博士論文　（要約）

Fish agri-food systems for improving diet quality and nutrition in rural Bangladesh

バングラデシュ農村地域住民の食事の質と栄養の向上に資する農水産物フードシステム

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Declaration

I, Akter Rumana,
Confirm that the work presented in this thesis is my own.
In case of information has been derived from other sources,
I confirm that this has been indicated duly in the thesis.

December 13, 2019

"Be the change that you want to see in the world"

Mahatma Gandhi

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Chapter 1
General Background

1.1 Global Impetus of Hunger, Food Insecurity, and Malnutrition

Malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients [1]. It is an universal problem and it has many forms. All forms of malnutrition are associated with various forms of ill health and mortality. Globally, around 822 million people remain undernourished, and 149 million children are stunted [2]. Undernutrition is associated with around 45% death among children age below five years, in low and middle-income countries [3]. Overweight and obesity contributed to an estimated 4 million deaths (7.1% of all deaths) and lost of 120 million healthy years of life (disability-adjusted life years or DALYs) [4], across people worldwide (4.9% of all DALYs among adults) [5].

Micronutrient deficiencies (vitamins and minerals deficiency) are often referred as 'hidden hunger', as they develop over time without showing any visible sign until irreversible damage has happened to people. This is a serious public health concern especially in developing countries. Globally more than two billion people suffer from micronutrient deficiency and contributing directly and indirectly to morbidity and mortality of billions of people worldwide [6][7]. Millions of children with micronutrient deficiencies have stunted growth, cognitive delays, weakened immunity and disease. Lack of essential vitamins and minerals can be catastrophic to pregnant women, increasing the risk of low birth weight, birth defects, stillbirth, and even death [8]. The burden of malnutrition around the world is unacceptably high, and progress is unacceptably slow[9].

Global panel on agriculture and food systems for nutrition has highlighted that adults earning are 2.4% reduced for 1% loss in attained height. It further added that an estimated US$18 return is achieved from every US$1 invested in reducing in wasting and stunting [10]. Hence, president of the Public Health Foundation of India, and Global Panel Member, prof K. Srinath Reddy quoted that *"Although the price of addressing malnutrition can be huge, evidence shows that the cost of doing nothing is immeasurably greater* [9]*."*

However, malnutrition is caused by various factors such as: water and sanitation, poor hygiene practices, income of household members, level of education, health care seeking behavior and quality health services. But a common cause across all forms of malnutrition is suboptimal diet (including inadequate breastfeeding for babies). Although only diets alone is

not enough to address malnutrition, but it is a necessary component of reducing disability and death from malnutrition across all ages and income groups [11].

To overcome these multiple malnutrition situation, Food and Agriculture Organization (FAO) of the United Nations and International Life Sciences Institute (ILSI) recommended four main strategies: (1) dietary micronutrient intake through increased production and consumption of micronutrient-rich foods; (2) food fortification; (3) supplementation; and (4) global public health and other disease control measures [12]. Food-based strategies, that include diversified food production rich in micronutrients, are the most sustainable approaches to prevent all forms of malnutrition. Increasing access to and consumption of a variety of foods not only has positive effects on nutrition for its intrinsic nutritional value, but also social and economic significance, especially for those living in developing countries where majority people depend on agriculture related activities for their life and livelihood [13]. Nutrition-sensitive agriculture is one of the food based approaches to agricultural development that puts nutritionally rich diversified foods including food fortification at the heart of overcoming malnutrition and micronutrient deficiencies [14].

1.2 Nutrition-Sensitive Agriculture for Reducing Hunger and Food Insecurity

Nutrition-sensitive agriculture is a food based approach that inclines to maximize agriculture's contribution to nutrition. It emphasizes multiple benefits derived from enjoying variety of nutrient rich foods for good nutrition, increased households income through increased production and productivity, and provide livelihood supports to the rural households (Figure 1). Nutrition-sensitive agriculture entails targeting rural poor households, promoting gender equity, and providing nutrition education especially to the women and decision maker of the households , to maximize utilization of the resources, to improve nutritional status of the household members, especially of young children and women. It also promotes partnerships with other sectors that causes malnutrition, namely education, health care, and social protection[15]. Therefore, investment in agriculture is considered as "a critically important opportunity for reducing malnutrition" [16]. Furthermore, agricultural investment need to ensure sustainable food system (SFS), which is "a food system that delivers food and nutrition security for all, in such way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised"[17]. However, a growing number donor organizations, development agencies,

and national governments are committed to support nutrition-sensitive agriculture to improve food and nutrition security and to achieve their development goals [18], as nutrition-specific interventions (interventions or programs that address the immediate determinants of fetal and child nutrition and development—adequate food and nutrient intake, feeding, caregiving and parenting practices, and low burden of infectious diseases) alone [19], will not meet global targets for improving nutrition, even if implemented at scale [20].

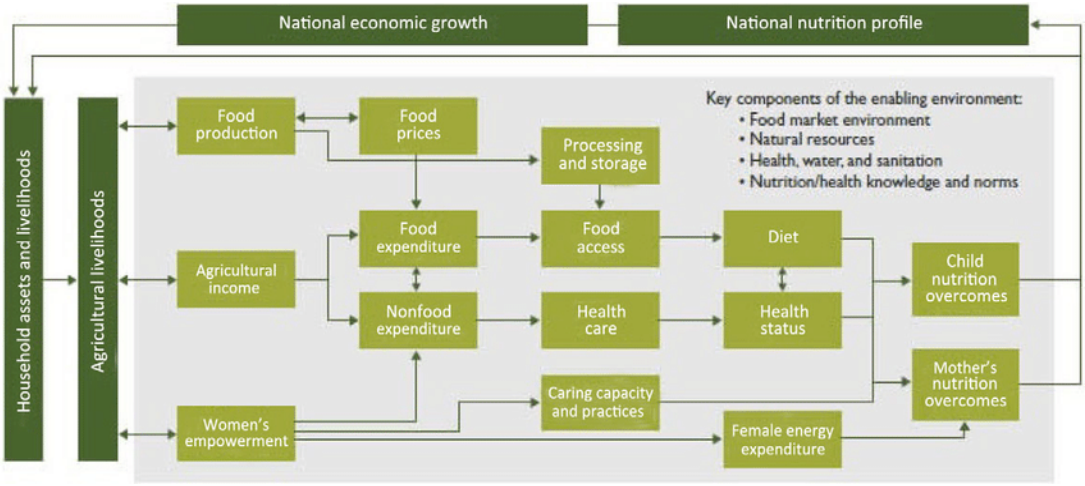


Figure: 1. Conceptual framework of agriculture and nutrition pathways
Source: Herforth & Harris, 2014 [19]

Agriculture has the strong potential to influence the underlying determinants of nutrition outcomes, through enhancing household food security, dietary quality, income, and women's empowerment [21]. Hence, the need of agriculture to support better nutrition and health has been recognized by the United Nations' 2030 agenda for Sustainable Development Goals [22]. Furthermore, identification of critical entry points for where nutrition goals can be incorporated through the nutrition-sensitive production system is also crucial [23]. However, one of the objectives of nutrition-sensitive agriculture is to produce nutrient rich diversified diets, which is a proxy measure for nutrient adequacy in the diet of individuals and a qualitative measure of food consumption that reflects household access to a variety of foods.

