.

Table 8. Water quality parameters from Study 2. Values are mean ± SD.

	Treatment 1	*Treatment 2*	*Treatment 3*
Temperature (°C)	29.39±1.25	29.57±1.22	29.60±1.45
Transparency (cm)	28.01±14.82	24.22±14.39	28.12±16.30
Total Alkalinity (mg/L)	136.33±39.83	141.59±34.48	135.96±36.32
pH	7.88±0.48	7.89±0.57	7.79±0.46
Dissolved Oxygen (mg/L)	5.22±1.43	4.93±1.43	5.04±1.60
Nitrate (mg/L)	0.19±0.18	0.20±0.19	0.22±0.18
Nitrite (mg/L)	0.13±0.15	0.10±0.15	0.13±0.13
Ammonia (mg/L)	0.34±0.26	0.35±0.57	0.31±0.33
Phosphate (mg/L)	1.51±0.81	1.14±0.83	1.20±0.70
Chlorophyll-a (µg/L)	96.01±95.32	108.93±102.06	158.90±158.01

Table 9. Benthic organisms identified in Study 2. Values are mean abundance (×10^3 cells/L) ± SD. Values with different letters are significantly different ($P < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*
Oligochaeta	230.45±237.63[a]	222.63±240.64[a]	436.63±487.81[b]
Chironomidae	590.53±494.35[a]	505.35±455.65[a]	1226.7±1156.41[b]
Mollusca	289.30±313.44	258.85±308.11	274.90±272.99
Unidentified	12.34±29.94	9.46±22.71	7.40±16.79
Total	1122.62±696.04[a]	996.29±646.25[a]	1945.63±1520.50[b]

Table 10. Plankton populations identified in Study 2. Values are mean abundance (×10^3 cells/L) ± SD. Values with different letters are significantly different ($P < 0.05$).

	Treatment 1	*Treatment 2*	*Treatment 3*
Bacillariophyceae	10.06±6.86	14.81±13.84	10.34±9.06
Chlorophyceae	14.50±15.50	12.47±11.61	10.09±9.70
Cyanophyceae	25.84±42.95	37.75±54.03	18.81±39.55
Euglenophyceae	2.81±4.05	2.75±3.68	4.88±11.88
Rhodophyceae	0.00±0.00	0.00±0.00	0.00±0.00
Xanthophyceae	0.00±0.00	0.00±0.00	0.03±0.18
Total phytoplankton	53.22±44.40	67.78±50.93	44.16±42.16
Copepoda	7.44±5.92[c]	12.41±10.30[a]	8.03±6.00[b]
Crustacea	0.00±0.00	0.00±0.00	0.00±0.00
Rotifera	17.56±21.80[b]	6.38±8.31[c]	20.66±23.67[a]
Cladocera	1.84±3.36[c]	7.25±15.18[a]	3.88±7.52[b]
Protozoa	0.00±0.00	0.00±0.00	0.00±0.00
Total zooplankton	26.84±24.10	26.03±23.95	32.56±26.39
Total plankton	80.06±44.72	93.81±54.40	76.72±43.81

Table 11. Growth performance outcomes for Study 1. Values are mean ± SD. Values with different letters are significantly different (*P* < 0.05). NA = not applicable.

