POLICY RESEARCH WORKING PAPER 8217

The Socioeconomics of Fish Consumption and Child Health in Bangladesh

Susmita Dasgupta
Mohammed Golam Mustafa
Tapas Paul
David Wheeler

WORLD BANK GROUP

Abstract

Child malnutrition in Bangladesh exceeds WHO's threshold for public health emergencies. Using more than 36,000 records from several waves of the Bangladesh Demographic and Health Survey, the research focuses on the socioeconomic determinants of household consumption of all animal-source foods; the socioeconomic determinants of fish consumption, given its importance in the Bangladeshi diet; and the impact of observed consumption patterns on mortality and resistance to infectious diseases for children in their first years of life. Better maternal education and family economic status significantly increase the level of animal-source food intake, but they decrease the consumption share of fish. This suggests that increased income and education impart a "status bias" toward eggs and meat, even though they are more expensive and less beneficial than fish for child health. In addition, mothers' individual preferences for different animal-source foods, and the seasonal availability of fish during the pre- and post-partum periods have large effects on child mortality and significant effects on resistance to several common childhood illnesses. These findings highlight the importance of programs to increase supply of fish, maternal nutrition education and more public health programs to promote fish consumption.

The Socioeconomics of Fish Consumption and Child Health in Bangladesh

Susmita Dasgupta*
Lead Environmental Economist, Development Research Group, World Bank, United States

Mohammed Golam Mustafa
Scientist, World Fish, South Asia

Tapas Paul
Lead Environmental Specialist, World Bank, India

David Wheeler
Senior Fellow, World Resources Institute

* Authors' names in alphabetical order.
Corresponding Author: Susmita Dasgupta. Email: sdasgupta@worldbank.org;
Tele phone: 1-202-473-2679; Fax: 1-202-522-2714

1. Introduction

Malnutrition is a primary source of health damage for children in poor countries, accounting for 45% of under-five mortality and 50% of years lived with disability for children aged four and under (Golden et al. 2013). Many children and adults in Bangladesh suffer from malnutrition, which is also responsible for estimated economic losses of around $US one billion per year (Howlader et al. 2012). Bangladeshi fish consumption is critical in this context, because fish are the largest source of high-quality protein (Roos et al. 2007, Kent 1987), as well as micronutrients that are difficult to obtain from plant-based foods in sufficient amounts (Murphy and Allen 2003, Michaelsen et al. 2009, Sandström et al. 1989). Micronutrient intakes are enhanced by whole consumption of small indigenous fish, which is common for poor households (Bogard et al. 2015b). This is particularly true for young children who eat small meals (Bogard et al. 2015a). Protein from fish and other animals also increases absorption of nutrients from dietary plant consumption (Neumann et al. 2001).

Extensive research has documented the health benefits of fish-intensive diets. Rimm and Mozaffarian (2006) find a 36% reduction in mortality risk from heart disease; Zhao et al. (2015) show that individuals who consume at least 60 grams of fish per day have 12% lower mortality than their counterparts. In a global study, Lim et al. (2012) find that 1.4 million deaths in 2010 can be attributed to deficiency in omega-3 fatty acids from fish. From the same database, Ezzati and Riboli (2013) calculate that diets low in fish and seafood account for about 1% of total disability-adjusted life years (DALYs). The stakes for children are particularly high, since micronutrient deficiencies can lead to increased mortality risk, damaged cognitive development and reduced immunity to disease (Golden et al. 2013).

Fish consumption plays multiple roles in health improvement, including higher concentrations of bioavailable minerals and vitamins; essential fatty acids and animal protein (Bogard et al. 2015b, Wheal et al. 2016); and vitamin B12, found only in animal food sources, which supports physical development,

various brain functions, and nervous system maintenance (FAO and WHO 2004). Small fish, commonly

consumed by the poor in Bangladesh, are a particularly important source of calcium in diets that are often

deficient in milk and milk products (Hansen et al. 1998), as well as zinc and iron (Thilsted et al. 2016).

Pre-partum consumption of omega-3 fatty acids from fish is associated with lower risk of pre-term

delivery (Imhoff-Kunsch et al. 2012), as well as higher likelihood of children's normal cognitive

development and fine motor skills (Hibbeln et al. 2007).

Several assessments for Bangladesh have established statistical associations between fish market

conditions, household socioeconomic characteristics, fish consumption and measures of child

undernutrition.[1] In aggregative cross-section and time-series studies, Dey et al. (2010) and Toufique

(2015) find that fish consumption is highly responsive to income and fish prices. Grant (2016 - Figures

8.5 and 8.6) finds a higher incidence of stunting in poor households, and for children with less-educated

mothers. However, it also finds significant stunting in wealthy households. NIPORT (2016) reports a

similar finding: Infant and young child feeding (IYCF) practices improve with maternal education and

wealth status, but remain unsatisfactory for 1/3 of children in the highest wealth quintile. After

investigating traditional beliefs in very poor households, Choudhury and Ahmed (2011) suggest that

improved IYCF practices may require targeted health behavior education.