1.3 Women Empowerment in Agriculture to Nutrition Pathway

Agriculture is central for economic growth and food security, particularly in countries where a significant number of the population depends on this sector for their livelihoods [24]. But the sector is underperforming in many countries in part because of gender inequalities in

access to agricultural assets and resources. Empowering women and reducing gender inequalities are two key objectives of development policy [25]. Women encompasses about 45% of agricultural labor force, both globally and in developing countries [26][27][28]. They make meaningful contributions to the agricultural and rural economies in all developing countries [29]. Studies have reported that women are ten-times more likely of spending their earning in their family's well-being, such as: child health, education, and nutrition than of men [30] [31]. Moreover, empirical evidence shows that women empowerment improves nutrition for mothers, their children, and other household members [32]. Hence, closing the gender gap in agriculture is essential to increasing agricultural productivity, achieving food security, and reducing hunger [33] [34]. The Women's Empowerment in Agriculture Index (WEAI) aims to increase understanding of the connections between women's empowerment, food security, and agricultural growth. It measures the roles and extent of women's engagement in the agriculture sector in five domains [35]: 1. decisions about agricultural production; 2. Access to and decision making power over productive resources; 3. control over use of income; 4. leadership in the community; and 5. time use.

1.4 Dietary Diversity as a Measure of Food Security and Nutrient Adequacy

According to the World Food Summit, 1996 [36], "Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life". Although agricultural production and productivity has been increased through extensification and intensification to meet the needs of all people in the world, yet food security has not been achieved by all [37]. But many poorer societies and communities do not have access to enough quantity or quality foods and are having multiple micronutrient deficiencies [38]. Furthermore, many households from low and middle income countries, are eating monotonous diets that are low in quality and lack diversity [39]. Therefore, promoting dietary diversity (DD) is suggested as one of the strategies to alleviate nutritional deficiencies in its all forms. Dietary diversity is a qualitative proxy measure of diet quality, especially important for the population with diets based on starchy staples [39]. Furthermore, studies showed that increasing dietary diversity at both household and individual level is associated with increased dietary energy, micronutrient intakes, and anthropometric outcomes [39]. Household dietary diversity score (HDDS) is a population-level indicator and is used as a

proxy measure of household food access [40]. Women reproductive aged (WRA, 15-49 years) are often more vulnerable due to their physiological demand during pregnancy and lactation. Their requirements for most nutrients become higher during pregnancy and lactation than of adult men [41][42]. Furthermore, nutrient intakes before and during pregnancy and lactation can affect both women and their infants [43]. Therefore, in recent years nutrition-sensitive programming in agriculture has been deploying so much of their focus towards good nutrition for women and children, especially during the critical 1,000-day period of a child life (from pregnancy up to the two years age of a child), to break the intergenerational cycle of malnutrition. The Minimum Dietary Diversity for WRA (MDD-W) is a powerful tool to measure impact of nutrition-sensitive efforts [44]. MDD-W is a food group diversity indicator that reflects one key dimension of diet quality and micronutrient adequacy, summarized across 11 micronutrients that are of concern globally [45]. Furthermore, MDD-W is a dichotomous indicator that measure whether or not WRA have consumed at least five out of ten defined food groups in the previous day or night. These ten food groups are: 1. Grains, white roots and tubers, and plantains; 2. Pulses (beans, peas and lentils); 3. Nuts and seeds; 4. Dairy; 5. Meat, poultry and fish; 6. Eggs; 7. Dark green leafy vegetables; 8. Other vitamin A-rich fruits and vegetables; 9. Other vegetables; and 10. Other fruits. The proportion of WRA who reach this minimum criteria of intake in a population, can be considered as achieving minimum acceptable diet, one important dimension of diet quality.

1.5 Animal-Source Food Intake for improving Diet Quality or Nutrient Adequacy

Most stunting (low height for age) manifests in the first 1,000 days of life of a child (from the pregnancy up to the end of two years of a child life) [46]. Stunting in early childhood is associated with low intakes of animal-sourced foods (ASFs) [47]. Various studies have reported that intake of ASFs is strongly associated with better growth, cognition, productivity, and pregnancy outcomes[48][49]. ASFs are not only rich sources of readily digestible high quality protein, but also rich sources of highly bioavailable nutrients of concern globally, such as iron, zinc, calcium, preformed vitamin A, vitamin B12, and folic acid [50]. For vitamin B12, ASFs are the only sources to meet the requirements[50][48]. Studies have shown that adding a small amount of ASF to a plant-based diet, can enhance the absorption of vitamins and minerals from these foods, and can significantly impact maternal health and child development[51][52]; although, certain ASFs such as red meat are subjected to debate, due to

saturated fats and cholesterol. ASFs intake in poorer countries are generally very low. Intake of ASF among young children is relatively low in sub-Saharan Africa and most of Asia. Moreover, multiple ASF consumption in a single day was low in Africa and Asia (<20%) [47]. Furthermore, strong associations between ASF consumption and child growth, particularly consumption of multiple ASFs was reported [47]. However, relatively higher price of ASFs are a critical constraint restricting consumption of these foods by people in developing countries.

1.6 Food Security and Nutrition Situation in Bangladesh

Despite significant achievements in the past in reducing childhood (aged <5 years) undernutrition, it still remains widespread in the country. Recent data shows that 35% children aged below five are stunted (low height for age), 31% underweight (low weight for age), and 10% are wasted (low weight for height). 16% reproductive age women are undernourished (Body Mass Index (BMI)≤18.5 kg/m^2)[53], 29% adult women are overweight (BMI=25–29.99 kg/m^2) and 12% obese (BMI≥30 kg/m^2)[53][54]. According to the Global Hunger Index's severity scale, which is an internationally comparable composite indicator of nutritional status, Bangladesh's situation was found in "serious" category in 2019 [55].

Multiple micronutrient deficiencies in Bangladesh remain high especially among young children, adolescent girls and reproductive aged adult women accounting for $7.9 billion losses of annual national GDP[1] [56]. 45.7% pregnant women, 40% reproductive aged women, and 40.3% pre-school children in Bangladesh are anemic [7]. 23.7% pregnant women and 21.7% pre-school children are vitamin A deficient. Furthermore, 6.5% pregnant women are night blind [57]. Nonetheless, 29.7% people are zinc deficient in the country [58]. Staple-based monotonous diets that lack diversity are largely responsible for the high rate of micronutrient deficiencies in Bangladesh [59][60]. Only 35% reproductive aged women were eating diversified diets in the preceding 24 hours at national level [53]. Common micronutrient deficiencies reported in Bangladesh are vitamin A, iron, calcium, folic acid, zinc, vitamin B12, and iodine [56].