	Treatment 1	*Treatment 2*	*Treatment 3*
Koi (*A.testudinius*)			
Stocking Weight (g)	2.94±0.87	2.94±0.87	2.94±0.87
Harvesting Weight (g)	129.24±36.27	148.39±28.39	144.13±15.79
Weight Gain (g)	126.30±36.27	145±28.39	141.19±15.79
Survival Rate (%)	72.64±23.46	64.36±9.92	77.36±11.74
Specific Growth Rate (SGR) (%/day)	3.13±0.25	3.26±0.17	3.24±.09
Gross Production (kg/ha)	4,324.76±390.17[b]	4,617.63±374.3[b]	5,459.23±532.17[a]
Net Production (kg/ha)	4,219.25±378.42[b]	4,524.16±381.24[b]	5,346.88±521.64[a]
Rohu (*L. rohita*)			
Stocking Weight (g)	22.92±3.20	22.92±3.20	NA
Harvesting Weight (g)	162.6±33.35	142.08±22.48	NA
Weight Gain (g)	139.68±33.35	119.16±22.48	NA
Survival Rate (%)	99.69±0.63[a]	90.88±7[b]	NA
Specific Growth Rate (SGR) (%/day)	1.62±0.17	1.51±0.13	NA
Gross Production (kg/ha)	1,282.11±268.31	1,272.06±188.51	NA
Net Production (kg/ha)	1,101.52±267.44	1,066.28±185.65	NA
Catla (*G. catla*)			
Stocking Weight (g)	30.7±10.29	NA	30.7±10.29
Harvesting Weight (g)	243.85±92.72	NA	198.7±44.10
Weight Gain (g)	213.15±92.72	NA	168±44.10
Survival Rate (%)	84.17±9.86[a]	NA	54.13±7.92[b]
Specific Growth Rate (SGR) (%/day)	1.68±0.34	NA	1.54±0.2
Gross Production (kg/ha)	394.57±116.59[b]	NA	1,086.29±356.48[a]
Net Production (kg/ha)	343.51±120.07[b]	NA	922.12±333.45[a]

Table 12. Economic analyses from Study 2. Mean values with different letters are significantly different ($P < 0.05$). NA = not applicable.

	Treatment 1	*Treatment 2*	*Treatment 3*
Financial Input (Taka/ha)			
Salt	5,928	5,928	5,928
Lime	8,892	8,892	8,892
Urea	7,231	7,231	7,231
TSP	5,529	5,529	5,529
Koi	98,800	98,800	98,800
Rohu	39,520^{b}	49,400^{a}	NA
Catla	17,784^{b}	NA	88,920^{a}
Feed	280,901	302,308	299,757
Labor and Others	10,000	10,000	10,000
Total Cost	474,585	488,088	525,057
Financial Return (Taka/ha)			
Koi	648,713^{b}	692,645^{b}	818,885^{a}
Rohu	217,959	216,250	NA
Catla	59,186^{b}	NA	162,943^{a}
Total Return	925,858	908,895	981,828
Net Return	451,273	420,807	456,771
BCR (Benefit Cost Ratio)	1.95	1.86	1.87

Note: Sale price of koi, rohu and catla were 150, 170 and 150 BDT/kg, respectively

