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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 benefit–cost 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 reduce the burden of micronutrient malnutrition in Bangladesh.

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 seen, 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

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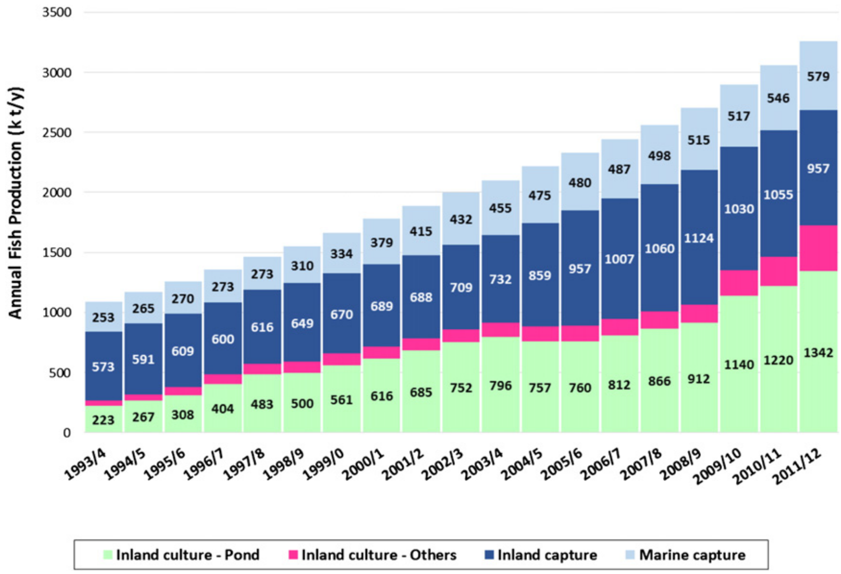

Fig. 1. Annual fish production by sector in, Bangladesh; 1993/94 to 2011/12.
Source: FRSS, 2003, 2006, 2013.

2009/10, pond aquaculture has been the most important source of fish consumed in Bangladesh (Toufique and Belton, 2014).

1.2. Fish and aquaculture in Bangladesh

As epitomized by the well-known idiom "*machee bhatee 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.[1] 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 this 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] 1 decimal = 40. 5 m^2 = 0. 004 ha.

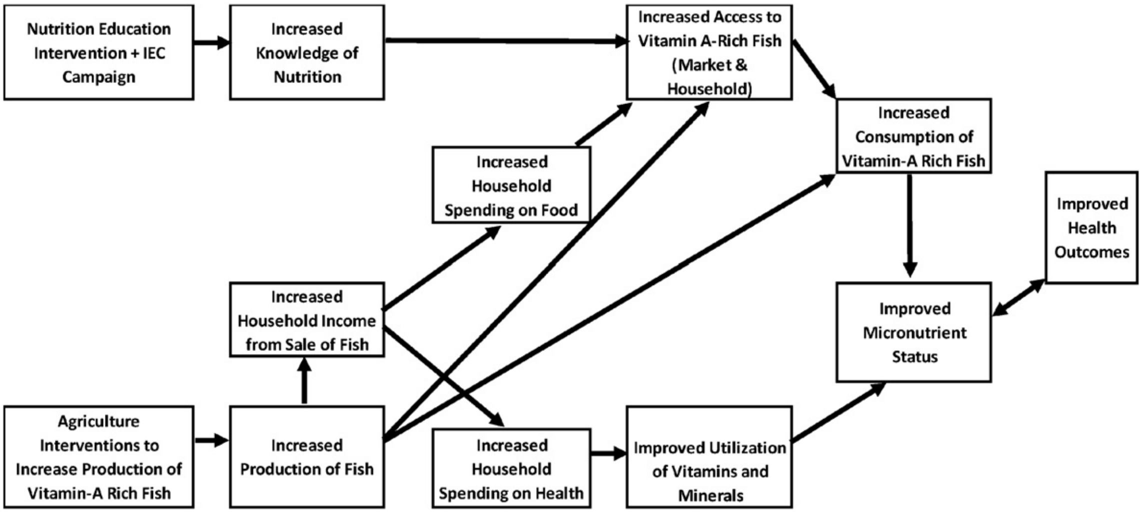

Fig. 2. Pathways from the Mola Promotion Program to improved nutrition and health. Note: IEC: Information, Education, Communication.
Source: Adapted from Masset et al., 2011; Girard et al., 2012.