Inadequate intake of animal-source foods (ASFs) is one of the major factors responsible for the poor diet quality, nutrient inadequacy, and undernutrition among young children and

[1] GDP, Gross Domestic Production

women in Bangladesh, as reported by the Food and Agricultural Organization (FAO) and World Health Organization (WHO) [61][47]. Bangladesh has come a long way from being a chronically food deficit country in the 1970s. The country has progressed so much in terms of calorie-sufficiency, (2318 kcal/day/person, which is higher than the estimated minimum requirement of 2122 kcal/day/person), but very little improvement has been occurred in terms of diet quality and diversity [62]. Global Panel on Agriculture and Food System for Nutrition has defined "nutrition of fueling growth of individuals, communities and entire nations rather than only feeding people to meet up the calorie requirements. Therefore, agricultural policy and food system need to be revisited to nourish people than only feeding [63]. It further stated that valuing nutrition quality of agricultural production is more important than yields alone. So far agricultural production systems has never been explicitly designed to meet the health and nutritional needs of the population; but to maximize yields and economic gains for producer [64]. A number of studies have shown that dietary intakes of smallholder households depend to a greater or lesser degree on the food supply from own production [65,66]. Therefore, for the sustainable solutions of malnutrition and to achieve Sustainable Development Goals (SDGs), agriculture/aquaculture production must be closely linked with the nutrition and health needs of people and must be reflected in the agriculture policy [67]. Considering multiple malnutrition problems and poor diet quality among people in rural Bangladesh, overarching research question (RQ) is to examine:

RQ: What are the gaps in dietary nutrient intakes among people in rural Bangladesh?

Specific research questions (RQs) investigated by the doctoral research are:

RQ1: What are the factors affecting diet quality of reproductive age adolescent girls (13-18 years) and adult women (19-49 years)?

RQ2: Whether diet quality of household members is influenced by the type of household engagement with aquaculture and/or horticulture production?

RQ3: What is the most commonly consumed and preferred animal source food by the rural household in southern Bangladesh?

RQ4: Whether nutrition-sensitive homestead pond polyculture food production system engaging women empower them and increase fish intakes of households?

To break the cycle of intergenerational transmission of malnutrition from mother to children, understanding dietary pattern of women reproductive aged (WRA) is crucial. Therefore, RQ1 has identified the gaps in dietary micronutrient intakes among reproductive aged adolescent girls and adult women, and factors affecting their diet quality; from the national rural representative households, in chapter 2.

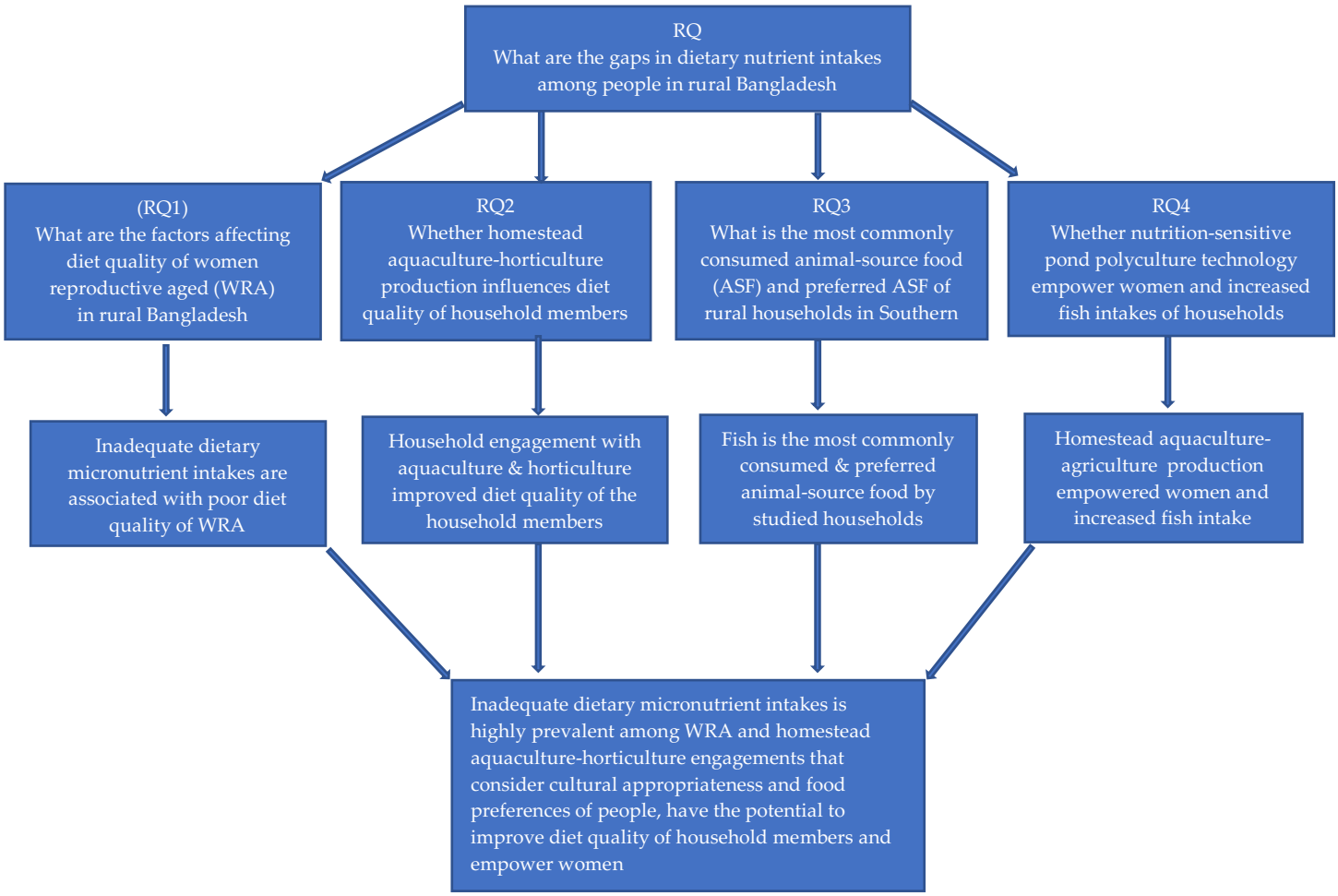
As agriculture is the main occupation for livelihood of about 80% people in rural Bangladesh [68]. Nonetheless, dietary intakes of subsistence farmer largely depend on the food supplies from their own farm. Hence, RQ2 has investigated type of aquaculture and/or horticulture engagements improve diet quality of household members, in chapter 3. This chapter further explored determinants of diet quality or nutrient adequacy of household members.

Studies have shown that inadequate intake of animal-source foods (ASFs) is one of the major factors responsible for poor diet quality and undernutrition, especially among young children and women in Bangladesh [61][69]. Furthermore, for the sustainable solution in malnutrition through improving diet quality among vulnerable groups of population, sustainable food system that is safe, nutritious, culturally preferable and affordable needs to be ensured. Hereafter, RQ3 explored to understand the most commonly consumed and preferred animal food sources, among three different types of households; namely: aquaculture project supported households, aquaculture non-project supported households, and non-aquaculture and non-project supported households; of a rural community in Southern Bangladesh, in chapter 4.