In summary, extensive nutritional research has established a significant link between fish

consumption and child health, and numerous aggregative studies have indicated that both fish

consumption and child health vary with maternal education and household economic status. However,

even relatively well-educated and wealthy mothers can have deficient IYCF practices. And more precise

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[1] These studies typically use WHO-recommended comparative physical measures based on reference populations or international standards : stunting (low height/length for age); wasting (low weight-for-height/length); and malnutrition (circumference of a child's upper arm, or a measure of weight for height).

impact assessment in Bangladesh has been hindered by the relative scarcity of individual-level multivariate analyses.

In this paper, we attempt a more precise quantification using a household panel database constructed from five Bangladesh Demographic and Health Surveys (2000, 2004, 2007, 2011, 2014). We also revisit the role of maternal beliefs in child nutrition and health first investigated by Choudhury and Ahmed (2011), extending the research to potentially-perverse status beliefs associated with income and higher education.

The remainder of the paper is organized as follows. Section 2 introduces our panel database, with a particular focus on its temporal and spatial components. Sections 3, 4 and 5 develop and estimate models for assessing children's intake of animal-source foods, the fish share of that intake, and the impact of fish consumption on health status. We summarize and conclude the paper in Section 6.

2. Data and Estimation Strategy

We construct our panel from georeferenced survey data collected by the Bangladesh Demographic and Health Surveys for 2000, 2004, 2007, 2011 and 2014 (NIPORT 2001, 2005, 2009, 2011, 2016). We include data for 2,263 DHS clusters, 27,827 households and 36,491 individuals, distributed across years as indicated in Table 1.

Table 1: DHS survey statistics by year, 2000-2014

Year	DHS Clusters	Households	Individuals
2000	341	4,847	6,813
2004	361	4,999	6,900
2007	361	4,626	6,150
2011	600	6,882	8,742
2014	600	6,473	7,886
Total	2,263	27,827	36,491

We focus on four sets of variables: animal-source foods and fish in children's diets; their gender, age and measured health characteristics; their mothers' education and income status; and spatially- and temporally-varying determinants of fish supply and consumption norms. All five DHS surveys ask mothers whether, during the previous 24 hours, their children have consumed any animal-source foods -- eggs, poultry, fish, and other meats. DHS 2011 and 2014 also separate fish from other animal sources. Our modeling exercise exploits all of this information in a two-part analysis. We investigate the determinants of consumption of animal-source foods using all five DHS surveys, while using DHS 2011 and 2014 to focus on fish consumption and its impact on child health.

2.1 The Spatial Dimension

We overlay the map of Bangladesh with a 0.25-degree grid to permit controls for spatial variation in fish supplies and consumption norms. As Figure 1 shows, this grid resolution allows for significant spatial differentiation while ensuring ample cluster representation within most populated cells.

Figure 1: DHS cluster locations by grid cell
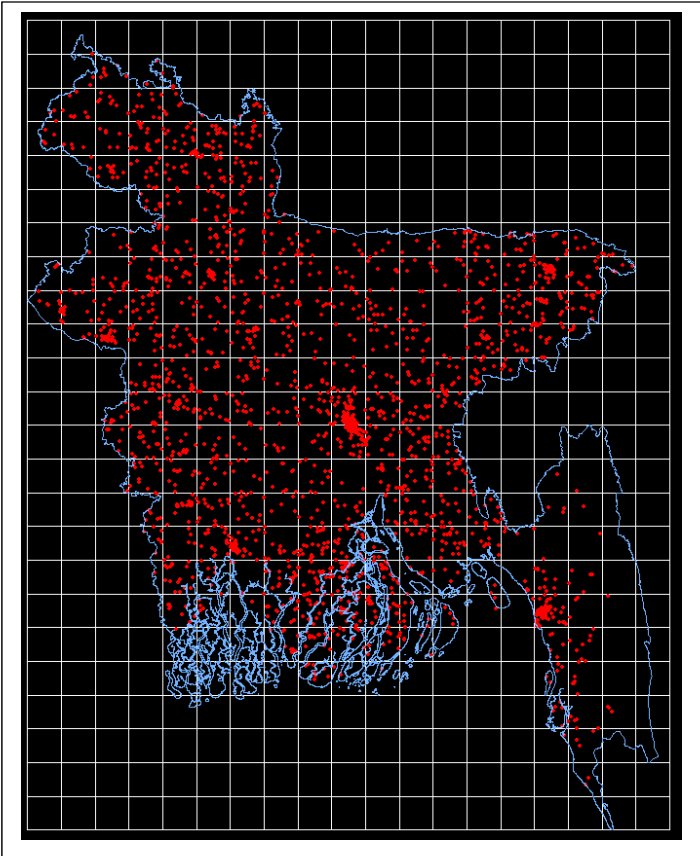
2.2 The Temporal Dimension