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.

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 6–14 years	6–11 years	12–14 years	Non-pregnant, non-lactating women 15–49 years
Vitamin A deficiency	76.9%	74.5%			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%

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 Bangladeshis;
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,

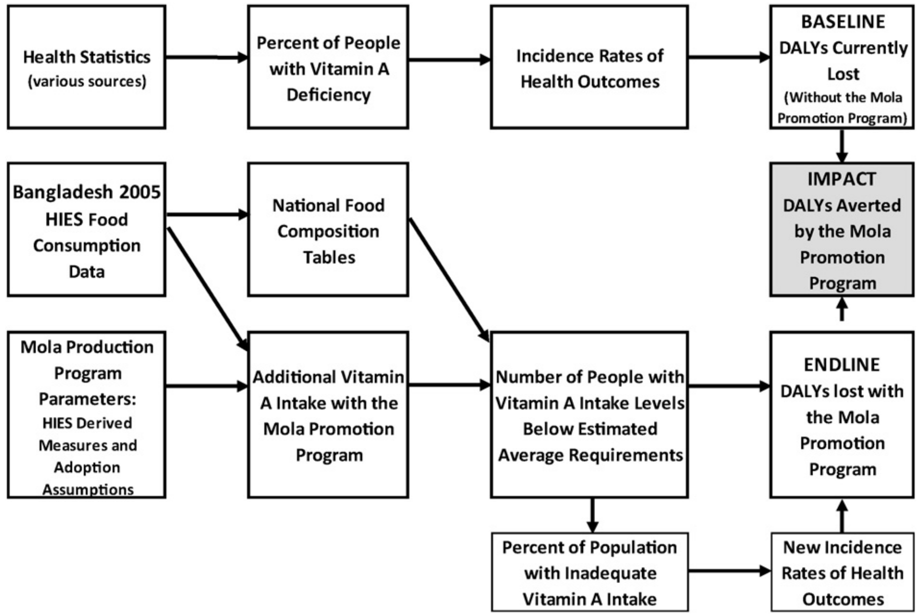

Fig. 3. Estimating the nutritional benefits of increasing homestead pond mola production and consumption in Bangladesh.
Source: Adapted from Stein et al., 2008.

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

[2] The calculation of the DALYs assumes a dose–response relationship (Hallberg et al., 2000; Zimmermann and Qaim, 2004; Stein et al., 2005). The key insight of the approach is the non-linearity and concavity of the association between vitamin A intake and adverse functional health outcomes. The relationship assumes that the risk of developing an adverse health outcome increases exponentially as the gap between a person's intake and requirement increases. Conversely, if two persons consume the same amount (or dose) of a micronutrient, the individual with the greater intake gap is expected to have a relatively larger reduction in risk or improvement in health status than the person whose intake level is closer to his or her requirement. The approach is operationalized by calculating an efficiency level for each individual observation, taking into account the individual's specific consumption pattern (see Stein et al., 2005 for details). The average efficiency of the intervention associated with particular age/gender groups is then applied to the incidence rates of the adverse outcomes associated with the particular type of micronutrient deficiency (among those groups) to calculate the new DALY estimate for the "with intervention" or endline scenario.

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 fish/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 annual average 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 annual 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%).