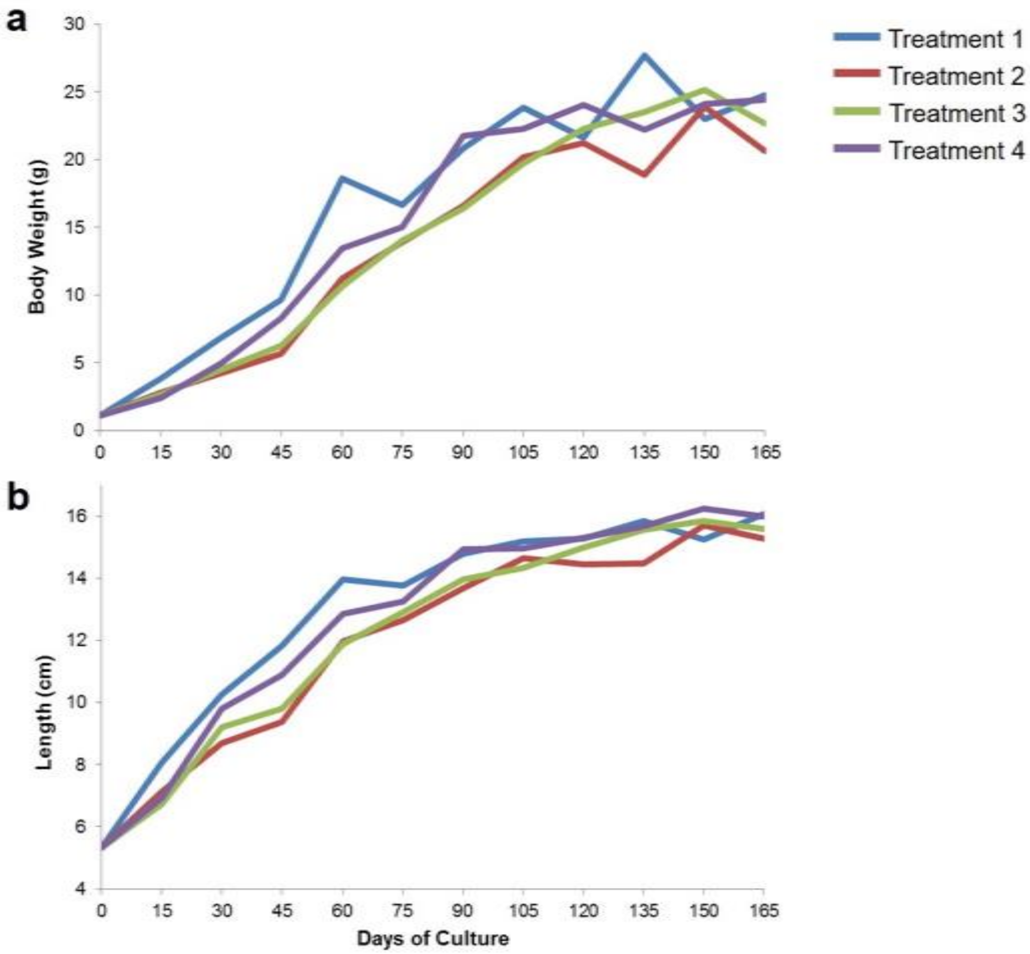

Figure 1. Weight (a) and length (b) of shing catfish (*H. fossilis*) at 15 day sampling periods in Study 1. There was no significant difference in weight or length between treatments throughout the study. Values are mean of the metric at the time of sampling.

