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Strengthening the contribution of aquaculture to food and nutrition security: The potential of a vitamin A-rich, small fish in Bangladesh

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ABSTRACT

Background: Since 1961, global per capita fish consumption has nearly doubled. Much of the increase has been due to aquaculture. Bangladesh, the world's eighth largest fish producing country, has been part of this transformation. Despite having vitamin A supplementation and fortification programs, the prevalence of inadequate vitamin A intake (IVAI) in Bangladesh is very high, estimated to be 60%. The promotion of a small indigenous fish, high in vitamin A – mola carplet – offers a promising food-based approach to improving vitamin A status of the 98% of Bangladeshis who eat fish. The objective of this paper was to conduct a cost–benefit analysis of a national household pond Mola Promotion Program (MPP) in Bangladesh.

Methods: Using the 2005 Bangladesh Household Income and Expenditure Survey (HIES) and nutrition and health statistics, we developed baseline estimates of usual vitamin A intake, the prevalence of IVAI and disability-adjusted life years (DALYs) attributable to vitamin A deficiency (VAD). Drawing on a WorldFish project and HIES data, we designed and modeled the implementation of a MPP, and calculated the additional vitamin A intake it would provide, calculated new incidence rates of VAD-related health outcomes and estimated MPP-attributable annual changes in DALYs. The MPP's total health benefits were calculated over the program's 11-year phase-in as the annual sum of DALYs saved. The MPP's costs were estimated as the sum of the costs of a small fish program of the Fisheries Development Program plus the costs of mola brood stock, other inputs and additional farmer training-related costs. Program costs and benefits were combined to produce estimates of the cost-effectiveness of the program.

Results: An 11-year, $23 million project would increase average daily vitamin A intakes by 7 μg retinol activity equivalent (RAE), reduce the prevalence of IVAI by 1.1 percentage points, and save 3000 lives and 100,000 DALYs, at a cost of $194 per DALY saved. The MPP's impact would be concentrated among homestead pond-fishing households that would consume 60% of the additional mola produced. Among these, it would reduce IVAI prevalence by 7 percentage points. If the MPP was implemented for at least 20 years, it would dominate – have higher health benefits and lower total costs – than a national vitamin A wheat flour fortification program.

Conclusion: By World Bank and World Health Organization criteria, the MPP is a cost-effective approach to reducing the burden of micronutrient malnutrition in Bangladesh.

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1. Introduction

1.1. The global rise of aquaculture

Fish is often the cheapest and most commonly consumed animal-source food in countries with food and nutrition insecurity (Food and Agriculture Organization [FAO], 2014a, 2014b; World Bank, 2006). Globally, since 1961, total fish consumption has grown at an annual rate of 3.6% while population has grown at 1.8%, enabling a near doubling of per capita annual fish consumption (FAO, 2014a, 2014b). This transformation has been spearheaded by aquaculture – the farming of fish and other aquatic organisms – which has become the most rapidly growing global food sector. Since the 1970s, aquaculture has grown at more than 8% annually.

Asia accounts for 88% of global aquaculture production, and it has, by far, the most dramatic growth in aquaculture. Bangladesh, one of the world’s leading fish producers, has been part of this transformation. While fish capture has historically been the most important source of fish, for the first time in Bangladesh’s history in 2010/11, aquaculture accounted for more than half of the total fish production in Bangladesh (Fig. 1), and it was dominated by pond culture. Since
2009/10, pond aquaculture has been the most important source of fish consumed in Bangladesh (Toufois and Belton, 2014).

1.2. Fish and aquaculture in Bangladesh

As epitomized by the well-known idiom “machee bhattee Bangali” (“fish and rice make a Bengali”), fish is of particular significance in the Bangladeshi culture, diet and economy. Fish is the third most commonly consumed food in Bangladesh, after rice and vegetables (Roos et al., 2003), and it is the most important source of animal protein. According to an estimate from the Bangladesh Bureau of Statistics (BBS) from 2007, fish provided 60% of daily animal-source protein (BBS, 2007). The estimate is 53% from Food Balance Sheets for 2007 and remains at 51% as of 2013 (FAOSTAT, 2015). Fish production contributes 4.4% of the Gross Domestic Product of Bangladesh (Azad, 2014). There are an estimated 3.9 million small household ponds across Bangladesh, with an average size of 15 decimals. Roughly, 20% of the Bangladeshi population has one or more ponds (Belton, 2011) which provide fish for consumption and sale. Homestead pond polyculture is generally dominated by production of various carp species. Fish is usually sold at certain times of the year and contributes 8–15% of total household income (Belton, 2011). Estimates based on the Bangladesh Bureau of Statistics (BBS) 2005 Household Income and Expenditure Survey (HIES) and official statistics suggest that approximately 360,000 t fish are produced from homestead ponds annually (BBS, 2006). In aggregate, 57% of the fish produced in small ponds is retained for household consumption (BBS, 2006). However at the household level, the average percent of production consumed is about 80%; at the 25th percentile, about 60% of production is consumed and 100% at the median (BBS, 2006).

1.3. Agriculture and nutrition linkages

A number of recent publications (Girard et al., 2012; Leroy and Frongillo, 2007; Masset et al., 2011) have highlighted the need for more analysis and research on the effects of agricultural interventions on nutritional outcomes as well as appropriate monitoring and evaluation of nutritional outcomes in agriculture programs. Agricultural investments and programs have the capacity to affect the determinants and causes of undernutrition through multiple pathways (Herforth, 2012; Leroy and Frongillo, 2007). The value of a large-scale investment in aquaculture can result in improved diets, increased income for the household, and enhanced market availability of fish. Increasing the production and consumption of micronutrient-rich fish should have a long-term impact on the persistent high rates of child malnutrition in Bangladesh, through the pathways illustrated in Fig. 2.

1.4. Health and nutrition in Bangladesh

Over the past three decades, Bangladesh has made enormous strides in reducing population growth, mortality and morbidity. It is one of the few countries that achieved the Millennium Development Goal (MDG) of reducing under-five mortality by two-thirds and over the same period reduced infant mortality and child mortality rates by 56% and 81%, respectively. However, nutritional deficiencies have persisted. For example, a nationally representative micronutrient survey conducted in 2011–12 found high levels of micronutrient deficiencies, as shown in Table 1.