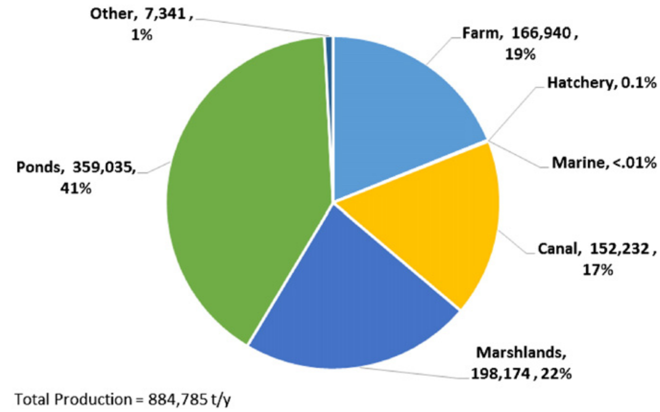

Fig. 4. Total fish production by source in Bangladesh (t/year).

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[a] Vitamin A (μg RAE)[b]	Mean % of daily requirement achieved % vitamin A EAR[c,d]	Prevalence of inadequate intake Vitamin A
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%**

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).
[a] AME: Adult consumption equivalent.
[b] RAE = Retinol activity equivalent.
[c] EAR: Estimated average requirement.
[d] Calculations exclude infants for whom there is no established EAR.

Table 3
Estimates of average pond size, average mola production and total maximum annual mola production by division in Bangladesh.

Divison	Total HHs	Total pond fishing HHs	% of all ponds	Total pond fish production (kg/year)	Conditional avg HH pond fishing production (kg/hh/year)	Average national pond fish area (ha)	Average national pond fish yield (kg/ha)	Total pond area (ha)	Conditional average pond size (ha/hh)	Average national mola yield (kg/ha/year)	Conditional avg HH production potential of mola (kg/hh/year)	Total annual mola production potential (kg/year)
Barisal	1,789,213	385,141	10%	30,159,665	78.3	–	–	19,657	0.051	–	19.9	7,666,056
Chittagond	4,928,860	415,979	11%	76,154,067	183.1	–	–	49,633	0.119	–	46.5	19,357,024
Dhaka	9,510,924	873,565	23%	89,727,089	102.7	–	–	58,480	0.067	–	26.1	22,807,048
Khulna	3,456,250	499,258	13%	32,029,605	64.2	–	–	20,875	0.042	–	16.3	8,141,362
Rajshahi	3,838,669	350,484	9%	62,458,284	178.2	–	–	40,707	0.116	–	45.3	15,875,797
Rangpur	3,528,478	1,231,924	32%	62,403,296	50.7	–	–	40,671	0.033	–	12.9	15,861,820
Sylhet	1,577,863	98,688	3%	6,102,825	61.8	–	–	3978	0.040	–	15.7	1,551,231
Bangladesh	**28,630,257**	**3,855,039**	**100%**	**359,034,831**	**93.1**	**0.0607**	**1534**	**234,001**	**0.061**	**390**	**23.7**	**91,260,338**

Notes: Assumes all pond fishing households adopt and produce mola. Conditional average calculations include only those households producing (consuming) some mola.
Bold values indicate significance at utilization of total annual homestead pond fishing production in Bangladesh.

harvested, and on average, they sold less than the households that reported they both ate and sold their harvest. The roughly one quarter of 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 mola 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

Table 4
Homestead pond fishing in Bangladesh
Number and percentage of households and utilization/disposition of fish.