De Graff (2003) documents the annual "pulse" of Bangladesh's inland fisheries, with a sharply-higher catch during September - December as monsoon floods reach their peak and begin receding. By implication, a complete analysis of fish consumption and child health should incorporate seasonal fluctuations in fish supply. Single-year DHS surveys do not permit this, since they are implemented in a subset of months. However, as Table 2 shows, full monthly effects can be incorporated into the five-year composite panel. Survey periods are November-April (DHS 1999-2000); January-May (DHS 2004); March-August (DHS 2007); July-December (DHS 2011); and June-November (DHS 2014). As the Total column shows, combining the surveys provides ample observations for all 12 months. This permits a full representation of seasonal effects in our exercise, combined with yearly controls to account for annual fluctuations in flood extent.[2]

Table 2: Distribution of DHS surveys by month and year

Month	Year 1999-2000	2004	2007	2011	2014	Total
January	1,596	1,860	0	0	0	3,456
February	1,521	1,226	0	0	0	2,747
March	694	1,389	479	0	0	2,562
April	3	1,416	1,501	0	0	2,920
May	0	1,009	1,448	0	0	2,457
June	0	0	1,126	0	127	1,253
July	0	0	1,206	1,786	1,914	4,906
August	0	0	390	1,201	2,066	3,657
September	0	0	0	1,388	2,063	3,451
October	0	0	0	1,797	1,315	3,112
November	1,551	0	0	1,411	401	3,363
December	1,448	0	0	1,159	0	2,607
Total	6,813	6,900	6,150	8,742	7,886	36,491

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[2] While the rationale for incorporating monthly effects seems compelling, we acknowledge the possibility of countervailing factors. For example, recent research has studied the impact of flooding in Dhaka on diarrheal disease (Schwartz et al. 2006) and mortality more generally (Thiele-Eich et al. 2015). Our assessment of disease incidence in Section 5 controls for this factor.

2.3 Modeling Approach

Studies for Bangladesh have found significant pairwise associations between children's protein intake and their mothers' education and economic status (Dey et al. 2010, Toufique 2015, Grant 2016, NIPORT 2016). Dey et al. (2010) and Toufique (2015) have shown that fish consumption in Bangladesh responds significantly to seasonal variations in fish supply. Building on these findings, we use our DHS panel database to explore the determinants of consumption of animal-source foods as well as fish and their impacts on children's health. Our econometric models incorporate annual and monthly fixed effects to control for temporal variations in fish supplies and disease vectors, and spatial fixed effects to control for regional variations in fish supplies, environmental disease factors, and consumption norms that affect intake of animal-source foods.

3. Determinants of Intake of Animal-Source Foods

3.1 Model Specification

All five DHS surveys [2000, 2004, 2007, 2011, 2014] include questions on children's intake of total animal-source foods (fish, meat, eggs). Drawing on the full panel database, we specify and estimate the following model:[3]

$$(1) \ P_i = \beta_0 + \sum_{j=1}^{5} \delta_j E_{ij} + \sum_{k=1}^{5} \gamma_k W_{ik} + \sum_{k=1}^{3} \alpha_k A_i^k + \sum_{l=1}^{12} \mu_l M_l + \sum_{m=2000}^{2014} \omega_m Y_m + \sum_{n=1}^{191} s_n C_{in} + \varepsilon_i$$

where

P_i = Intake of animal-source foods by child i during the previous 24-hour period (1 if yes; 0 if no)

E_{ij} = Mother's years of education [1 none; 2 primary (1-6); 3 middle (7-9); 4 secondary (10-12); 5 post-secondary (12+)]

W_{ik} = Household wealth status [five groups by DHS household possession count]

A_i = Child age

M_l = Survey month

Y_m = Survey year (1999-2000 consolidated to 2000)

C_{in} = Dummy variable for grid cell of survey cluster (see Figure 1)

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[3] We exclude gender from this specification because prior experimentation has revealed that animal-source food intake is gender-neutral after accounting for the variables in model (1).

ε_i = Random error term

3.2 Estimation

We estimate (1) by probit, using the 13,997 observations with non-missing values for all model variables. Table 3 reports their joint distribution by quintile for household asset ownership and mother's years of education. The sample populates all cells of the table, although observations are relatively sparse for extreme pairs (e.g. [asset quintile 5, mother's education none]; [asset quintile 1, mother's education post-secondary]).