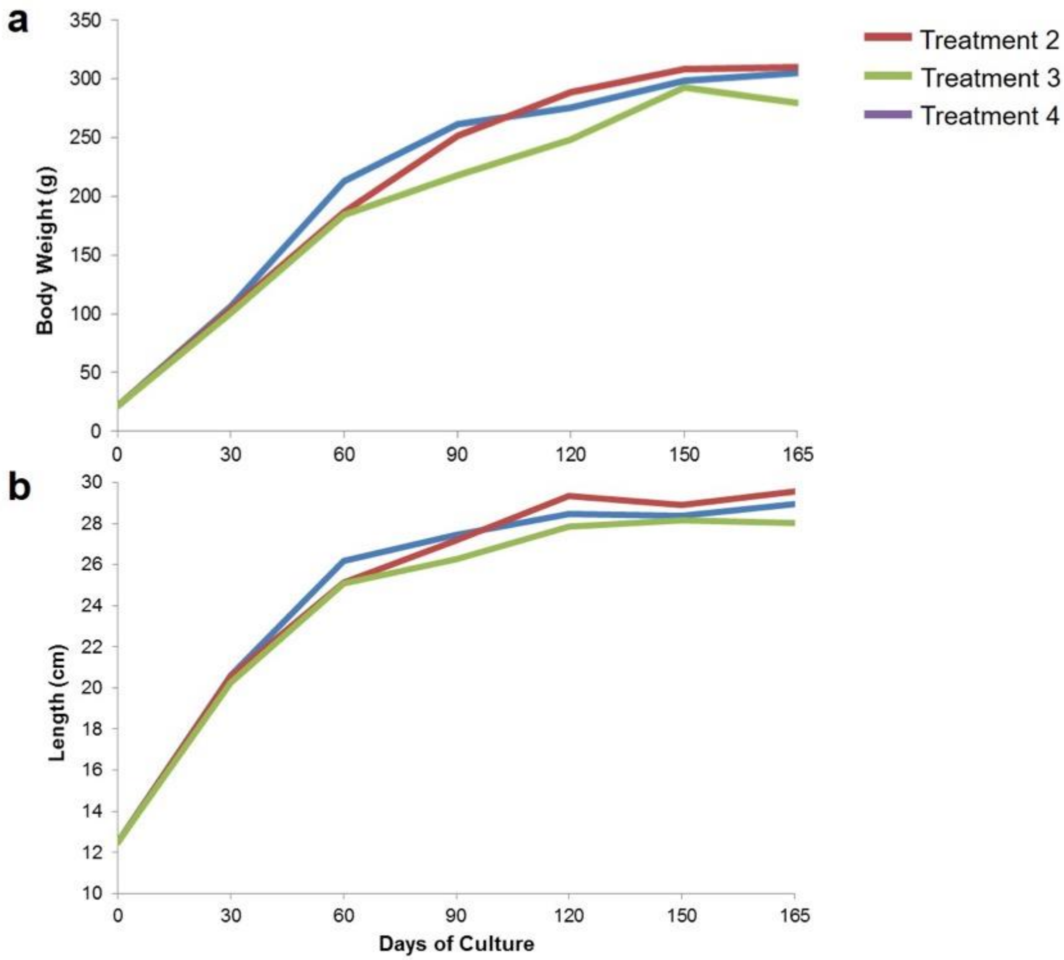

Figure 2. Weight (a) and length (b) of rohu (*L. rohita*) at 15 day sampling periods in Study 1. There was no significant difference in weight or length between treatments throughout the study. Values are mean of the metric at the time of sampling.

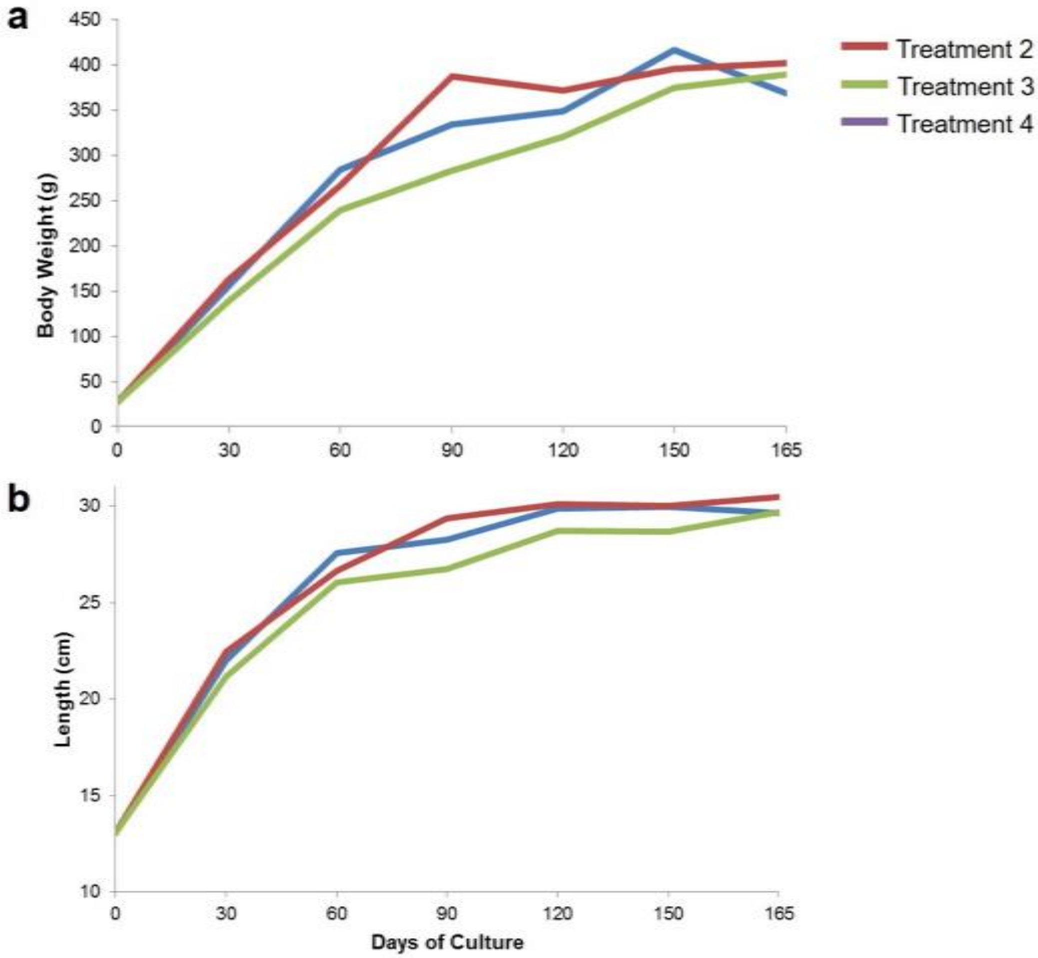

Figure 3. Weight (a) and length (b) of catla (*C. catla*) at 15 day sampling periods in Study 1. There was no significant difference in weight or length between treatments throughout the study. Values are mean of the metric at the time of sampling.