Utilization of fish (kg/year)	Households number percent		Kilograms of fish per year: Eaten	Sold	Total harvested	Percentages: Eaten	Sold	Total
Eaten & sold	884,759	Mean:	82.5	168.8	251.3	37%	100%	64%
	24%	Total:	72,959,048	149,347,925	227,580,797			
Eaten only	2,832,510	Mean:	43.7	0.0	44.9	63%	0%	36%
	76%	Total:	123,895,494	0	127,201,796			
Sold only	2722	Mean:	0.0	140.0	140.0	0%	0%	0%
	0.1%	Total:	0	381,105	381,105			
Total	3,719,991	Mean:	58.6	168.7	94.1	100%	100%	100%
	100%	Total:	196,854,542	149,729,030	355,163,698			
				Percent of grand total:		**57%**	**43%**	**100%**

Note: 135,048 (3.5%) of homestead pond-fishing households did not respond to the disposition question, resulting in discrepancies in Table 5's total number of households and its total kg harvested relative to similar figures reported elsewhere in this table. This source is in addition to any discrepancies that might result from the very different recall periods used in the agriculture/production module and the food consumption modules, as noted in the text.
Bold values indicate the national unconditional average household fish consumption.

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 from fish. It is followed by mala-kachi/chala-chapila and shoal/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.[3] If a relatively small amount of additional mola were produced and consumed – just 41,026 t/year, the equivalent of 2.1% of the quantity of inland fish currently consumed – it would provide an equivalent amount of vitamin A, doubling the quantity of vitamin A Bangladesh currently obtains 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.[6] 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

[3] The simulations assume that the average retinol content of mola is 2680 μg RAE/100 g. This is a simplification that does not take into account any variability owing, for instance, to differences that might result from feed, soils or seasonality.

[4] EARs for vitamin A are specific for age, gender and physical activity level (Institute of Medicine [IOM], 2006). The vitamin A EAR for an average Bangladeshi is 482 μg RAE/d.

[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 3169 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.

Table 5
Unconditional[a] average household fish consumption, Bangladesh.

Domain	Number of households	Percent of all households	Total Amount of fish consumed by source (t/year)				Mean fish consumption g/d			Percent of national total consumption			Percent by source of fish consumed		
			Purchased	Home produced	Gifts & other	Total	Purchased	Home produced	Total	Purchased	Home produced	Total	Purchased	Home produced	Total
Rural	**21,367,244**	75%	1,195,008	180,406	84,174	1,459,588	153	23	187	68%	96%	71%	82%	12%	100%
Urban	**7,263,012**	25%	567,201	8324	13,169	588,695	214	3	222	32%	4%	29%	96%	1%	100%
Household fishing pond	**3,855,039**	13%	225,571	86,984	18,738	331,294	160	62	235	13%	46%	16%	68%	26%	100%
Household without pond	**24,775,217**	87%	1,536,638	101,746	78,605	1,716,989	170	11	190	87%	54%	84%	89%	6%	100%
Barisal	**1,789,213**	6%	99,714	17,658	13,612	130,984	153	27	201	6%	9%	6%	76%	13%	100%
Chittagong	**4,928,860**	17%	448,047	9265	4563	461,876	249	5	257	25%	5%	23%	97%	2%	100%
Dhaka	9,510,924	33%	634,139	75,575	30,846	740,560	183	22	213	36%	40%	36%	86%	10%	100%
Khulna	3,456,250	12%	172,250	31,726	10,584	214,560	137	25	170	10%	17%	10%	80%	15%	100%
Rajshahi	3,838,669	13%	150,507	18,445	10,147	179,098	107	13	128	9%	10%	9%	84%	10%	100%
Rangpur	3,528,478	12%	112,920	33,201	13,092	159,213	88	26	124	6%	18%	8%	71%	21%	100%
Sylhet	1,577,863	6%	144,631	2861	14,498	161,991	251	5	281	8%	2%	8%	89%	2%	100%
Bangladesh	**28,630,256**	**100%**	**1,762,209**	**188,730**	**97,343**	**2,048,282**	**169**	**18**	**196**	**100%**	**100%**	**100%**	**86%**	**9%**	**100%**

Bold values indicate the total National Consumption of Inland Fish in Bangladesh.
[a] All households at the divisional and national level.

households, it falls from 78.5% to 61.4%, a 17.1 percentage point reduction.