Table 3: Intake of animal-source foods **regression sample, DHS 2000-2014**

| Household Asset Quintile | Mother's Years of Education | | | | | |
	0	Primary (1-6)	Middle (7-9)	Secondary (10-12)	Post-Secondary	Total
1	1,351	749	135	28	7	2,270
2	1,736	2,623	1,260	290	28	5,937
3	404	1,106	1,092	444	67	3,113
4	128	456	706	496	164	1,950
5	38	85	222	268	114	727
Total	3,657	5,019	3,415	1,526	380	13,997

We report our results in Table 4, excluding estimates for the 191 grid cell dummy variables. To prevent total collinearity, our specification drops dummy variables for mother's education [0 years], household asset quintile 1, survey year 2000 and survey month January. For each category (education, etc.), estimates should therefore be interpreted as increments from partial effects for the excluded variable levels.

We find high significance for the variables in each category. The effect of mother's education increases steadily by schooling level, while the impact of asset ownership increases rapidly for quintiles 2 and 3 and more slowly for quintiles 4 and 5. We approximate the age effect with a log-cubic

Table 4: Probit results - child animal-source food intake[a]

Mother's Education (0 Excluded)	Parameter Estimates		Month (January Excluded)	Parameter Estimates
Primary	0.153		February	-0.047
	(4.24)**			(0.66)
Middle	0.422		March	0.048
	(10.05)**			(0.64)
Secondary	0.496		April	-0.021
	(9.18)**			(0.27)
Post-Secondary	0.637		May	-0.045
	(7.02)**			(0.55)
			June	0.091
Asset Quintile (Q1 Excluded)				(0.87)
Q2	0.142		July	0.176
	(3.09)**			(2.17)*
Q3	0.366		August	0.267
	(6.80)**			(3.06)**
Q4	0.407		September	0.361
	(6.42)**			(3.95)**
Q5	0.415		October	0.257
	(4.99)**			(2.82)**
			November	0.334
Log Age	-3.331			(4.21)**
	(8.82)**		December	0.279
[Log Age]**2	3.061			(3.34)**
	(13.99)**			
[Log Age]**3	-0.539			
	(14.12)**		Constant	-3.459
				(11.39)**
Year (2000 Excluded)				
2004	0.435			
	(7.77)**			
2007	0.187			
	(2.76)**			
2011	0.108			
	-1.73			
2014	0.145			
	(2.08)*			

[a] **Grid location results excluded for brevity**

Observations: 13,987
Absolute value of t statistics in parentheses [* significant at 5%; ** significant at 1%]

specification, which indicates that, ceteris paribus, intake probability of animal-source foods increases rapidly after the first months of life and then passes an inflection point toward an asymptote around 24 months. Our monthly results are consistent with significantly-expanded fish supplies in the period September - December (per De Graaf (2003)). Controlling for monthly effects, we find that fish supply was particularly ample in 2004 and somewhat greater than the 2000 supply in the other survey years.

### 3.3 Temporal Impacts: Mother's Education and Economic Status

We use the probit results to predict monthly animal-source food intake probabilities for 23-month-old children in 2014. Figure 2 presents monthly results by mother's education group for a household in the lowest asset quintile. Figure 3 presents monthly results by asset quintile for a mother with zero years of education.

The figures highlight two particularly-striking features of the results. First, as previous research has suggested, both mother's education and household economic status have large impacts on the probability of child intake of animal-source foods. For households in the lowest asset quintile (Figure 2), the median difference in intake probability of animal-source foods for children of the most highly-educated and least-educated mothers is 24%.[4] For mothers with no education (Figure 3), the median difference in intake probability of animal-source foods for children in the lowest and highest asset quintiles is 16%.[5] Table 5 provides evidence on the joint impact of mothers' education and economic status. In January, child animal-source food intake probability for mothers with no education in the lowest asset quintile is 38%. In contrast, the probability is 78% for mothers with post-secondary education in the highest asset quintile -- an increase of 40%.

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[4] This is the median probability difference over 12 months for mothers with no education and those with post-secondary education.
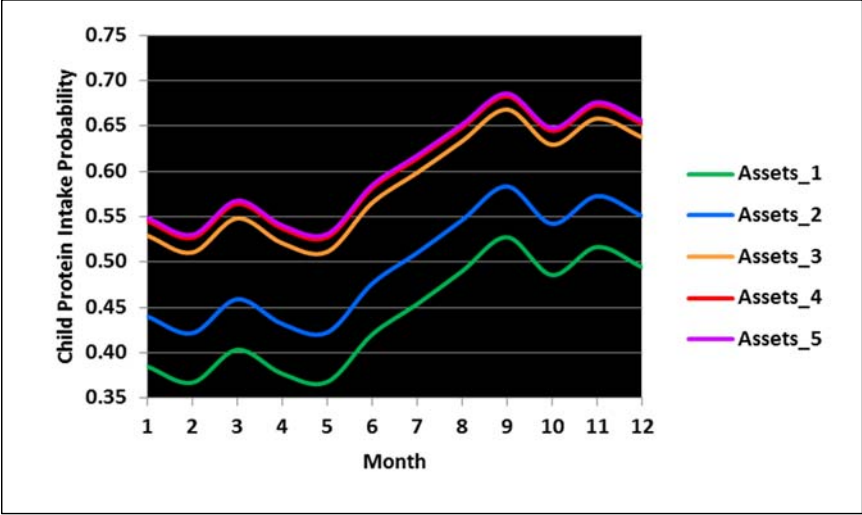
[5] This is the median probability difference over 12 months for mothers with no education in the lowest-asset quintile and those in the highest-asset quintile.