Despite the fact that the country has had what is widely regarded as one of the most successful vitamin A supplementation programs in the world for more than two decades and has been fortifying vegetable oil with vitamin A since 2012, the prevalence of vitamin A deficiency (VAD) has changed little since the two previous national nutrition surveys which were conducted in 1975–76 and 1981–82. In addition, vitamin A supplementation coverage has declined in recent years. While there has not been any evaluation of the oil fortification program, which has now grown to include 16 of 22 vegetable oil companies and covering 80–85% of Bangladesh’s vegetable oil supply, it has been estimated that it will reduce the prevalence of IVAI by 20 percentage points, from 80% to 60%, if the program is implemented as designed and sustained (Fiedler et al., 2014). Even if the oil fortification program is effective, however, VAD will continue to be a serious public health problem in Bangladesh and there remains a need to examine additional means to accelerate reduction in VAD. While Bangladesh has actively considered introducing the fortification of wheat flour with vitamin A (along with other micronutrients) for more than a decade (Dary and Rassas, 2004), the food industry conglomerates that own the roller mills have not been supportive, and the likelihood of it being initiated is uncertain (Fiedler et al., 2015).

1 decimal = 40.5 m² = 0.004 ha.
1.5. The case for increased mola production and consumption

Over the past 20 years, interventions to improve water body and wetlands management in Bangladesh have increased aquaculture yields and market access for fishing households, and there is growing evidence that increased production and productivity can lead to increased consumption of fish (Hossain et al., 2014; Roos et al., 2007; Wahab et al., 2011) and improved nutrition (Roos et al., 2003; Thompson et al., 2002). The widespread availability of household ponds suitable for small-scale fish production in many parts of Bangladesh enables many households to have easy access to various fish species. While rice provides 70% of the total energy in the Bangladesh diet (Fiedler, 2014), the rice-dominated diet is low in micronutrients and contains phytates that reduce the bioavailability of certain micronutrients (Arsenault et al., 2013; Bermudez et al., 2012). With respect to vitamin A in particular, using oil to cook fish increases the consumption of vegetable oil - roughly 80% of which is now assumed to be fortified with vitamin A - and it enhances the bioavailability of provitamin A carotenoids in vegetables (Tang, 2010). There is considerable potential for increasing the contribution of fish as a source of nutrients by increasing production, productivity and consumption of fish with higher intrinsic nutrient contents. In this analysis, we focus on a program designed to affect this pathway, specifically on increasing vitamin A intake by using mola. A small indigenous fish, mola (mola carplet, Amblypharyngodon mola), has a vitamin A content of 2680 μg RAE/100 g when consumed (as it customarily is in Bangladesh), inclusive of head and eyes (Roos et al., 2002). As the vitamin A content of mola is many times greater than that of most other fish species consumed in Bangladesh (Thilsted, 2012), increasing production and consumption of this fish may offer potential for reducing IVAI.

This paper seeks to contribute to the literature on the effects of agricultural interventions on nutritional outcomes by providing an analysis of the nutritional benefits and costs of a food-based approach. It assesses the promotion of homestead pond polyculture production of vitamin-A rich mola as well as the consumption and additional intake of vitamin A in the diet. More specifically, this analysis seeks to:

1. Examine the potential reduction in IVAI and the distribution of this outcome among Bangladeshi;
2. Estimate the benefits of this intervention using the disability-adjusted life year (DALY), which is a metric that combines morbidity and mortality into one indicator and enables comparisons across projects and country-specific contexts;
3. Determine the overall costs of implementing such a program in order to assess its financial feasibility; and
4. Determine the cost-effectiveness of the program, using the DALY as the measure of benefits, in order to provide some context as to how this intervention compares with other nutrition-related health interventions.

2. Material and methods

Fig. 3 shows the major methodological components of this study and the data sources used to measure the proposed program's nutritional benefits. Nutrition and health statistics, together with a proxy for food consumption data developed from the HIES, were used to characterize the “current situation” (or baseline), by estimating the usual intake of vitamin A, the prevalence of IVAI and the burden of VAD measured using DALYS.

Then, implementation of a Mola Promotion Program (MPP) was modeled with alternative scenarios consisting of combinations of generated data and assumptions about key adoption parameters. Added vitamin A intake was calculated as the estimated quantity of mola consumed multiplied by the vitamin A content of mola. The usual intake of vitamin A at endline was estimated as the sum of baseline vitamin A intake and the added vitamin A intake attributable to mola consumption. Using intake estimates at endline and baseline, new incidence rates of VAD-related health outcomes were calculated, as well as the number of DALYs lost after the introduction of the MPP.

| Table 1 | Nutritional deficiencies in Bangladesh, 2011–12. Source: icddr,B, UNICEF/Bangladesh, GAIN, Institute of Public Health and Nutrition, 2013. |
|-------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Prevalence of nutritional deficiencies | Preschool aged children | School aged children | Non-pregnant, non-lactating women 15–49 years |
| Vitamin A deficiency | 76.9% | 74.5% | 6–14 years | 6–11 years | 12–14 years | 39.7% |
| Anemia | 33.1% | 19.1% | 17.1% | 26.0% |
| Iron deficiency | 10.7% | 3.9% | 9.5% | 7.1% |
| Iron deficiency anemia | 7.2% | 1.3% | 1.8% | 4.8% |
| Zinc deficiency | 44.6% | 57.3% |
| Iodine deficiency | 40.0% | 42.1% |
| B12 deficiency | 6.1% |
| Folate deficiency | 9.1% |

![Fig. 2. Pathways from the Mola Promotion Program to improved nutrition and health. Note: IEC: Information, Education, Communication. Source: Adapted from Masset et al., 2011; Girard et al., 2012.](image-url)
and the total number of DALYs saved annually. \(^2\) Total health benefits of the MPP were calculated over an 11-year implementation period of the MPP as the sum of the annual DALYs saved over the 11 years.

The remainder of this section describes the database and the methods used in modeling the mola production and consumption behaviors posited in this ex-ante Benefit–Cost analysis of the MPP.

Note: HIES: Household Income and Expenditure Survey.

2.1. Estimating “usual” vitamin A intakes and the prevalence of inadequate intake with the Bangladesh 2005 HIES database

There are no national level data on the number of ponds producing mola, or about the quantity of mola produced or consumed annually in Bangladesh. While this study is based primarily on data from the 2005 HIES, the HIES data are about all fish consumption and all pond-fish production, and needed, therefore, to be combined with parameters from other sources and assumptions about the mola adoption rates to make it mola-specific.