In Bangladesh, agricultural sector is heavily dominated my male; role of women in agriculture mostly limited to pre and post-harvest processing [70]. Traditionally, men are in charge of major decision making, in terms agricultural production, sale, food purchasing, and especially use of income. In contrast, women are involved mainly in household chores and child care; besides these, women substantially participate in homestead agriculture, poultry, and animal husbandry and non-farm activities and play a crucial role in maintaining food security in the family. In recent years, women empowerment increasingly is seen as a strategy to enhance food and nutrition security of households [71][27]. Women empowering has direct impact on agricultural productivity, households food security [68][72] and nutrition of mother, their children and household members [32][73]. Therefore, closing these gender gaps are essential to bring positive outcomes not only for the women or family, but also for the global food

security [74] . Hence, in chapter 5, RQ4 has investigated whether nutrition-sensitive (an approach that seeks to maximize agriculture's contribution to nutrition) homestead aquaculture production system targeting women empower them, in terms of decision making in choosing fish production technology, harvesting for sale and consumption. For the abridged version of thesis, we are only going share the chapter 4, which has already been published.

Conceptual Framework of the Research



Chapter 2

Dietary diversity and micronutrient adequacy among reproductive aged women in rural Bangladesh

"The contents of chapter 2 are anticipated to be published in a scholarly journal. Therefore, they cannot be published online, due to contractual obligations to the publishing company."

Chapter 3

Household Engagements with Aquaculture-Horticulture Production is Associated with Diet Quality of Household Members

"The contents of chapter 3 are anticipated to be published in a scholarly journal. Therefore, they cannot be published online, due to contractual obligations to the publishing company."

Chapter 4

Fish is the Preferred Animal-Source Food in the Rural Community of Southern Bangladesh

4.1 Introduction

Despite a significant improvement in reducing hunger and food insecurity in Bangladesh, malnutrition (under- and over-nutrition) continues to remain a serious public health concern [1]; 35% of children under five years children are stunted (low height for age), and 35% of adolescent girls and 16% of adult females have low body mass index (BMI) [2]. While there is a steady but slow decrease in under-nutrition among young children and women; a sharp continual increase in over-nutrition (overweight and obesity), is also seen among the same population [3,4]. In addition, multiple micronutrient (essential vitamins and minerals, for example, vitamin A, vitamin B12, folic acid, riboflavin, thiamin, niacin, calcium, iron, zinc, and iodine) deficiencies reported in Bangladesh, are highly prevalent especially among women of reproductive age (15–49 years), and pre-school and school-aged children [5–8]. Co-existence of these nutritional problems reflects a monotonous dietary pattern, high in energy but low in a variety of essential micronutrients [9–12]. Poor diet quality, which lacks diversity is associated with higher nutritional deficiencies, globally, and especially in low income countries [13]. Young children and women are particularly vulnerable to this situation [14,15]. Inadequate intake of animal-source foods (ASFs) is one of the major factors responsible for the poor diet quality, nutrient inadequacy, and undernutrition among young children and women in Bangladesh, as reported by the Food and Agricultural Organization (FAO) and World Health Organization (WHO) [16,17]. In Bangladesh, traditionally, the major part of the food plate is occupied by the staple food, rice [18]. The amounts of ASFs and other plant-source foods consumed are far below the recommended dietary guidelines of Bangladesh, as well as global standard [19,20]. Fish (mostly from aquaculture) is the most commonly consumed ASF in Bangladesh, compared to other ASFs, such as: meat (beef, lamb and mutton, sheep, goat, and pork) milk, egg, and chicken [21]; but the amount of per capita intake is minimal. Cultured fish has become more prominent in recent years, in Bangladesh; to compensate declining fish production from capture fisheries [22]. However, eating meat and chicken is occasional and festive. Regular intake of milk, milk products, and egg is also uncommon [23]. Various studies have reported that intake of ASFs is strongly associated with better growth, cognition, productivity, and pregnancy outcomes [14,24]. ASFs are not only rich sources of readily digestible high quality protein, but also rich sources of highly bioavailable nutrients of concern globally, such as iron, zinc, calcium, preformed vitamin A,

vitamin B12, and folic acid [9]. For vitamin B12, ASFs are the only sources to meet the requirements [9,14]. Studies have shown that adding a small amount of ASF to a plant-based diet, can enhance the absorption of vitamins and minerals from these foods, and can significantly impact maternal health and child development [9,12,13]; although, certain ASFs such as red meat are subjected to debate, due to saturated fats and cholesterol.

Given the complex nutritional situation (prevalence of under- and over-nutrition in the same population, household, or individual level) in Bangladesh, and poor diet quality; increased intake of ASF is crucial for improved food and nutrition security. Therefore, this study aims to explore current behaviors of intake of ASFs, in three different groups of households and in children (aged 6–59 months), in a rural district of southern Bangladesh. The study further investigated what would be the preferred ASFs of the households, if the households had increased food purchasing capacity. To bring sustainable behavior change in ASFs intake, sustainable food system needs to be ensured, that is culturally acceptable and liked by the target people.

4.2 Materials and Methods

Qualitative and quantitative data were collected, using a semi-structured questionnaire in February 2018, in Barisal, a rural district in southern Bangladesh. Barisal district was selected to be able to include households, which had participated in a large-scale United States Agency for International Development (USAID)—funded project for five years. Using a purposive sampling method, three groups of households were selected, namely 1) aquaculture intervention (AI); 2) aquaculture non-intervention (ANI); and 3) non-aquaculture non-intervention (NANI) households, having at least one child, aged 6–59 months. A total of 100 households were selected for conducting the survey. This sample size was based on resources available for this survey. Half of the households (AI, n = 50) had participated in the USAID-funded aquaculture project, conducting pond aquaculture either in their own ponds or leased ponds, with technical support on fish culture (mainly tilapia, mola carplet; carp species, and pangasius were also cultured) from the project; called intervention households. In addition, AI households also received nutrition education on the importance of eating and feeding diverse diets including fish to the children. The other half of the non-intervention households (ANI, n = 25; and NANI, n = 25), were not engaged in any kind of aquaculture projects,

although ANI households were conducting pond aquaculture out of their own interest, and the NANI households were not involved in any kind of aquaculture activities.

As fish is the most commonly consumed ASF reported by various studies in Bangladesh [18,25,26], these three different groups of households were selected purposively, to investigate if intake of fish and other ASFs vary by the type of households. For better comparison amongst the three study groups, all households selected had a similar socio-demography (housing condition (observational), current main occupation of the household head and educational level of the father and mother of the child). Consistent with the revised Helsinki Declaration in 1983, informed consent was obtained orally from all study participants, before interviews were conducted. Furthermore, the study was approved by the Ethics Review Committee of the University of Tokyo.