Figure 2: Predicted child animal-source food intake probability vs. mother's education[a]
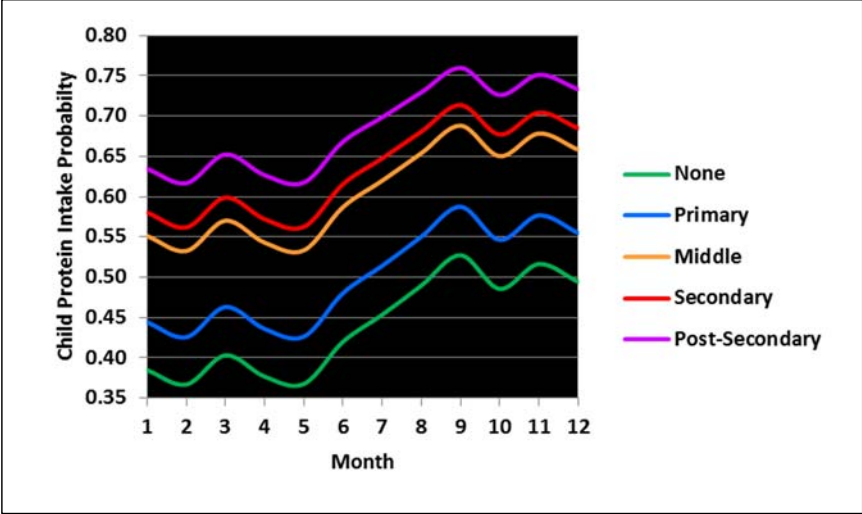
Figure 3: Predicted child animal-source food intake probability vs. household asset ownership[a]

Table 5: Mother's education, household asset ownership and child animal-source food intake probability[a]

Household Asset Quintile	Mother's Education (Years)				
	0	**Primary (1-6)**	**Middle (7-9)**	**Secondary (10-12)**	**Post-Secondary**
1	0.38	0.44	0.55	0.58	0.63
2	0.44	0.50	0.61	0.63	0.69
3	0.53	0.59	0.69	0.72	0.76
4	0.55	0.60	0.70	0.73	0.77
5	0.55	0.61	0.71	0.73	0.78

[a] Predictions computed for January

The second striking feature of the results is the seasonal impact of fish supply on child nutrition. Table 6 displays predicted animal-source food intake probabilities by education and asset group for September, a peak catch month, and February, after the floods have receded. For mothers with no education, children's September animal-source food intake probability in the lowest asset quintile (53%) matches the February probability for children in the highest asset quintile. In the lowest asset quintile, children's September intake probability for mothers with no education (53%) matches the February probability for mothers with middle school education (7-9 years). Taken together, the results in Table 5 highlight the critical importance of expanded fish supply for children's animal-source food intake in the poorest, least-educated households.

Table 6: Economic and education status vs animal-source food intake probability: Seasonal comparison

	Mother's Education: 0 Years				
	Household Asset Quintile				
Month	**1**	**2**	**3**	**4**	**5**
February	0.37	0.42	0.51	0.53	0.53
September	0.53	0.58	0.67	0.68	0.69
	Mother's Household Asset Status: Quintile 1				
	Mother's Education (Years)				
Month	**0**	**Primary (1-6)**	**Middle (7-9)**	**Secondary (10-12)**	**Post-Secondary**

February	0.37	0.43	0.53	0.56	0.62
September	0.53	0.59	0.69	0.71	0.76

3.4 Spatial Variations

We have estimated the animal-source food intake regression with controls for 191 grid cells overlaid on the Bangladesh map (Figure 1). To assess the spatial dimension, we use our probit results to predict animal-source food intake probabilities for children in the lowest asset ownership quintile whose mothers have no formal education.[6] Figure 4 presents monthly distribution statistics for grid cell predictions, from the 5th percentile to the 95th. The results reflect Figures 2 and 3 in revealing substantial variation between the peak and off-peak catch seasons. However, they also suggest that the seasonal catch advantage varies widely by location. Across 191 grid cells and 12 months, the median difference between predicted animal-source food intake in the 5th and 95th percentile cells is 36%. This is nearly as great as the difference attributable to shifting a mother's education and economic status from the lowest to the highest quintiles in Table 5.