The 2005 HIES used a two-stage stratified sampling design, using probability proportional to size based on the 2001 population census (Asian Development Bank [ADB], 2006; BBS, 2010). A total of 10,080 households (6400 rural and 3680 urban) are included in the sample which is representative at the national level and for each of the seven divisions. The total number of individuals in the sample is 48,969.

Sample weights, adjusted for non-response, were used to develop total population estimates of households and persons.

The 2005 HIES consumption module contains 134 food items. The quantity, value and source (purchases, in-kind wage, own production and gifted food) of each food item consumed were reported for the entire household, for each day during the 14-day reporting period. We used the food consumption data together with energy and nutrient values from food composition tables (FCT) to estimate the household's total energy intake and total vitamin A intake (Bermudez et al., 2012). In addition to the specific foods identified in the food list, each of the 13 general food groups contained an entry labeled “Other.” For these “other” categories (e.g. “other fruit,” “other vegetables”), energy and nutrient values were estimated by taking the FCT average of all other items within the general food category. The 2005 HIES also includes several “dining out” meals, and differentiates these by their primary ingredient (e.g. rice). Typical recipes were used to estimate the energy and nutrient composition of these meals (see Bermudez et al., 2012 for further details). To estimate the household’s “usual daily intake” from the 14-day diary totals, we divided the total intake by 14.

To estimate each household member’s nutrient intakes, we assumed that a household’s food was distributed to its members in direct proportion to each member’s share of the household’s total energy requirements, expressed as adult male consumption equivalents (AMEs) (FAO, 2001). We used the cut-point method to evaluate the prevalence of inadequate vitamin A intakes. We compared the individual’s estimated vitamin A intake levels with her/his age- and gender-specific EAR levels to characterize the individual’s intake as “adequate”, for a level equal to or greater than the EAR, or “inadequate”, if a level less than the EAR (Institute of Medicine [IOM], 2006).

2.2. Modeling increased mola production

The HIES does not collect information specifically about mola production or mola consumption. It does, however, provide household level data on a number of fishing-related behaviors that we used in combination with mola-specific data from a WorldFish project and other studies to enable constructing an evidence-based approach to estimating the cost and benefits of the MPP. The HIES also collects information about the quantity of fish households caught or harvested.
in the preceding 12 months, from seven sources: fish farms, fish hatcheries, marine, canal/river, swampland/marsh, pond/sink or other. The amount and value of the fish, how much of it was consumed by the household and how much of it was sold are reported. We used these data to estimate the number of households engaged in various forms of fishing as well as the total production from these sources. Next, we calculated the total number and percentage of households engaged in pond fishing across Bangladesh in order to understand where MPP efforts should or should not be focused. To further understand this variation, we calculated how much of the total production from pond fishing was sold versus retained for home consumption and categorized households as to whether they consumed all of what they produced; sold and consumed what they produced; or predominantly sold what they produced.

We used the number of households that reported they had engaged in pond fishing to provide a rough estimate of the number of ponds. We combined this estimate with the Belton and Azad (2012) estimate that the average national pond size is 15 decimals (0.06 ha) to estimate the total national pond area. The HIES reports households’ pond fish production, but contains no data about household’s individual pond size or pond fishing yields. Therefore we calculated the average annual national pond fishing yield of all fish (kg/ha/year) by dividing the total production obtained from the HIES with the derived hectarage of all ponds in Bangladesh. To derive this value, we multiplied the value of the average national pond size of 15 decimals (0.06 ha) reported by Belton and Azad, 2012, by the number of ponds (estimated by the HIES’ number of households that reported they had engaged in pond fishing). We assumed the average national yield was applicable to all households and used this value to calculate the average pond size for each division. To do so, we first calculated the total number of hectares in each division by dividing each division’s total fish pond production by the national average yield, and then divided this value by the number of division-specific ponds to attain a division-specific average pond size.

We assumed that all variation in division pond production was attributable to two sources; differences in the average pond size and in the number of pond fishing households. We further assumed that all households in a division had the same size pond and that the divisional variations in pond size were equally applicable to mola. Drawing on reports of the average production of mola, (Asadujjaman et al., 2013; Roos et al., 2007), we assumed that the average annual mola production was 390 kg/ha/year. Finally, multiplying our derived estimate of each household’s pond size by this average yield, we estimated the average pond production of mola and the total national annual production of mola (Roos et al., 2003).

2.3. Modeling increased mola consumption

The HIES food consumption module asks households about their consumption of all fish in the previous two weeks. Mola is not specifically asked about and its consumption is presumably captured in the “other fish” category. The percentage of households reporting consuming “other fish” was 17.5%, and this consumption represents 4.2% of the total fish consumption. Not having mola consumption data, we resorted to making some assumptions about the consumption of mola, based on general fish production and consumption behaviors of the households.

Having identified the specific households that we assumed would adopt and produce mola in response to the MPP and having estimated each household’s mola production, in order to maximize our contextualization of the modeling, we needed to identify the amount of mola each mola producing household would consume. We did so by taking into account how the increased production of mola is likely to be used. From the HIES fish production module, we calculated the proportion of homestead pond fish production that households reported they used for their own consumption to be 57%, while selling the residual 43%. We assumed that households that would adopt and produce mola would consume a slightly higher share of mola, on average 60%.

We assumed the proportion consumed would be slightly more both because 60% is the share of mola that homestead pond fishing households in the IFAD-funded WorldFish “Small Fish and Nutrition” project sold and because the MPP will include an education component that will encourage the pond fishing households that produce mola to consume it. We further assumed that the mola sold would be purchased by all households (including mola-producing households) purchasing any fish, and that they would purchase and consume the mola that would be sold in direct proportion to their consumption of all fish. We arrived at our estimate of the total quantity of mola consumed by reducing total mola produced by 13% for cleaning waste.

2.4. Specifying the key parameters of the Mola Promotion Program

In each division, we randomly selected from the households currently engaged in homestead pond fishing those homesteads that we assumed would participate in the MPP. We assumed that households that both consume and sell a portion of their production were more likely to participate in the MPP. We assumed an adoption rate of 30% of the households currently practicing homestead pond polyculture.

An ex-ante analysis of the MPP requires considering a multiple year process, over which the adoption, production and consumption of mola are promoted and grow. This, in turn, requires introducing a discount rate to enable comparing benefits and costs over time. This is especially important when the benefits and costs have different temporal profiles. Based on experience from projects implemented by WorldFish and others, we assumed that fisheries extension agents could introduce the MPP to approximately 400,000 new households a year, and posited an 11-year program that would be rolled out by division, sequencing the division by the number of homestead fishing ponds they contained.