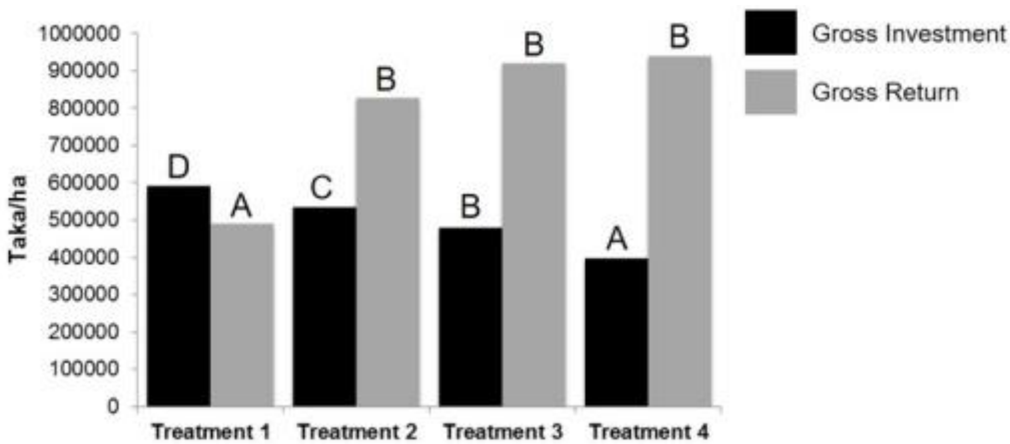

Figure 4. Combined gross investment and return for shing catfish (*H. fossilis*), rohu (*L. rohita*), and catla (*C. catla*) in Study 1. The gross investment was significantly lower in treatment 4 where shing catfish were raised along with both rohu and catla in fertilized ponds fed on alternate days. The gross return for treatment 1 was significantly lower than treatments 2, 3, and 4. Values are mean for treatments. Bars with different letters represent significant differences among treatments ($p < 0.05$).