Figure 4: Animal-source foods intake probability: percentiles by month

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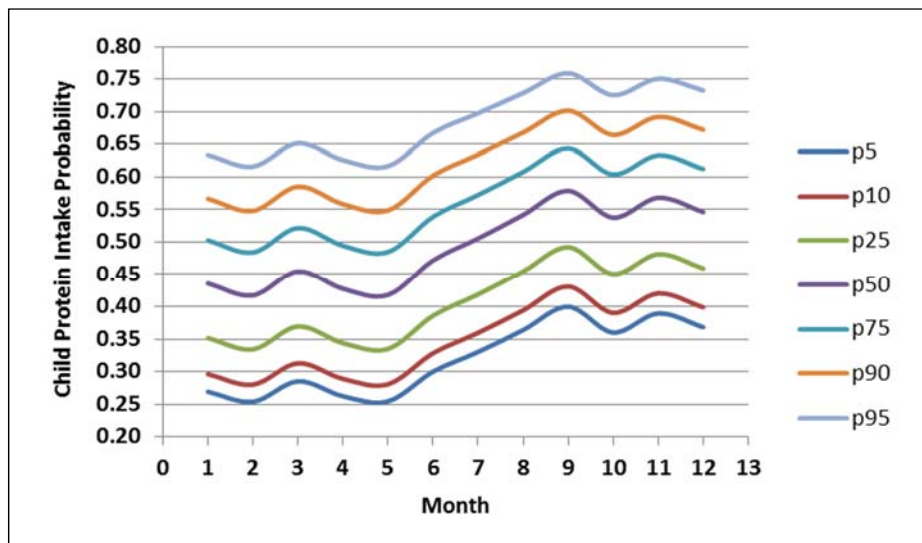
We also find that local variations exhibit significant spatial clustering. Figure 5 plots predicted animal-source food intake probabilities in September for children in the lowest household asset quintile whose mothers have no education. For a clear representation of regional clustering, we color-code probabilities in two categories: P [intake of animal-source foods] ≤ 60% (blue) and P > 60% (red). Figure 5 reveals two clear clustering patterns: (1) Most of the red probabilities (higher animal-source food intake) are west and south of the Padma and Jamuna Rivers, and most of the blue probabilities (lower animal-source food intake) are in the east; (2) the coastal region is dominated by red probabilities. We conclude that, other things equal, local supply conditions convey a notable animal-source food intake advantage to children in the red-dominated regions.

Figure 5: Spatial distribution of animal-source food intake probabilities (September): Children in lowest-quintile households [education, assets]
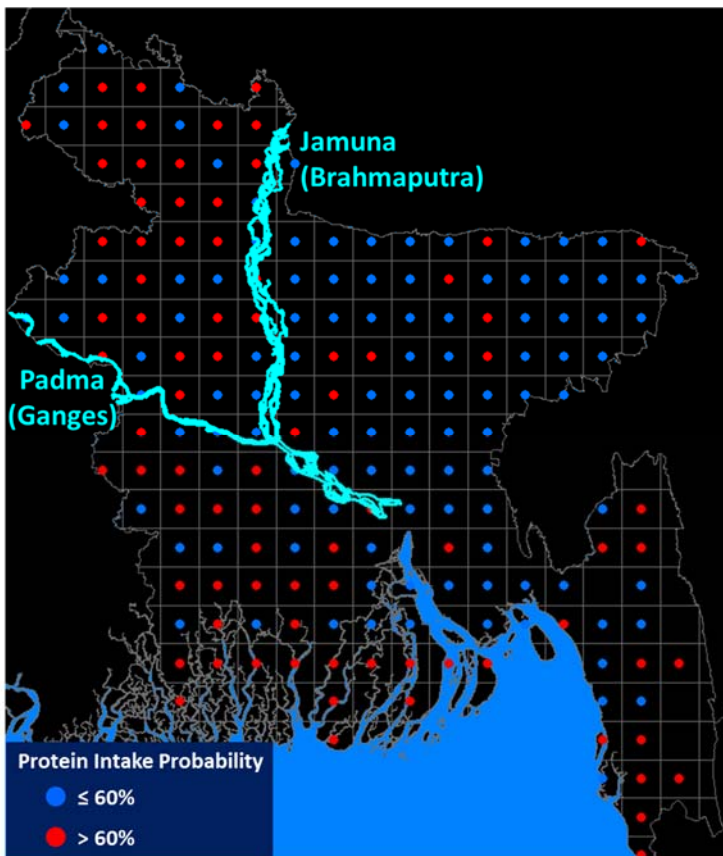
4. The Share of Fish in Consumption of Animal-Source Foods

All five DHS surveys ask mothers whether, during the previous 24 hours, their children have consumed any animal-source food -- eggs, poultry, fish, and other meats. In Section 3, we have used the full data set to explore the determinants of total consumption of animal-source foods. In this section, we extend the analysis to fish consumption using the source-specific information in DHS 2011 and 2014.