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 findings and a cost-effectiveness comparison

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 mola produced, 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

Table 6
Vitamin A content and contribution to Vitamin A intake by type of inland fish consumed in Bangladesh

Categories of fish	Vitamin A content (μg RAE/100 g raw, edible parts[a])	Vitamin A content as a percent of molas[b]	Quantity consumed (t/year)	Quantity consumed (t/d)	Total μg RAE provided per day	Percent of μg RAE provided from fish
Hilsa	46	1.7%	138,833	380.4	174,967,705	5.8%
Rui/Catla/Mrigal/Kalbaush	9	0.3%	297,446	814.9	226,431,233	7.5%
Thai Pangas/Boal/Air	15	0.6%	179,024	490.5	74,440,206	2.5%
Kai/Magur/Shing/Khalisha	46	1.7%	29,621	81.2	38,339,167	1.3%
Koi	9	0.3%	28,440	77.9	20,495,179	0.7%
Silver carp/Grass carp/Mirror carp	9	0.3%	312,550	856.3	83,063,593	2.8%
Shol/Gojar/Taki	9	0.3%	119,805	328.2	515,299,934	17.1%
Punti/Big Punti/Tilapia/Nilotica	57	2.1%	402,374	1102.4	1,039,787,950	34.5%
Mola-Kachki/Chela-Chapila	57	2.1%	225,456	617.7	599,273,930	19.9%
Dried fish	64	2.4%	53,519	146.6	95,685,025	3.2%
Eel fish/Tengra	9	0.3%	58,533	160.4	15,292,741	0.5%
Bailla/Tapashi	19	0.7%	16,043	44.0	8,525,941	0.3%
Other fish	25	1.1%	81,101	222.2	120,461,215	4.0%
Weighted averages:	**56.6**	**2.0%**				
Totals:			**1,942,745**	**5322.6**	**3,012,063,819**	**100.0%**

Note: Exclusive of marine fish. If the amount of vitamin A provided from inland fish were to be obtained from mola alone, then the amount of mola required would be 41,026 t/year equivalent to 112.4 t/d, amounting to only 2.1% of total inland fish.
Bold values indicates National total homestead pond mola production and consumption by source.
[a] RAE: retinol activity equivalent.
[b] Vitamin A content in mola: 2680 μg RAE/100 g raw, edible parts (Roos et al., 2002).

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, Roos et al., 2003, 2007; Wahab et al., 2011).[8] 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 mincronutrient-rich fish (Roos et al., 1999).[9] 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 (Thilsted, 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?[10] 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 are 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 (Sununtnasuk 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

[8] The ponds in the seminal paper by Roos et al. (1999) were stocked with mola at a density of 25,000/ha. The mean total fish production was 2.87 t/ha and the mean mola production was 0.34 t/ha/season. Mola contributed 10.3% of the total fish production. Mola production and frequency of reproduction vary by water quality and pond ecology. A series of trials have been conducted with the objective of optimizing the polyculture technology of large carp species as a cash crop and small indigenous fish species (SIS) as food for the household (Asadujjaman et al., 2013; Hossain et al., 2014; Hoque and Rahman, 2008; Milstein et al., 2009; Wahab et al., 2011).

[9] Ponds are seasonal or perennial in Bangladesh. Seasonal ponds have water for an average of seven months of the year.

[10] No adjustments are made in the following discussion in the baseline measures for the MPP and WFF for any impact that the oil fortification program may have on vitamin A intakes.

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	8.52	0.26
Rajshahi	350,484	106,663	4,842,766	4,213,206	2,527,924	1,685,283	23.7	0.47
Rangpur	1,231,924	367,805	4,734,961	4,119,416	2,471,650	1,647,766	6.72	0.52
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** **100%**[a]	**14,289,710** **60%**	**9,526,473** **40%**	**12.41**	**0.35**

Bold values indicates total number of households trained in mola production in the MPP, by division.
[a] 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
Number of households trained in mola production by program year and division.