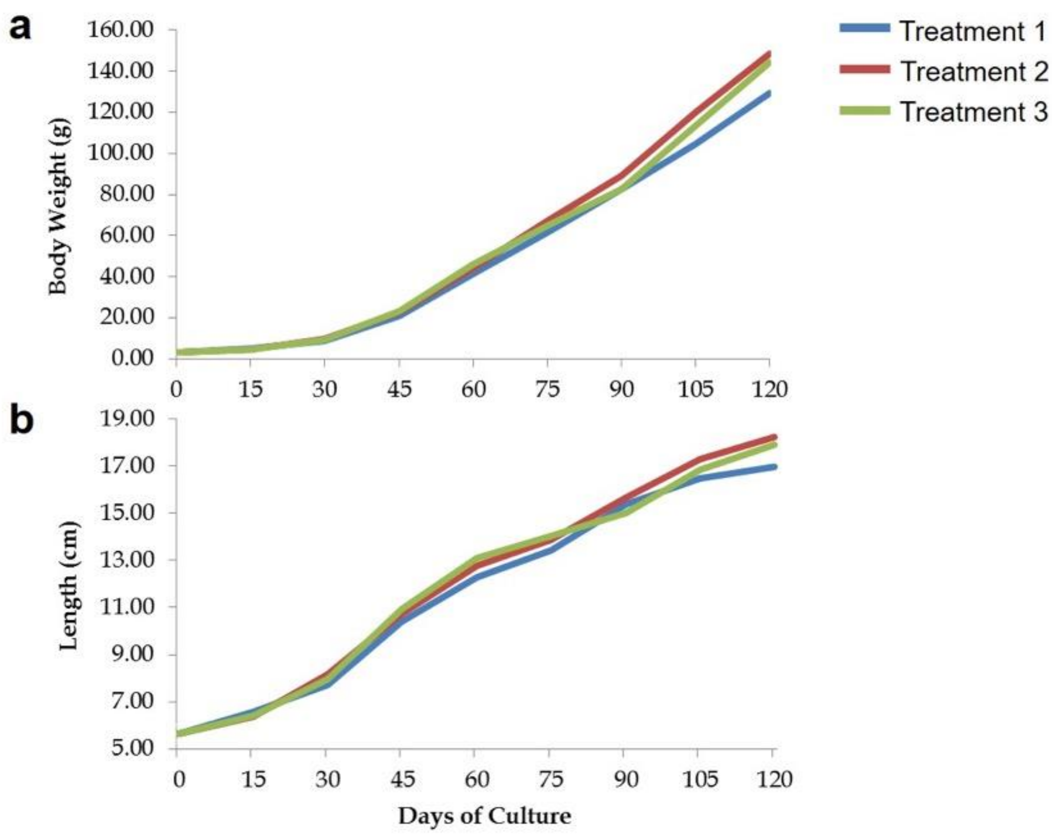

Figure 5. Weight (a) and length (b) of koi (*A. testudineus*) at 15 day sampling periods in Study 2. There was no significant difference in weight or length between treatments throughout the study. Values are mean of the metric at the time of sampling.