As Table 7 shows, understanding the determinants of fish consumption is particularly important for the poor in Bangladesh. The table summarizes DHS survey responses on children's consumption of fish, eggs and meat during the 24 hours prior to the survey date. For each child, we code each animal-source food as 1 if it was consumed and 0 otherwise. We focus on cases with positive consumption (total coded value > 0) and compute the fish share of animal sources by dividing the fish consumption code [0,1] by total coded value. The computed ratio can be interpreted as the share of fish in animal-source foods, conditional on non-zero consumption.

Table 7 reports mean and median shares by asset quintile. The results highlight the particular importance of fish as a animal-source food for the poorest children. In household asset quintile 1, the mean and median fish shares are 66.7% and 100%, respectively.

**Table 7: Share of fish in children's animal-source foods
by household asset class**

Asset Quintile	Mean Fish Share (%)	Median Fish Share (%)
1	66.7	100.0
2	57.5	50.0
3	52.6	50.0
4	41.3	50.0
5	35.0	33.3

To assess the determinants of fish shares more fully, we specify a form of equation (1) that incorporates the years and months covered by DHS 2011/2014.[7] Prior experimentation has revealed that child age is not significant in this case, so we have excluded it.

$$(2)\ F_i = \beta_0 + \sum_{j=1}^{5} \delta_j E_{ij} + \sum_{k=1}^{5} \gamma_k W_{ik} + \sum_{l=6}^{12} \mu_l M_l + \sum_{m=2011}^{2014} \omega_m Y_m + \sum_{n=1}^{191} s_n C_{in} + \varepsilon_i$$

where

F_i = Share of fish in animal-source foods {Fish consumed [1,0] / Sum (protein consumed (fish [1,0], eggs [1,0], meat [1,0])}
E_{ij} = Mother's educational status [1 none; 2 primary; 3 middle; 4 secondary; 5 post-secondary]
W_{ik} = Household wealth status [five groups by household possession count]
M_l = Survey month
Y_m = Survey year
C_{in} = Grid cell of survey cluster (see Figure 1)
ε_i = Random error term

For each surveyed child, the variable F can take on four values: 0, .33, .50, 1. The appropriate estimator in this case is fractional logit, since the dependent variable is appropriately bounded by [0,1] and includes intermediate values. Table 8 reports our results, with t-statistics computed using robust standard errors.[8] For brevity, we exclude the dummy variable estimates for 191 grid cells.

Our results indicate a high degree of statistical significance for mother's education, household economic status and the temporal variables. Ceteris paribus, we find increasingly-negative impacts on the fish share as mother's education and household economic status increase. In this case, the limitation of DHS 2011/2014 to June - December hinders comparison between months of peak fish catch and off-peak months. However, the September - December estimates are significantly higher than the June estimate, and higher than the July estimate as well.

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[7] As Table 2 shows, survey data collection was restricted to the period June - December for DHS 2011/2014.
[8] We employ Stata glm [link(logit), family(binomial), robust]

Taken together, the seasonal results in Tables 4 and 8 suggest that children's fish intake, and therefore animal-source food intake, increase with the pulse in fish supply during September - December. And, as Tables 6 and 7 show, this increase is particularly important for poor households. Figures 6 and 7 highlight two important facets of these results: the impact of the peak-season fish catch (Figure 6) and the joint impact of economic status and mother's education (Figure 7).

**Table 8: Fractional logit results - share of fish in animal-source foods[a]**

Mother's Education (0 Excluded)	Parameter Estimates		Month (June Excluded)	Parameter Estimates
Primary	-0.319		July	1.385
	(2.71)**			(3.14)**
Middle	-0.518		August	1.815
	(4.19)**			(4.15)**
Secondary	-0.726		September	1.777
	(5.23)**			(4.04)**
Post-Secondary	-1.053		October	1.899
	(5.28)**			(4.24)**
			November	1.565
Asset Quintile (Q1 Excluded)				(3.48)**
Q2	-0.666		December	1.48
	(2.14)*			(3.22)**
Q3	-0.707			
	(2.25)*		Constant	-0.308
Q4	-1.081			(0.46)
	(3.38)**			
Q5	-1.175			
	(3.54)**			
Year (2011 Excluded)				
2014	-0.203			
	(2.59)**			

[a] Grid location results excluded for brevity

Observations: 3,201
Absolute value of t statistics in parentheses [* significant at 5%; ** significant at 1%]