4.2.1 Training and Data Collection

Four Bengali speaking enumerators who had experience conducting similar household surveys were recruited to assist the author in data collection. The enumerators received two days of intensive training on administering the semi-structured questionnaire, and practical training on conducting an interview. Pre-testing of the questionnaire was conducted and adjustments made. The semi-structured questionnaire captured

both qualitative and quantitative information. Qualitative information includes: name of the most commonly consumed ASF and preferred ASFs; reasons of eating commonly consumed ASFs by the households and children (aged 6–59 months); name of the first given ASF to the child; name of the cultured fish species (AI and ANI); level of education of the mother or caregiver of the child and the father; current main occupation of the household head; and if there is any seasonality effect on the intake of ASFs by the households. Quantitative information includes: household size; age of children; estimated amount (grams/day) of the most commonly consumed ASF by the household; and number of days in a week the household eats the most commonly consumed ASF. Household and child level ASFs intake information were collected from the recall of the mother or caregiver of the child, responsible for preparing and serving foods to household members. Pre-testing of the questionnaire was conducted and adjustments made. Data were cross-checked for any inconsistency by the enumerators, on the same day of conducting the survey, after finishing the interview.

4.2.2 Data Entry and Analysis

Data were entered in Microsoft Excel and analyzed using the statistical software (Stata 15.1). Descriptive results are presented as mean (mean±SD) and percentage (%). As sample size in each non-intervention group (ANI = 25 and NANI = 25) was half of that of the USAID-project intervention group (AI = 50), Fisher's exact test was performed to see whether there was any statistical significant differences, in terms of the prevalence of the most commonly consumed ASF among study groups. The estimated amount of daily fish intake by the household, was divided by the number of household members, to obtain the amount of daily per capita fish intake, as suggested by FAO [27,28]. One-way analysis of variance (ANOVA) was performed, to see whether the quantity of daily per capita fish intake differed among three study groups. Tukey's post hoc test was conducted to confirm where the fish intake amount differed between groups. A p value less than 0.05 was considered as statistically significant.

4.3 Results

4.3.1 Basic Characteristics of the Study Households

The current main occupation (Table 1) for most of the household heads was farming (AI 43.1%; ANI 38.2%; and NANI 41.9%). More than half of the women respondents had received education up to the secondary level (AI 54.9%; ANI 60.9%; and NANI 50%). About one-third of the women respondents had education up to the primary level (AI 31.4%; ANI 30.4%; and NANI 38.5%).

Table 1. **Basic characteristics of the study households**

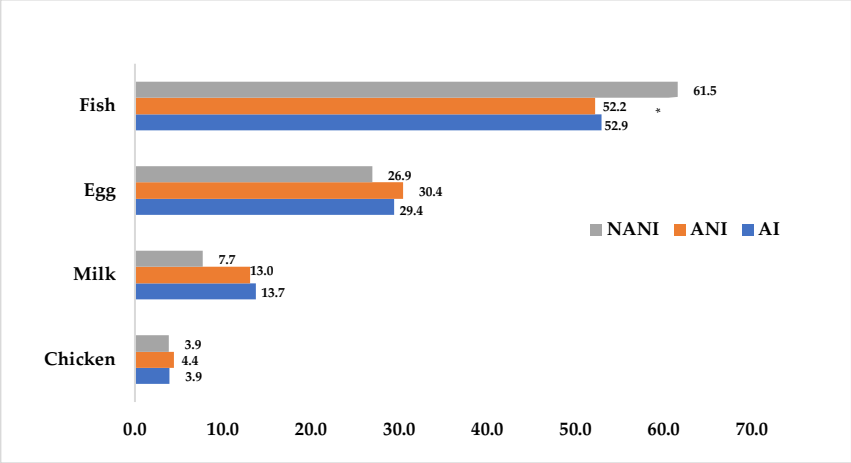
	%		
	AI, n=50	**ANI, n=25**	**NANI, n=25**
Current main occupation of household head			
Farming	43.1	38.2	41.9
Self-employed [a]	18.4	23.7	15.4
Daily wage labor [b]	15.6	14	18
Production [c]	16	17.6	19.1
No earning	4.9	3	4.7
Salaried work [d]	2	3.5	0.9
Education level of women respondents			
Up to secondary (up to grade 10)	54.9	60.9	50
Up to primary (up to grade 5)	31.4	30.4	38.5
College to graduate	11.8	8.7	11.5
No education	2.0	0	0
Household size (mean±SD)	4.8±0.2	5.3±0.2	4.3±0.2

SD, standard deviation, a Tailor, potter, electrician; b Agriculture day labor/earth work; c Factory or garment worker; d Teacher, NGO worker; AI, Aquaculture intervention households; ANI, Aquaculture non-intervention households; NANI, Non-aquaculture non-intervention households

4.3.2 Commonly Consumed ASFs by the Households

Fish was the most commonly consumed ASF compared to other ASFs, reported by the majority of NANI households (61.5%; Figure 1). Similar responses were given by the other two groups (AI 53% and ANI 52.2%); and the differences in fish intake prevalence among three different groups were not statistically significant ($p > 0.05$), confirmed by the Fisher's exact test.

Figure 1. Most commonly consumed ASF by the households (%)



*p>0.05, using Fisher's exact test; AI, Aquaculture intervention households;
ANI, Aquaculture non-intervention households;
NANI, Non-aquaculture non-intervention households; ASF, animal-source food

However, the one-way ANOVA (Table 2) shows that daily average per capita fish intake quantity, was statistically significantly different ($F(2.97) = 8.6$, $p< 0.001$), among study groups. Quantity of daily per capita fish intake (mean±SD) reported by NANI households was much lower (105.5±53) of that of the other two groups (AI, 163.6±64.7; and ANI, 159.6±53). Tukey's post-hoc test confirmed that there was statistically significantly ($p< 0.001$) lower fish intake quantity (person/day) among the NANI households compared to AI and ANI households (Table 3).

Table 2. One-way ANOVA showing daily average per capita fish intake quantity (n=100)

	Mean (g/d/person)	SD	df	F	*P*
AI	163.6	64.7	99	8.6	<0.001
ANI	159.6	57.5			
NANI	105.5	53.0			

df, Degrees of freedom; SD, standard deviation; AI, Aquaculture intervention household;.
ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household.

Table 3. Pairwise comparisons of means with equal variances (Tukey post-hoc test)

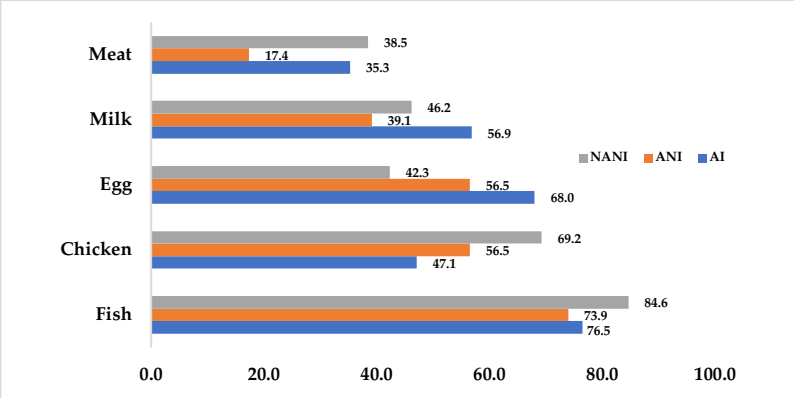
			Tukey		
	Contrast	SE	t	Sig	95% CI
ANI vs. AI	-4.0	15.1	-0.3	0.963	-40.0 to 32.1
NANI vs. AI	-58.1	14.5	-4.0	<0.001	-92.7 to -23.5
NANI vs. ANI	-54.1	17.3	-3.1	0.01	-95.2 to -13.1

AI, Aquaculture intervention households; ANI, Aquaculture, non-intervention households; NANI, non-aquaculture non-intervention households; SE, standard error; Sig, significance/*P*-value; CI, confidence interval.