Three separate scenarios are examined for the MPP. Scenario 1 is based on the following key assumptions:

- There are 3.86 million pond fishing households.
- After 11 years, the MPP will reach all 3.86 million pond fishing households.
- In each division, 30% of the pond fishing households will adopt mola production.
- Average mola yields in all divisions will be 390 kg/ha/year.
- Divisional average mola production per pond will vary by pond size.
- The pond fishing households that adopt mola production will consume on average 60% of the mola they produce and sell 40%.
- 13% of mola produced is waste (removed in cleaning).

We assume that the MPP is implemented at the same rate throughout all divisions. As part of the implementation plan, we also assume that there is no attrition: that each year, 400,000 pond fishing households are trained by extension agents and 30% (120,000 households) adopt mola, begin mola production and remain mola producers in perpetuity.

In addition to Scenario 1, two alternative scenarios demonstrate the sensitivity of the results to the two key assumed parameters: the average mola production and the mola production adoption rate. Scenario 2 assumes an average production of 512 kg mola/ha/year, 31% greater than in Scenario 1, while holding all other parameters constant. Scenario 3 doubles the adoption rate to 60% and retains the other parameters of Scenario 2.

2.5. Costs of the Mola Promotion Program

The Government of Bangladesh Country Investment Plan: a road map towards investment in agriculture, food security and nutrition (Government of Bangladesh, 2010) proposes an eight years’ small fish program as part of the Fisheries Development Program, with an average annual cost of US$ 1.3 million. The program’s costs reflect plans to
utilize existing government staff and resources, including upazila fisheries extension workers, and include the direct costs of implementing advocacy, training, carp fingerlings and brood stock in demonstration ponds. We use this very similar type of program to provide an estimate of the MPP’s core costs. To this, we add additional input requirements which would include mola brood stock and preparation costs, as well as additional support for farmer training. Next, we add these estimates to the total government’s estimated annual costs of the initiative to yield an annual estimate of the cost of the MPP.

2.6. Measuring impact: estimating DALYs saved and cost-effectiveness

This study uses an approach developed by the HarvestPlus biofortification program to estimate the number of DALYs that would be saved by implementing a micronutrient deficiency intervention program (Stein et al., 2005). The methodology for estimating impact uses a counterfactual approach: it estimates impact as the difference in the number of DALYs attributable to VAD before and after the introduction of the MPP. The baseline level of DALYs is estimated from the current burden of VAD, calculated from reported incidence rates of clinical outcomes associated with the deficiency such as diarrhea, measles infections, blindness and child mortality, among specific target populations as well as other comparative risk assessment-based estimates. The endline estimates of IVAI are then used to develop new estimates of the number and percent of persons who are deficient by adjusting and calculating new incidence rates of the related health outcomes associated with VAD. The new incidence rate of VAD-related health outcomes are used to estimate the number of DALYs lost after the introduction of the MPP. The difference between the baseline and endline estimates is the number of DALYs saved by the MPP in one year. The total DALYs saved by the MPP is the sum of the 11 annual estimates of DALYs saved. Finally, to produce measures of cost-effectiveness (cost per DALY saved), we annually discount benefits and costs at 3% and value DALYs at US$ 1000.

3. Results

3.1. The baseline prevalence of inadequate vitamin A intake

Table 2 shows the mean daily vitamin A intake, the percent of the EAR achieved and the prevalence of IVAI estimated from the consumption section of the HIES. The prevalence of inadequate intake varies substantially across divisions: the rates are high, ranging from 72% to 94%. The highest prevalence of inadequate intake is observed in Sylhet whereas Khulna has the lowest prevalence. However, there is neither great variation between rural (84%) and urban (81%) area, nor between households fishing ponds (78%) and those that do not (84%).

3.2. Pond fishing households, production and use

Fig. 4 shows the distribution of the total annual homestead fish production of nearly 885,000 t by source. Pond fishing accounted for 359,035 t, 41% of the total, and was engaged in by 3.86 million households, 13.5% of all Bangladeshi households (Table 3). The practice of homestead pond fishing varies substantially by division, with the highest number of households, 34.9% in Rangpur, and Rangpur and Dhaka accounting for 55% of all Bangladeshi pond fishing households. All other divisions, except Sylhet, accounted for roughly similar shares, 10–13%, of all pond fishing households.

Table 3 also shows total household pond fishing production by division. Dhaka is the biggest producer, with 25% of the national total. While Rangpur has the highest proportion of households engaged in pond fishing, its pond fishing households have the country’s lowest average annual production, 50.7 kg. Chittagong and Rajshahi have by far the highest average household production levels, both producing nearly twice the national average.

Table 4 shows how pond fishing households reported they utilize the fish they harvested in the past 12 months; 57% of the total harvested fish was eaten by the household and 43% sold. More than three-quarters of the pond fishing households reported they only ate the fish they harvested, and on average, they harvested 44.9 kg of fish over the past year. There were very few households that only sold what they

Table 2

Baseline nutrient intakes: mean daily nutrient intake per AME and percent of daily requirement achieved.

| Domain                  | Number of persons | Mean daily intake per AME<sup>a</sup> | Vitamin A (µg RAE)<sup>b</sup> | Mean % of daily requirement achieved | Prevalence of inadequate intake |
|-------------------------|-------------------|-------------------------------------|--------------------------------|-----------------------------------|--------------------------------|
| Rural                   | 104,498,016       | 395                                 | 63.7                           | 83.5%                             |
| Urban                   | 34,319,733        | 424                                 | 68.3                           | 80.8%                             |
| Household fishing pond  | 21,136,927        | 436                                 | 70.3                           | 78.1%                             |
| Household without pond  | 117,680,822       | 396                                 | 63.9                           | 83.7%                             |
| Divisions               |                   |                                     |                                |                                   |
| Barisal                 | 8,905,211         | 423                                 | 67.8                           | 83.4%                             |
| Chittagong              | 26,727,815        | 410                                 | 66.3                           | 84.0%                             |
| Dhaka                   | 44,714,603        | 401                                 | 64.7                           | 83.8%                             |
| Khulna                  | 16,292,108        | 486                                 | 78.0                           | 71.7%                             |
| Rajshahi                | 17,027,785        | 383                                 | 61.7                           | 82.2%                             |
| Rangpur                 | 16,351,424        | 356                                 | 57.5                           | 84.2%                             |
| Sylhet                  | 8,798,802         | 334                                 | 54.0                           | 93.7%                             |
| Bangladesh              | 138,817,749       | 402                                 | 64.9                           | 82.9%                             |

Note: Bold values indicate significance at the absolute and relative importance of alternative sources of total annual homestead fish production in Bangladesh (t/year and percent).