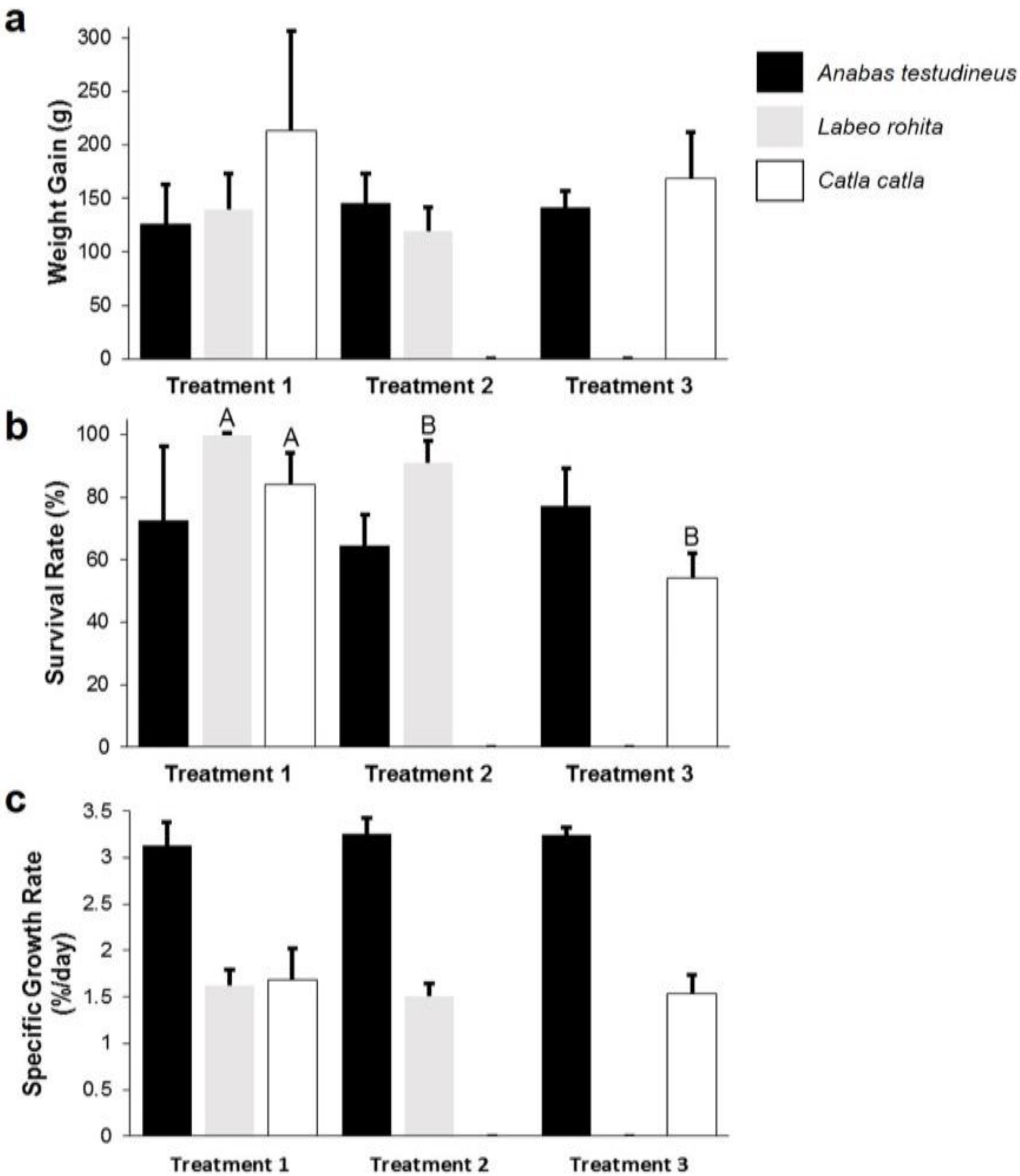

Figure 6. Weight gain, survival rate, and specific growth rate (SGR) for koi (*A. testudineus*), rohu (*L. rohita*), and catla (*C. catla*) in Study 2. There was no difference in weight gain (a) or SGR (c) for any species between treatments or for survival rate for koi (b). The survival rate for rohu in treatment 1 was significantly higher than treatment 2 and for catla in treatment 1 than in treatment 3. Values are mean ± SD. Different letters signify differences between treatments for the each respective species ($P < 0.05$).