4.3.3 Preferred Animal-Source Foods by the Study Households

Fish (mostly from aquaculture) is not only the most commonly consumed ASF (from Figure 1), but is also the preferred ASF, reported by the majority households from all study groups (Figure 2). More than three-quarter of the respondents (84.6%) from NANI households reported fish as the preferred ASF (Figure 2). Similar responses were given by AI (76.5%) and ANI households (73.9%). More than two-quarters of NANI households (69.2%) also reported chicken as the preferred ASF. Similarly, more than two-quarter of AI households (68%) also reported egg as the preferred ASF, followed by milk (56.9%). Furthermore, more than half of ANI households (56.5%) also reported chicken and egg as preferred foods too.

Figure 2. Preferred ASFs of study households (multiple responses, %)



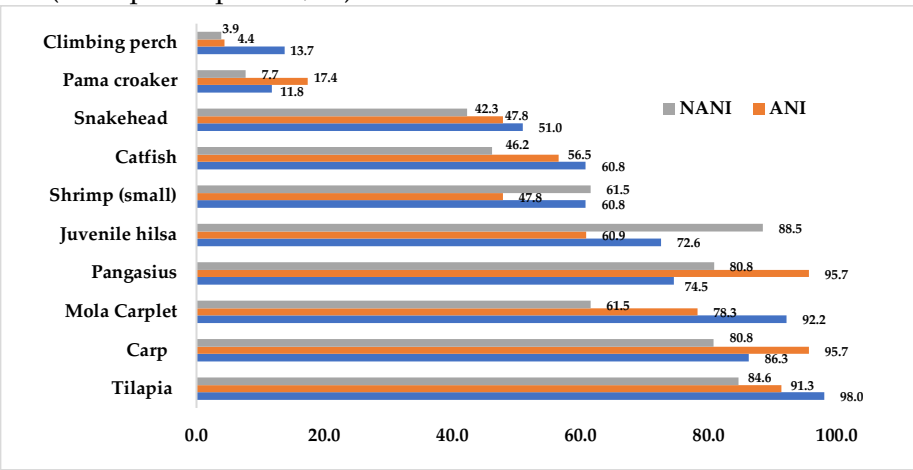
AI, Aquaculture intervention household; ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household; ASF, animal-source food

4.3.4 Commonly Consumed Fish Species by Study Households

Almost all AI households reported eating tilapia (98%) most frequently, followed by mola carplet (92%) and carp species (86.3%; Figure 3). Whereas the majority of the ANI households (95.7%) reported eating pangasius and carp species, followed by tilapia (91.3%), and mola carplet (78.3%). In contrast, juvenile hilsa (from wild catch) was the most commonly

consumed fish reported by the majority of NANI households (88.5%), followed by tilapia (84.6%), and pangasius and carp species (80.8%).

Figure 3. Commonly consumed fish species by study households (multiple responses, %)

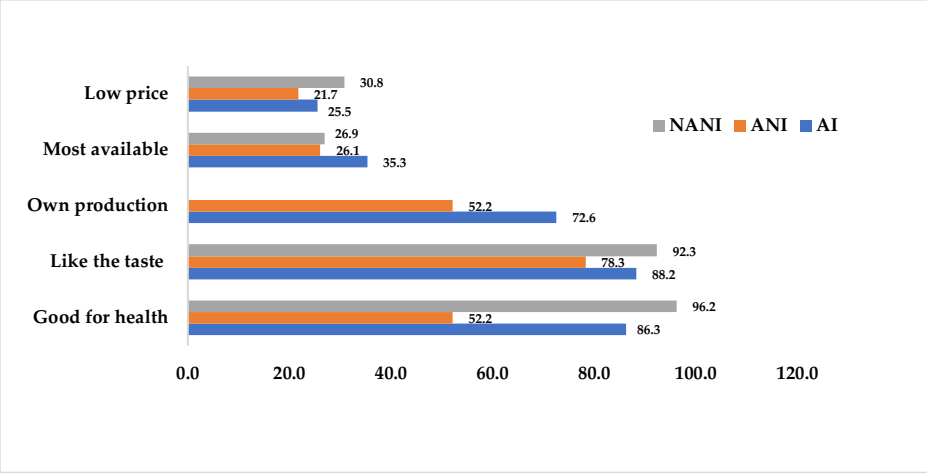


AI, Aquaculture intervention household; ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household

4.3.5 Reasons for Consumption of Common Fish Species by Study Households

The majority of households (Figure 4) in all three groups (78.3–92.3%) gave the reason for eating these fish species as: "like the taste". Almost all NANI households (96.2%) said that fish is "good for health", followed by AI households (86.3%). The reason for eating these species was due to availability from "own production", mentioned by about three-quarters (72.6%) of AI and half of ANI (52.2%) households. About one-fourth (21.7–30.8%) of households from all groups mentioned "low price" as the reason for eating these fish species.

Figure 4: Reasons for consumption of common fish species by study households (multiple responses, %)

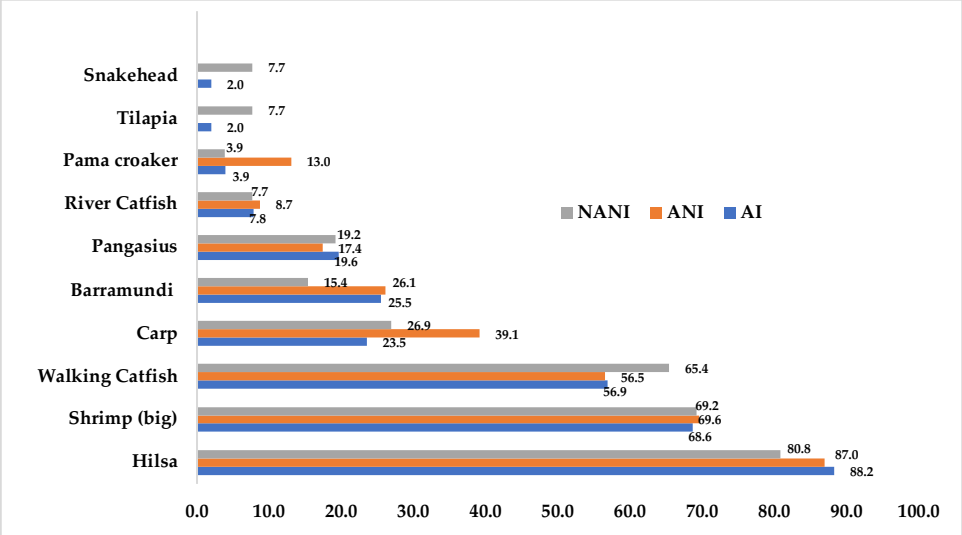


AI, Aquaculture intervention household; ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household

4.3.6 Preferred Fish Species by Study Households

Hilsa was the preferred fish species (Figure 5), reported by the majority of households from all groups (AI 88.2%; ANI 87.0%; and NANI 80.8%); followed by large shrimp (ANI 69.6%; NANI 69.2%; and AI 68.6%) and walking catfish (NANI 65.4%; AI 56.9%; and ANI 56.5%). Interestingly, almost none of the AI and ANI households mentioned tilapia as their preferred fish species, whereas, it was the most commonly consumed fish by the majority of households (Figure 3).