<sup>a</sup> AME: Adult consumption equivalent.

<sup>b</sup> RAE = Retinol activity equivalent.

<sup>c</sup> EAR: Estimated average requirement.

<sup>d</sup> Calculations exclude infants for whom there is no established EAR.
### Table 3

| Division   | Total pond area (ha) | Average national pond fish yield (kg/ha/year) | MPP (kg/year) |
|------------|----------------------|----------------------------------------------|---------------|
| Dhaka      | 28,630,257           | 359,035                                      | 1.789,213     |
| Chittagong | 19,657               | 49,633                                       | 4,928,860     |
| Rangpur    | 4,671                | 40,707                                       | 3,528,478     |
| Sylhet     | 5,848                | 398                                           | 1,577,863     |
| Rajshahi   | 9,510                | 58,480                                       | 3,838,669     |
| Bangladesh | 38,55,039            | 0.0607 (ha/hh)                               | **23,816,166**|

Notes: Assumes all pond fishing households that both ate and sold, sold two-thirds of their total harvest. These households constitute 3% of Bangladesh’s total households and they account for nearly two-thirds of the total homestead pond harvest. On average, they harvested nearly six times more, and eat nearly twice as much fish as other pond fishing households. The largest share (28%) of these pond fishing households are in Dhaka division.

As mentioned above, the total production of pond-sourced fish calculated from the HIES was 359,035 t. The total number of hectares, calculated from the estimated number of ponds and the reported average pond size by Belton and Azad was 234,001 ha (Table 3), remarkably close (97%) to the 241,159 ha estimate reported in the 2005 Agricultural Sample Survey (BBS, 2006). The resulting average annual national pond fishing yield of all fish was calculated as 1534 kg/ha/year. Dividing the division-specific total production estimates by this value and then dividing the result by the number of ponds for each division yielded average pond sizes for each division which are shown in Table 3. Average farm sizes vary by a factor of 4, ranging from 0.12 ha in Chittagong to 0.03 ha in Rangpur. So while Rangpur accounts for the greatest share of total ponds in Bangladesh, households generally have smaller ponds in this division. At the national level, multiplying our derived estimate of each household’s pond size by the average national yield, we estimated the average annual maximum pond production of mola, 23.7 kg mola/hh/year (= 390 kg mola/ha/y × 0.0607 ha/hh). Multiplying this value by the total number of mola-producing households (1,151,413), the total national annual production of mola was calculated to be 27,375 t mola/year. Assuming a loss of 13% in cleaning waste, we estimated that after the completion of the phasing-in of the MPP, that the total national consumption of mola would be 23,816 t/year. Using the derived division-specific average pond sizes, the maximum average household mola production and maximum aggregate annual pond production by division were calculated (Table 3). Chittagong and Rajshahi have the largest average conditional production potential of mola (46.5 kg/pond/year and 45.3 kg/pond/year) while Rangpur (12.9 kg/pond/year) and Sylhet (15.7 kg/pond/year) have the lowest. However, in aggregate Dhaka (22,807 t/year) and Chittagong (19,357 t/year) have the greatest annual mola production potential.

### 3.3. Fish consumption

From the HIES consumption module, the total annual consumption of all fish (inland capture, inland culture and marine) in Bangladesh is estimated to be 2,048,282 t. Table 5 shows the annual total fish consumption in Bangladesh by location, source and per household. Seventy-five percent of households in Bangladesh are located in rural areas and account for 71% of total fish consumption. While the proportion of households that consume fish is extremely high and similar in rural and urban areas, the quantity of fish consumed varies; 191 g/household/d in rural and 225 g/household/d in urban households, 18% higher than in rural households.

Purchased fish accounts for 86% of all fish consumed by Bangladeshis. The consumption of home produced fish comes in at a distant second, accounting for 9% In-kind payments and gifts accounted for 4% and 1% of all fish consumed, respectively. 95% of Bangladesh households purchase fish and 17% consume fish from home production. Overall (unconditional) average household daily consumption of fish from purchases is 169 g/d and 18 g/d from home production. In absolute terms, Dhaka—with one-third of the country’s population—accounts for 36% of all fish consumed in Bangladesh, followed by Chittagong (23%). When analyzing the average household consumption level, however, the situation looks quite different: Sylhet consumes the greatest amount of fish per household (283 g/household/d), 10% more than Dhaka’s average (213 g/household/d) and 41% more than the national average. At the other end of the spectrum are Rangpur and Rajshahi, both with...
a consumption of about 125 g/household/d, 35% below the national average.

Pond fishing households consume disproportionately large quantities of fish. They constitute 13.5% of the total households in Bangladesh but consume 16.2% of the total purchased fish and 46% of the total home produced fish. The remainder, 54%, is caught or harvested in water bodies other than homestead ponds. Pond fishing households’ average consumption from home production of fish is more than five times the quantity of non-pond fishing households – 62 vs 11 g/day, respectively (Table 6) – and their consumption from the sum of fish from purchases and own production is 24% greater than non-pond-fishing households (235 vs 190 g/household/d) and 19% greater than the national household average of 196 g/household/d.