No. of homestead ponds	Rangpur	Dhaka	Khulna	Chittagong	Barisal	Rajshahi	Sylhet	Total
	1,231,924	873,565	499,258	415,979	385,141	350,484	98,688	3,855,039
MPP Year 1	400,000							400,000
MPP Year 2	400,000							400,000
MPP Year 3	400,000							400,000
MPP Year 4		400,000						400,000
MPP Year 5		400,000						400,000
MPP Year 6		100,000	300,000					400,000
MPP Year 7			200,000	200,000				400,000
MPP Year 8				200,000	200,000			400,000
MPP Year 9					200,000	150,000		350,000
MPP Year 10						200,000	100,000	300,000
MPP Year 11						——–Follow-up——		
Total:	**1,200,000**	**900,000**	**500,000**	**400,000**	**400,000**	**350,000**	**100,000**	**3,850,000**
Baseline prevalence of inadequate vitamin A intake (IVAI)	84%	84%	72%	84%	83%	82%	94%	83%
Prevalence of IVAI 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 1[a] endline			Scenario 2[b] endline			Scenario 3[c] endline		
	Household fish ponds adopting mola production	Intake of VA[d] μg RAE	Baseline prevalence of IVAI[e]	Intake of VA μg RAE	Prevalence of IVAI	Change in prevalence (PPT)[f]	Intake of VA μg RAE	Prevalence of IVAI	Change in prevalence (PPT)	Intake of VA μg RAE	Prevalence of IVAI	Change in prevalence (PPT)
Rural	104,498,016	297	83.9%	308	82.5%	1.4%	311	82.0%	1.9%	323	80.5%	3.4%
Urban	34,319,733	327	81.2%	327	81.2%	0.0%	327	81.2%	0.0%	327	81.1%	0.1%
Household fishing pond	21,136,927	337	78.5%	387	71.5%	7.0%	402	69.3%	9.2%	463	61.4%	17.1%
Household without pond	117,680,822	299	84.1%	299	84.1%	0.0%	299	84.1%	0.0%	299	84.1%	0.0%
Barisal	8,905,211	321	83.7%	331	82.2%	1.4%	334	81.4%	2.3%	346	79.9%	3.8%
Chittagong	26,727,815	306	84.3%	315	82.9%	1.4%	317	82.6%	1.7%	328	80.9%	3.4%
Dhaka	44,714,603	303	84.2%	309	83.2%	0.9%	311	82.9%	1.3%	318	81.7%	2.5%
Khulna	16,292,108	373	72.3%	379	71.7%	0.6%	381	71.5%	0.8%	388	71.1%	1.2%
Rajshahi	17,027,785	295	82.6%	306	81.1%	1.5%	309	80.7%	1.9%	322	79.1%	3.5%
Rangpur	16,351,424	271	84.6%	282	83.4%	1.2%	285	82.9%	1.7%	299	81.9%	2.7%
Sylhet	8,798,802	248	93.8%	249	93.7%	0.1%	250	93.6%	0.2%	253	93.3%	0.5%
Bangladesh	138,817,749	305	83.2%	312	82.2%	1.1%	315	81.8%	1.4%	324	80.6%	2.6%

[a] Scenario 1: 30% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 23.7 kg/pond/year.
[b] Scenario 2: 30% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 31.0 kg/pond/year.
[c] Scenario 3: 60% of pond fishing households adopt Mola Promotion Program (MPP), national annual pond production = 31.0 kg/pond/year.
[d] VA: vitamin A.
[e] IVAI: inadequate vitamin A intake.
[f] PPT: percentage point change.