Figure 5. Preferred fish species by study households (multiple responses, %)



AI, Aquaculture intervention household; ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household

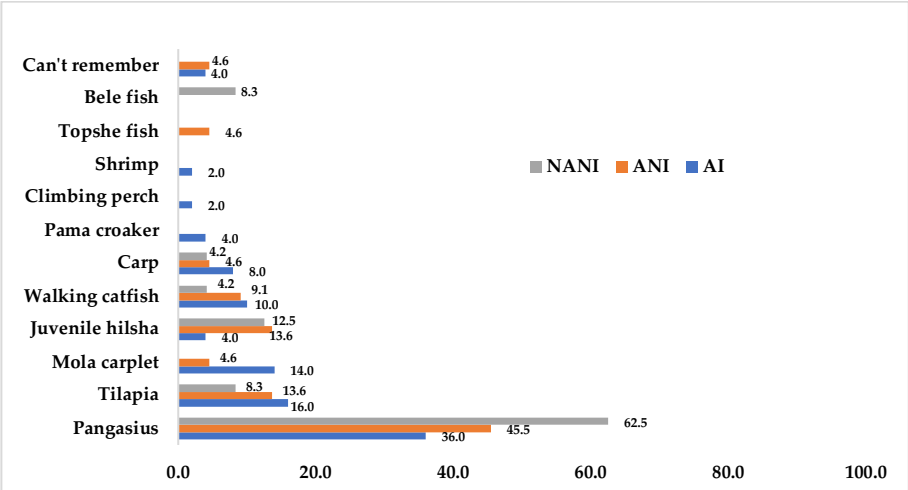
The reasons for liking these species were "very delicious" and "rarely found" mentioned by most of the respondents of all three groups (data not shown). On average, households from all groups reported eating fish three to five days in a week. Furthermore, household level fish consumption was reported to be influenced by seasonality. A larger quantity and diverse fish species were eaten in the peak fishing season (July to November) due to high availability in the market from wild catch and also low price.

4.3.7 Fish Species that was First Fed to the Child

Almost all respondents from all three groups, reported feeding fish to their young children, aged 6–59 months (data not shown). Pangasius was reported as the first fish species, fed to the child (Figure 6), by the majority of respondents (62.5%) from NANI households, followed

by ANI (45.5%) and AI (36%). Mola carplet was mentioned as the first fish species, fed to many children (14%) of AI households.

Figure 6. Fish species that was first fed to the child (%)

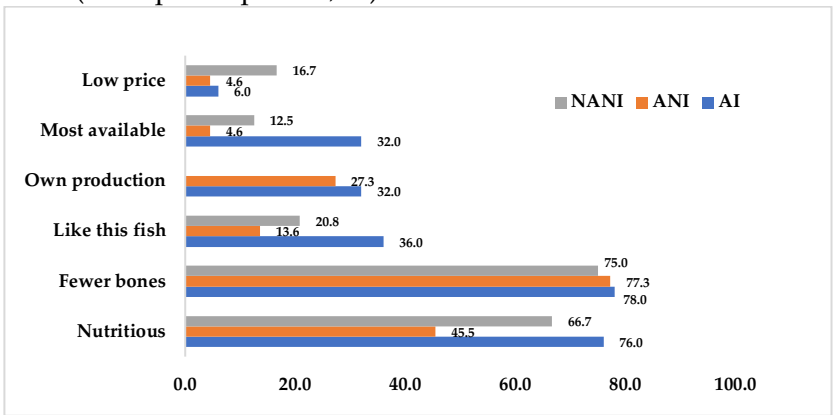


AI, Aquaculture intervention household; ANI, Aquaculture non-intervention household; NANI, Non-aquaculture non-intervention household

4.3.8 Reasons for Choosing the Fish Species to be First Given to the Child

One of the important reasons for giving pangasius to children was "fewer bones" (Figure 7), mentioned by the majority of the respondents from all three groups (75–78%), followed by "nutritious" (AI 76%; NANI 66.7%; and ANI 45.5%). About one-third (32%) of respondents from AI households reported, the reasons for feeding fish to the child were: "most available" and "own production". "low price" of fish was also reported by NANI households (16.7%) for fish species chosen to be fed to children.

Figure 7. Reasons for choosing fish species to be first given to the child(multiple responses, %)



AI, Aquaculture intervention households; ANI, Aquaculture non-intervention households; NANI, Non-aquaculture non-intervention household

4.4 Discussion

Fish is the most commonly consumed ASF reported by households in all three study groups (Figure 1). This finding is consistent with many other studies in Bangladesh [18,21,29]. Fish was also the preferred ASF reported by the majority of households in all study groups (Figure 2). These results further reinforce the importance of fish in the diet of the study population. Fish is the second most valuable agricultural food crop in Bangladesh, after rice [30]. Traditionally, people eat fish, irrespective of region, ethnicity, income, or education category. The species selected for consumption can vary, depending on the purchasing capacity of the household or an individual and the availability of fish species, as reflected in this study (Figures 4 and 7). Fish has a special places in the Bengali diet, with people celebrating traditional festivals (e.g., Bengali New Year, and a wedding), by eating and gifting fish to each other (family, friends, and relatives). Chicken, egg, and milk were also preferred ASFs, as reported by the many households from all three groups; however, the prevalence of intake of these ASFs (chicken, egg, and milk), at the national level are quite low (22%, 21%, and 23.2%, respectively) [18,31]. Furthermore, eating chicken and meat (beef, goat, lamb and mutton, and pork) are occasional and festive; and regular intake of egg and milk is uncommon. In addition, intake of multiple ASFs in a single day is rare in Bangladesh [21].

Tilapia, and mola carplet were the most commonly consumed fish species by the AI households, perhaps due to these households producing these species as a part of the aquaculture intervention project. Therefore, they were the most convenient and accessible species and did not have to be purchased (Figure 3). This finding is consistent with studies, showing that people tend to eat the food they produce and is available at home [32,33]. Intake of mola carplet was particularly higher among AI households, compared to the other two groups. This is important to note that the AI households received nutrition education on the importance of fish consumption, especially small indigenous fish such as mola carplet, as these species are rich sources of multiple micronutrients, especially vitamin A, vitamin B 12, folic acid, calcium, iron, and zinc; which are mostly deficient in the Bangladeshi population [5,26,34–36]. Therefore, it is assumed that along with availability and

accessibility, nutrition education might have also influenced AI households, to consume the fish species produced in their ponds. This kind of fish consumption behavior indicates the importance of the food environment and the necessity of health promotion activities, to

promote intake of specific target foods [37,38]. In Bangladesh, the most cultivated fish species are: carp species, tilapia, pangasius, and in some cases mola carplet; due to the availability of proven production technologies and these species are more resilient to the environment [21,22,39]. Therefore, consumption of carp species, pangasius, and tilapia by the majority of households from all study groups is not surprising. Furthermore, close proximity to AI households may have indirectly influenced ANI and NANI households, to consume these cultured fish species through market access and nutrition information. Moreover, there have been nationwide campaigns on eating mola carplet, due to its high nutritional quality (mola carplet is a rich source of vitamin A, which is highly deficient among Bangladeshi people [5]). Therefore, consumption of mola carplet by many ANI and NANI households is also not surprising. Furthermore, the reason for eating juvenile hilsa (from wild catch) by the majority of NANI households (Figure 3) may be due to its low price, compared to other fish species; which was also reflected by the responses of one-third of NANI households; "low price" was the reason of eating commonly consumed fish species (Figure 4).