Table 6 shows fish consumption patterns of inland fish capture and fish culture. The quantities of the 13 categories of fish included in the HIES database that are consumed and the amount of vitamin A they provide are shown. The puti/tilapia/nilotica category is the single most important, accounting for slightly more than one-third of the total vitamin A consumed. It is followed by mala-kachi/chala-chapila and shal/gajar/taki, which provide 19.9% and 17.1%, respectively. These three categories account for 71.5% of the total vitamin A Bangladeshis derive from the fish they consume. The current mix of fish consumed by Bangladeshis has an average vitamin A content that is just 2.0% of that of mola. If a relatively small amount of additional mola were produced and consumed – just 41,026 t/year, the equivalent of 21% of the quantity of inland fish currently consumed – it would provide an equivalent amount of vitamin A, doubling the quantity of vitamin A Bangladeshis currently obtain through inland fish consumption. The consumption of fish currently provides 4% of the Bangladesh population’s total daily vitamin A requirements, which is just less than 7.0 billion μg RAE/d, equivalent to 22 μg RAE/capita/d.4

To provide a reference point, we consider the most extreme and highly improbable case: if the current fish consumption pattern of Bangladesh were drastically changed and all inland fish consumed in Bangladesh were to become mola, it would result in the share of the vitamin A intake coming from inland fish increasing from the current level of 4% to 225%. The proposed MPP provides a different model which makes use of the ecological niche of mola in homestead pond polyculture in Bangladesh. The fact that, if properly managed, the aquaculture of small amounts of mola can be introduced in existing ponds without affecting the production of the other fish species being produced in the pond provides a unique opportunity for improving vitamin A nutriture in Bangladesh. The wonder of mola is that it can be introduced in existing homestead pond polyculture in Bangladesh and provide additional vitamin A and other essential nutrients without resulting in trade-offs in the form of reductions in the production and consumption of the other fish in the pond.

3.4. Modeling the Mola Promotion Program

Table 7 shows the key endline parameters of the 11 year MPP we posited in the Methods section for Scenario 1.

Modeling the incremental production of mola with the HIES data on households’ pond data and modeling the incremental consumption of mola with the HIES data on fish, we estimate national annual mola production will be 27,374 t and 23,816 t mola will be consumed each year.5

The mola implementation plan figures are shown in Table 8. As noted earlier, by the end of the MPP, we estimate that 3,850,000 households will have been trained and 1,151,413 households will be producing mola.

Table 9 presents impact results of the three scenarios. The results of the different scenario are as follows: Scenario 1 reduces IVAI in Bangladesh from 83.2% to 82.2%. The impact is concentrated in rural areas, where it reduces IVAI from 83.9% to 82.5%, and, is greatest among households that engage in homestead pond fishing. Among the pond fishing households, the MPP reduces IVAI from 78.5% to 71.5%. In all three scenarios, 99% of the added vitamin A intake attributable to mola is delivered by the consumption of mola from own production and 1% provided by mola that is purchased. The MPP has the biggest impact on vitamin A intake in Rajshahi, followed closely by Barisal and Chittagong; and with almost no impact in Sylhet.

In Scenario 2, the increased mola production results in an annual average pond production of 31.0 kg/pond/year. As shown in Table 9, this results in a modest further reduction in the endline prevalence of IVAI by 0.4 percentage points compared to Scenario 1, and a further reduction of 1.8 percentage points among pond fishing households. In Scenario 3, the total national prevalence of IVAI falls from 83.2% to 80.6%. In rural areas, it falls from 83.9% to 80.6% and among pond fishing households, it falls from 83.2% to 80.6% and among pond fishing households.

5 We do not have data on the baseline (i.e., pre-MPP) production levels of mola. The quantity produced and consumed is some portion of the “other fish” totals. Our estimates of the impact of the MPP are due to incremental additions to the unknown quantities currently produced and consumed, and the quantities discussed in this section are the MPP-induced increases.

6 At baseline, 28,879 or 0.021% of the entire (survey weighted) population of 138,817,749 had estimated vitamin A intakes in excess of the upper limit. When the MPP is fully phased-in, the number increased (scenario #1) by 3,169 to 0.023% of the population. All of the persons whose intake comes to surpass the upper limit as a result of the MPP are children 1–3 years old and all have increases in vitamin A intake that are at most 32% greater than their upper limit of 600 μg RAE/day.
3.5. Estimating the costs of the Mola Promotion Program

Based on costs of the “Small Fish and Nutrition” project, we estimate that the additional requirements for mola brood stock and preparation costs as well as additional support for farmer training will cost US$ 3.50 per pond. Given our assumption that 30% of trained households will adopt mola production and that 3,850,000 households will be trained, these additional direct costs will annually average US$ 420,000. Adding these to the total government’s estimated annual costs of the initiative yields an annual estimate of US$ 1.713 million and a total (undiscounted, 11 years’ duration) MPP cost of US$ 23 million.

3.6. DALYs saved, Benefit–cost and cost-effectiveness analysis of the Mola Promotion Program

The number of DALYs saved, benefit–cost ratios and measures of cost-effectiveness are shown in Table 10.

At the end of the 11 year long MPP, the benefit–cost ratio will be five in Scenario 1, six in Scenario 2 and 11 in Scenario 3. The cost of changing one person’s vitamin A intake status from inadequate to adequate varies from US$ 14 in Scenario 1, to US$ 11 in Scenario 2 and US$ 6 in Scenario 3 (not shown). When DALYs are valued at US$ 500, the benefit–cost ratios fall to half these levels, but in all cases, the MPP remains an attractive investment. By the cost-effectiveness metric of cost per DALY saved, the three scenarios are good investments. With cost per DALY saved of US$ 194, US$ 171 and US$ 90 in Scenarios 1,2 and 3, respectively, all three scenarios are highly cost-effective by World Bank and WHO criteria (World Health Organization 2003).

3.7. Time sensitivity of the MPP

Table 10 also shows the benefits and costs of the three Scenarios over four accounting periods - the 11-years MPP that has been the focus of discussion up until now, as well as 5-, 10-, 20- and 30-year periods – to investigate the sensitivity of the findings to the length of the accounting period. The MPP is not expected to stop generating benefits at the end of its 11 years’ duration. If it is assumed that adopters continue producing mola indefinitely, and there is no attrition, then the benefits produced by the MPP in its final active year, will continue indefinitely (although their present value will be eroded each additional year into the future, as each year’s benefits are increasingly subject to the discount rate). The costs of the MPP, on the other hand, are assumed to go effectively to zero at the end of the 11 years, as all recurrent costs of mola production become costs absorbed by the pond fishing households.7

Each year that the benefit–cost analysis of the MPP is extended results in an increase in its benefit–cost ratio because annual benefits continue to accrue while annual costs are effectively zero. As a result, Scenario 1 goes from having a Benefit–cost ratio (using the US$ 1000 valuation of DALYs) of five, if the MPP total discounted costs are US$ 19.4 million, to having a benefit–cost ratio of 10, with a 20-year accounting period, and a ratio of 15, with a 30-year accounting period.