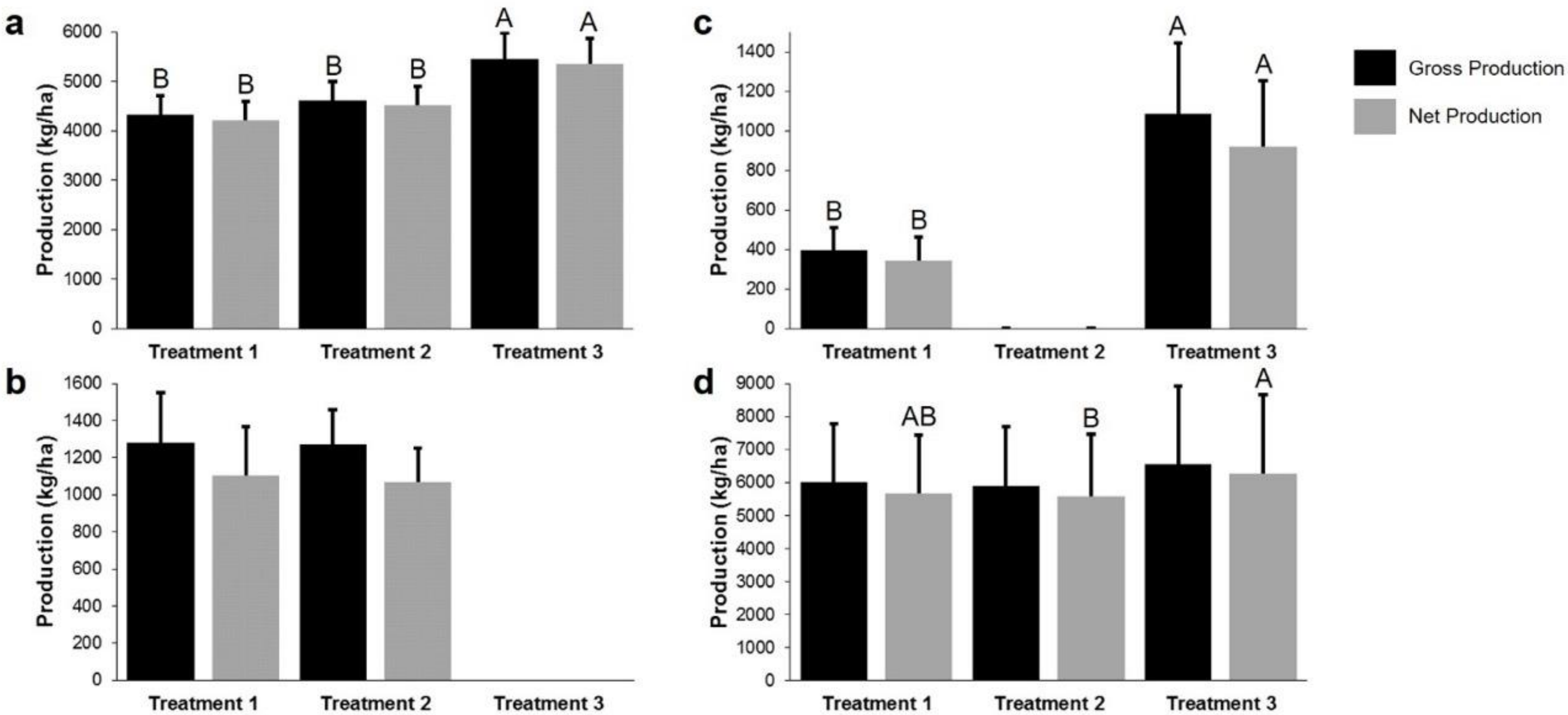

Figure 7. Gross and net production parameters for koi (*A. testudineus*, a), rohu (*L. rohita*, b), catla (*C. Catla*, c), and for combined species (d) in Study 2. Both parameters were significantly higher for koi in treatments where the koi were grown with catla only than when grown with rohu only or both catla and rohu. Catla grown at a stocking rate of 1.0 fish/m^2 resulted in production parameters that were significantly higher than when stocked at 0.2 fish/m^2. There was no significant difference in production of rohu between treatments. When combined, only net production was significantly different between treatment. Values are mean ± SD. Values with different letters are significantly different ($p < 0.05$).

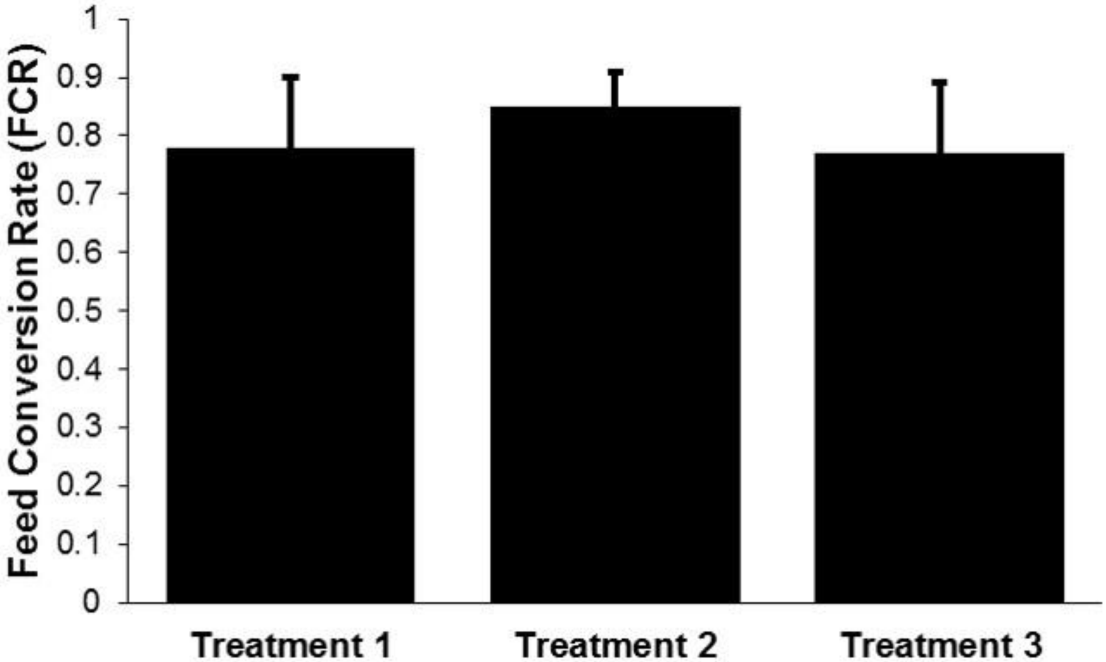

Figure 8. Combined feed conversion ratio (FCR) for koi (*A. testudineus*), rohu (*L. rohita*), catla (*C. catla*) in Study 2. There was no significant difference in overall FCR between treatments. Values are mean ± SD.