The estimated amount of daily per capita fish intake in all three groups was lower compared to the recommended intake quantity of ASFs [19,20]. Daily per capita fish intake quantity was further lower among NANI households (Table 3), compared to the two other groups of households (AI and ANI), and the differences in intake quantity were statistically significantly lower ($p < 0.01$), among NANI households (Table 2). A combination of availability and accessibility of fish at the household level from their own production might have influenced the higher quantity of fish intake in AI and ANI households, compared to NANI households. These findings are also reflected by the responses of AI and ANI households; the majority of the respondents reported availability from their "own production" as the reason for eating these fish species (Figure 4). Nonetheless, alike many other studies in Bangladesh, this study also found that respondents across all study groups "like the taste" of fish [25,30,40]. "good for health" or "nutritious" was an important reason for eating and feeding children fish, mentioned by respondents in all study groups.

It is interesting that hilsa was named as the preferred fish by the majority of households from all three study groups, if households had sufficient money to buy foods (Figure 5). In Bangladesh, hilsa is the national fish, considered special and eaten at the Bengali New Year. Traditionally, people like hilsa due to its taste, texture, and flavor. The cost of an adult hilsa

(about 1 kg) is high compared to other fish species and mostly not affordable by rural households. Large shrimp and walking catfish are also expensive compared to commonly consumed fish species. Therefore, naming these fish species as preferred fish by all study groups is not surprising; as these fish species are mostly beyond their reach and they aspire to eat them.

Most of the respondents from all three groups mentioned of feeding pangasius to their child as the first fish species (Figure 6), due to this fish having fewer small bones compared to other commonly consumed fish species (Figure 3). This finding is consistent with another study in Bangladesh, in the same area [41]; mothers reported not feeding all fish species to their children that they ate themselves, due to the fear of bones. Mola carplet was given to more children in AI households than ANI, which might be due to the availability of this fish from their own production due to the project intervention, as well as nutrition education provided by the project. This result indicates that if households or individuals can be communicated about the health and nutritional benefits of a culturally acceptable and affordable food; it is likely that this food will be consumed [39].

Results of this study as well as the literature review show the importance of fish in the diet of the Bangladeshi people, which is consistent with the traditional proverb "Mache bhate Bangali" meaning "fish and rice make a Bengali"; although species selection is guided by various factors, such as: food environment, affordability, social norm, and context (e.g., age, and seasonality). One of the objectives of nutrition-sensitive interventions is, to make micronutrient-rich foods available and accessible, so that the household can readily consume these foods, either from own production or nearby market [42]. This pathway is supported by the study results from the AI and ANI households, having a greater household level consumption than the NANI households [43]. As "low price" of fish was one of the important reasons for eating fish, mentioned by many respondents from all groups (Figure 4), it was assumed that if people had increased food purchasing capacity; they would shift their food choice from fish to other ASFs. The results from this study does not support this; the respondents reported that they would eat fish if they had enough food purchasing capacity; however, their choice of species would be different (Figure 5). They would want to eat more delicious, expensive, and rare fish species. Therefore, increased purchasing capacity along with production diversity might create an enabling food environment, for households and

individuals to eat a larger quantity of fish and more diversified fish species, thus improving diet quality [43,75].

Food availability at the global, national, or sub-national level does not guarantee food and nutrition security at the community or households level [76,77]. Access to food (physical and economic access) by households or individuals plays a vital role for the food choice of people [78], which is also reflected by the results of this study. This study further reveals that personal food preferences are determined by various factors, such as: availability, convenience, taste, value, culture, knowledge, and age [46,49]. These results are aligned with the food choice process model of Cornel University [79], which shows that food preferences of an individual is influenced by the life course events and experiences (early life exposure and upbringing), including current factors, such as: context, accessibility, health condition, convenience, and taste. The personal food choice of an individual is a cognitive process and early family cuisine and food preferences provide food roots of people that people carry over time [50,51]. Therefore, dietary interventions need to prioritize cultural acceptability and food preferences, when deciding on intervention components. This study provides useful information regarding current ASFs intake behaviors, and preferred ASFs of households in a rural district of southern Bangladesh.

4.5 Conclusions

Fish is the most commonly consumed and preferred ASF, across study groups. People were more likely to consume the fish species that was available from their own production. Selection of fish species for consumption was led by the taste, health benefits, or nutrition knowledge of household members, availability in the market, price, and age of child. Daily per capita amount of fish intake was lower in households (NANI) did not produce fish, compared to households (AI and ANI) produced fish. In feeding fish to children (aged 6–59 months), fish species with fewer small bones were the species of choice. Therefore, this study suggests dietary interventions to consider the age of child, when choosing specific micronutrient-rich food to promote, for improved food and nutrition security. Considering the malnutrition situation in Bangladesh and the cultural acceptability and preferences of fish, this study recommends that dietary interventions to prioritize fish in targeting increased intake of ASFs for improved nutrition. This effort will contribute to achieving targets under

the Sustainable Development Goals (SDGs), through reducing malnutrition, child mortality, and improving school attainment of children.

Limitations of the study: The study was conducted in one rural district in southern Bangladesh and therefore, the findings do not represent the country as a whole.

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Academic Contribution of the Research

For the sustainable changes in the food intake behavior and for improved food and nutrition security, dietary intervention programs need to prioritize cultural acceptability and food preferences of people to be targeted, while deciding appropriate intervention components [82]. Furthermore, inadequate intake of animal-source foods (ASFs) is one of the major factors responsible for the poor diet quality, nutrient inadequacy, and undernutrition among young children and women in Bangladesh, as reported by the Food and Agricultural Organization (FAO) and World Health Organization (WHO) [61][83]. Hence, identifying most commonly consumed and preferred animal sources foods (ASF) by the rural households, in southern Bangladesh, would be useful research findings, while targeting increased animal-source food intake by the target households and especially by the children.

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Chapter 5

Nutrition-Sensitive Homestead Pond Polyculture Technology Improved Fish Intake and Empowered Women in the Rural Community of Southern Bangladesh

"The contents of chapter 5 are anticipated to be published in a scholarly journal. Therefore, they cannot be published online, due to contractual obligations to the publishing company."

Chapter 6
General Discussion and Conclusions

"The contents of chapter 6 are anticipated to be published in a scholarly journal. Therefore, they cannot be published online, due to contractual obligations to the publishing company."