7 There are annual recurrent costs of US$ 3.50 per pond which are more than offset by the proceeds from the sale of 40% of the harvested mola. In the “Small Fish and Nutrition” project, mola production averaged 27.6 kg/pond/y, and pond size averaged 10 decimals. Project households on average sold 40% of the harvested mola and generated an annual income of BDT 563/decimal. Our analysis assumes the same average mola production and pond size, but based on HIES pond production data, we have estimated that the average pond size is 50% larger. Adjusting for pond size, we estimate that mola sales would average BDT 8445/pond/y. We chose not to include these minor costs in the analysis as they unduly complicate it and have no impact on the findings.

US$ 1 = BDT 76.8
The cost per DALY saved from the base scenario with an 11-year accounting period is US$194, making it a very cost-effective intervention, as categorized by World Bank and WHO criteria. Extending the accounting period results in increasingly lower costs per DALY saved for the MPP.

4. Discussion and conclusions

A program promoting the production and consumption of mola is appealing for several reasons that have not been taken into account in this study. Firstly, mola can be cultured in homestead ponds in combination with carp species, without reducing the production and productivity of carp (Hossain et al., 2014; Hoque and Rahman, 2008; Milstein et al., 2009; Roos et al., 1999, 2003, 2007; Wahab et al., 2011). Mola has been found to breed in most ponds within a few weeks after stocking, and may breed several times in a season (Asadujjaman et al., 2013). Mola may be periodically partially harvested, thereby controlling over-population, and at the same time, providing a supply of micronutrient-rich fish (Roos et al., 1999). As compared with the way in which carp is harvested (a few times per year, at the end of the five to seven months’ production season), the periodic, partial harvesting of mola is more conducive to frequent home consumption.

A second reason for the appeal of the MPP is that it can also improve nutrition indirectly, by improving household income. Mola’s relative price has increased in the last few years as its nutritional value has come to be increasingly recognized (Thisted, 2012) and its demand in urban areas in particular has grown (Apu, 2014). As noted earlier, Bangladesh has recently introduced vegetable oil fortification which, if implemented as designed, could reduce IVAI by as much as 20 percentage points. If oil fortification proves effective, it will attenuate the impact estimates of the MPP presented here. Even with oil fortification, however, and 60% of Bangladeshis still expected to be plagued by IVAI, the MPP can be expected to make an important public health contribution. Is there another vitamin A program that should be considered? Would the introduction of the vitamin A wheat flour fortification (WFF) be more cost-effective? Fig. 5 shows the cost per DALY saved of the two programs using 10-, 20- and 30-year accounting periods. With a 10-year accounting period, the MPP is 39% less cost-effective than the WFF. Over time, however, the cost-effectiveness of the MPP increases as its costs fall to zero in year 11 and remain zero thereafter, while its DALYs saved continue to accrue annually, and the cost-effectiveness of the WFF falls in both absolute and relative terms. After the initial investment cost of the MPP is paid, the MPP becomes more cost-effective, has lower costs and generates a larger public health impact than the WFF. In the longer term, for Bangladesh, promoting mola production and consumption is a wiser investment than fortifying wheat flour.

There are several limitations of this study which primarily stem from the use of the HIES datasets. Firstly, we use a household-based survey to estimate the vitamin A intake adequacy of individuals. To do so, we assume that all food, including mola, is distributed within the household in direct proportion to each member’s share of the household’s total energy requirements, using the AME. While a recent study in Bangladesh (Sununtmasuk and Fiedler, 2015) suggests that this method provides a reasonable proxy estimate for individuals three years of age and older, we are uncertain as to how accurate it might be for estimating specifically the consumption level of mola by children less than three years of age and who provide an important part of the total DALY-based impacts. It is possible, therefore, that our results overestimate the mola consumption of this important population group and its impact.

A second limitation is that HIES fieldwork was implemented over the course of an entire year. Each primary sampling unit (PSU) was visited once a month so as to minimize distortions that might otherwise have been caused by seasonality. Still, the results remain vulnerable to possible distortions caused by seasonality of ponds which might affect the quantities and types of fish produced, harvested and consumed and are more likely to have a larger effect in the north of the country, resulting in some overestimation of impact. Thirdly, the HIES does not provide any detailed information about the quantities and types of food consumed.
### Table 7
Homestead pond mola production and consumption by division and source.

| Division | Pond fishing households | Mola adopters (30%) | Total mola production (kg/hh/year) | Household mola Consumption by source | Average household mola consumption |
|----------|------------------------|---------------------|-----------------------------------|-------------------------------------|-----------------------------------|
|          |                        |                     |                                   | All consumers (kg/hh/year) | Consumption from home production (kg/hh/year) | Consumption from purchasing (kg/hh/year) | Mola producers from home production (kg/hh/year) | All consumers from purchases (kg/hh/year) |
| Barisal  | 385,141                | 114,332             | 2,286,631                         | 1,989,369                         | 1,193,621                                   | 795,748                                   | 10.44                                         | 0.51                                           |
| Chittagong| 415,979                | 123,597             | 5,767,853                         | 5,018,032                         | 3,010,819                                   | 2,007,213                                   | 24.36                                         | 0.41                                           |
| Dhaka    | 873,565                | 262,364             | 6,875,737                         | 5,981,891                         | 3,589,135                                   | 2,392,756                                   | 13.68                                         | 0.26                                           |
| Khulna   | 499,258                | 148,260             | 2,419,884                         | 2,105,299                         | 1,263,179                                   | 842,120                                    | 23.7                                          | 0.47                                           |
| Rajshahi | 350,484                | 106,663             | 4,842,766                         | 4,213,206                         | 2,527,924                                   | 1,685,283                                   | 6.72                                          | 0.52                                           |
| Rangpur  | 1,231,924              | 367,805             | 4,734,961                         | 4,119,416                         | 2,471,650                                   | 1,647,766                                   | 23.7                                          | 0.47                                           |
| Sylhet   | 98,688                 | 28,392              | 447,091                           | 388,969                           | 233,382                                     | 155,588                                    | 8.22                                          | 0.10                                           |
| Bangladesh| 3,855,039              | 1,151,413           | 27,374,923                        | 23,816,183                        | 14,289,710                                   | 9,526,473                                   | 12.41                                         | 0.35                                           |

Bold values indicates total number of households trained in mola production in the MPP, by division.

Mola consumed is 87% of total mola production; 13% is cleaning waste.