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

Scenario	Accounting period (years)	Total cost	DALYs Saved	Lives saved	Benefit–cost ratio		Cost/DALY saved	Cost/Life saved
					US$ 500/DALY	US$ 1000/DALY		
Scenario 1	5	9,832,631	22,034	660	1	2	446	14,899
30% of pond fishing households adopt MPP[a]	10	18,195,979	73,357	2197	2	4	248	8282
	11	19,443,600	100,127	2999	3	5	194	6484
Yield: 23.7 kg mola/pond/year	20	19,443,600	196,784	5894	5	10	99	3299
	30	19,443,600	289,506	8671	7	15	67	2242
Scenario 2	5	9,832,631	25,076	756	1	3	392	12,998
30% of pond fishing households adopt MPP	10	18,195,979	83,483	2518	2	5	218	7225
	11	19,443,600	113,948	3438	3	6	171	5656
Yield: 31.0 kg mola/pond/year	20	19,443,600	223,948	6756	6	12	87	2878
	30	19,443,600	329,469	9939	8	17	59	1956
Scenario 3	5	9,832,631	47,694	1436	2	5	206	6850
60% of pond fishing Households adopt MPP	10	18,195,979	158,782	4779	4	9	115	3807
	11	19,443,600	216,727	6523	6	11	90	2981
Yield: 31.0 kg mola/pond/year	20	19,443,600	425,945	12,820	11	22	46	1517
	30	19,443,600	626,643	18,861	16	32	31	1031

Note: DALYs and Costs are discounted at 3%/year.
[a] MPP: Mola Promotion Program.

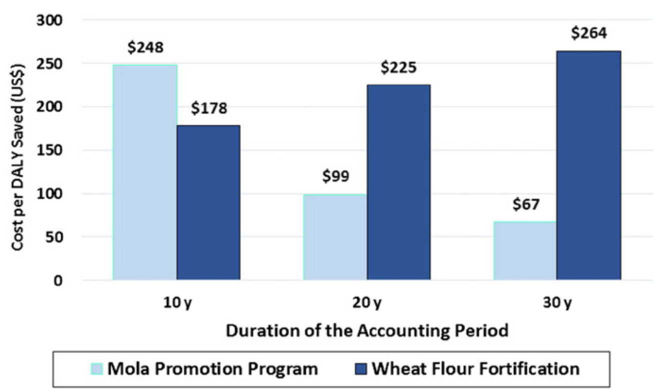

Fig. 5. Cost-effectiveness of Mola Promotion Program versus wheat flour fortification in Bangladesh; Scenario 1.

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 groups 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 approach includes algorithms only for impacts that have been estimated with an adequate degree of rigor. As a result, it captures only the vitamin A-related health impacts of pregnant and lactating women and of children less than five years old. No other population groups' vitamin A-related impacts are captured in this study. Given these limitations, 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 (40% of the total mola produced), because 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 under-estimating its impact. To provide an idea of the potential significance of both the underestimated impact of mola that is sold and the underestimated impact due to the lack of population-wide DALY algorithms, we recalculated the consumption of the additional mola produced under Scenario 1, and assumed that it would be consumed only by women of childbearing age and children under five years old. The estimates (Table 11) reveal the impact would be more than doubled. This suggests that it might be strategically important to make the targeting of these population groups a priority in social marketing efforts to increase mola production and consumption.

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.

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

	Baseline			Endline				
	Number of Persons	Mean µg RAE[a] Intake	Prevalence of inadequate vitamin A intake	Added vitamin A intake from consumption of own mola (µg RAE)	Added vitamin A Intake from purchased mola (µg RAE)	Mean vitamin A intake (µg RAE)	Prevalence of inadequate vitamin A intake	Percentage point change in prevalence
All women & children	51,456,183	263.6	83.9%	18.92	0.08	282.6	81.4%	2.4%
Household fishing pond	7,373,676	289.8	78.7%	132.01	0.08	421.8	61.8%	16.8%
Household without pond	44,082,506	259.3	84.7%	0.00	0.08	259.4	84.7%	0.0%

Note: It is assumed that all mola produced are consumed by women 15–50 years and children under five years of age.
[a] RAE: Retinol activity equivalent.

2. It investigates the potential of homestead pond polyculture, based on production and consumption of a small indigenous fish, mola carplet, 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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