### Table 8
Implementation plan to promote homestead pond production and consumption of mola to combat vitamin A deficiency

| No. of homestead ponds | Rangpur | Dhaka | Khulna | Chittagong | Barisal | Rajshahi | Sylhet | Total |
|------------------------|---------|-------|--------|------------|---------|----------|--------|-------|
| MPP Year 1             | 400,000 |       |        |            | 400,000 |          |        | 800,000 |
| MPP Year 2             | 400,000 |       |        |            | 400,000 |          |        | 800,000 |
| MPP Year 3             | 400,000 |       |        |            | 400,000 |          |        | 800,000 |
| MPP Year 4             | 400,000 | 100,000 |      |            | 200,000 |          |        | 700,000 |
| MPP Year 5             | 400,000 | 200,000 |      |            | 400,000 |          |        | 1,000,000 |
| MPP Year 6             | 400,000 | 200,000 |      |            | 200,000 |          |        | 800,000 |
| MPP Year 7             | 400,000 | 200,000 |      |            | 400,000 |          |        | 1,000,000 |
| MPP Year 8             | 400,000 | 200,000 |      |            | 200,000 |          |        | 800,000 |
| MPP Year 9             | 400,000 | 200,000 |      |            | 400,000 |          |        | 1,000,000 |
| MPP Year 10            | 400,000 | 200,000 |      |            | 200,000 |          |        | 800,000 |
| MPP Year 11            | 400,000 | 200,000 |      |            | 400,000 |          |        | 1,000,000 |

Total: 1,200,000 900,000 500,000 400,000 400,000 350,000 100,000 3,850,039

Baseline prevalence of inadequate vitamin A intake (IVA): 84%
Prevalence of IVA at baseline: Number: 13,767,899 37,470,837 11,681,441 22,451,365 7,426,946 13,996,839 8,244,477 115,039,805
Percent: 12% 33% 10% 20% 6% 12% 7% 100%

Bold values indicates the total national impact of mola on the prevalence of inadequate vitamin A intake in Bangladesh.

### Table 9
Impact of mola on the prevalence of inadequate vitamin A intakes, Bangladesh.

| Domain | Mola production | Baseline | Scenario 1st endline | Scenario 2nd endline | Scenario 3rd endline |
|--------|----------------|----------|----------------------|----------------------|----------------------|
|        | Households fish ponds adopting mola production | Intake of VA μg RAE | Inadequate vitamin A Intake (%) | Intake of VA μg RAE | Inadequate vitamin A Intake (%) | Intake of VA μg RAE | Inadequate vitamin A Intake (%) |
| Rural  | 104,498,016     | 308      | 82.5%                | 311                  | 82.0%                | 315                  | 82.5%                |
| Urban  | 34,319,733      | 307      | 82.1%                | 309                  | 82.2%                | 311                  | 82.5%                |
| Household fishing pond | 21,136,927 | 308      | 82.5%                | 311                  | 82.0%                | 315                  | 82.5%                |
| Household without pond | 117,680,822 | 299      | 84.1%                | 299                  | 84.1%                | 299                  | 84.1%                |
| Barisal | 8,905,211      | 331      | 82.2%                | 331                  | 82.2%                | 331                  | 82.2%                |
| Chittagong | 26,727,815 | 315      | 82.9%                | 317                  | 82.6%                | 317                  | 82.6%                |
| Dhaka  | 44,714,601     | 309      | 83.2%                | 311                  | 82.5%                | 311                  | 82.5%                |
| Khulna | 16,292,108     | 379      | 71.7%                | 381                  | 71.5%                | 381                  | 71.5%                |
| Rajshahi | 17,027,785 | 306      | 81.5%                | 309                  | 80.7%                | 309                  | 80.7%                |
| Rangpur | 16,351,424   | 282      | 83.4%                | 285                  | 82.9%                | 285                  | 82.9%                |
| Sylhet | 8,798,802      | 248      | 93.8%                | 250                  | 93.6%                | 250                  | 93.6%                |
| Bangladesh | 138,817,749 | 312      | 82.2%                | 315                  | 81.8%                | 315                  | 81.8%                |

Bold values indicates total number of households trained in mola production in the MPP, by division.

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Scenario 1: 30% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 23.7 kg/pond/year.
Scenario 2: 30% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 31.0 kg/pond/year.
Scenario 3: 60% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 31.0 kg/pond/year.

VA: vitamin A.
IVA: inadequate vitamin A intake.
PPT: percentage point change.
Note: DALYs and Costs are discounted at 3%/year.

Note: It is assumed that all mola produced are consumed by women 15 years old and children under 5 years old.

Impact of Mola on vitamin A intakes: modified Scenario #1.

Table 11
Impact of Mola on vitamin A intakes: modified Scenario #1.

Table 10
Cost-benefit and cost-effectiveness analysis of a homestead pond Mola Promotion Program.

Identify women who are pregnant or lactating. No adjustment therefore could be made in the EAR for these population groups. We therefore treated all women as non-pregnant and non-lactating. Given that these populations have higher vitamin A EARs, this results in an underestimation of the prevalence of vitamin A inadequacies and vitamin A EAR gaps.

In addition, a shortcoming of the DALY methodology is that it does not take into account the reduction of VAD in all individuals. The methodology is applied to only a subset of the entire population, and therefore underestimates impact and DALYs saved.

In modeling the consumption of the mola that pond fishing households sell, we could not identify who the purchasers of mola were, we assumed that it was evenly purchased by all households. This assumption spreads the mola sold and purchased so thinly, that there is little discernible impact of the mola on Bangladeshis’ vitamin A intakes and thus little impact on the prevalence of inadequate intakes. As such, this limitation in our analysis results in our dissipating the impact of mola, and underestimating its impact.

A final limitation of the study is that we do not assess the income impacts of the sale of mola, under-estimating the benefit–cost ratio. While it is acknowledged that some of these limitations result in underestimation of impacts and others in overestimations, the MPP looks to be a good food-based investment for improving nutrition in Bangladesh, especially in the longer term.

Statement of relevance

1. This paper provides a specific example of how aquaculture might be better linked to food and nutrition security in Bangladesh.
2. It investigates the potential of homestead pond polyculture, based on production and consumption of a small indigenous fish, mola carp, in improving vitamin A intakes in Bangladesh; most notably among the 20% of Bangladeshis who engage in homestead pond fishing.

3. This is the first paper to evaluate the impact of an aquaculture food-based approach by modeling human nutrition and health impacts using disability-adjusted life years (DALYs).

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