Figure 6: Monthly fish share in intake of animal-source foods by household asset group[a]
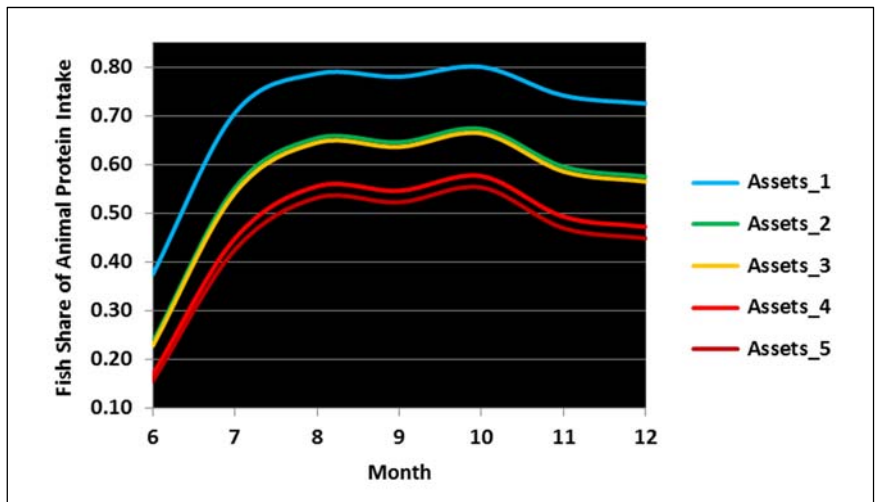
[a] **For mothers with no formal education**

Figure 7: Fish share in intake of animal-source foods by household asset group and mother's education[a]
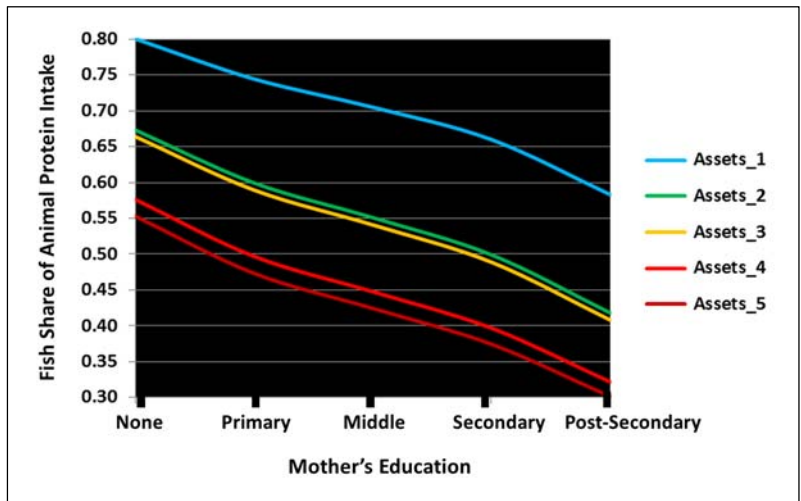
[a] **For October 2014**

Figure 6 reflects Figure 3, with the focus narrowed from animal-source foods to fish. The peak-season catch sharply increases children's fish intake, which translates to a sharp increase in the likelihood of intake of animal-source foods. Unfortunately, as Figure 7 shows, the potential health benefits of expanded fish supply are attenuated by both income and education effects. As we note in the Introduction,

extensive research has shown that fish consumption conveys more health benefits than consumption of other animal sources. Nevertheless, our results for Bangladesh clearly indicate a "status bias" favoring non-fish animal-source food consumption as mothers' education and household economic status increase. The education result seems particularly unfortunate, with two possible interpretations: Either current school instruction pays little attention to the health benefits of fish consumption, or the effect of this instruction is overwhelmed by the higher status assigned to non-fish protein sources. In any case, our results for both education and economic status suggest a powerful and perverse "status goods" effect on fish consumption. We believe that these findings have potentially-important implications for health education policy in Bangladesh.

5. Child Health Impacts

Using DHS 2011 and 2014, we investigate the incremental health impacts of consuming fish and other animal-source foods (eggs, meat) using an estimation model that includes the following elements:

(i) Secular declines in mortality and morbidity risk from improved public health services.

(ii) The socioeconomic, temporal and spatial determinants of consumption of animal-source foods incorporated in models (1) and (2): mother's education; household economic status, seasonal variations in fish supply, and spatial variations in fish supply and consumption norms. After incorporating these variables (and gender) into the estimation exercise, we also include the animal-food sources themselves. Ceteris paribus, the direct estimates for these sources can be interpreted as indicators of individual preferences. Our approach assumes that these preferences are constant through time.

(iii) Maternal fish consumption in the immediate pre-partum and post-partum periods. Although we do not have direct evidence[9], basic economics suggests that mothers' fish consumption should also

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[9] We are unable to include direct survey information on maternal fish consumption because the relevant questions were excluded from DHS 2011 and 2014.

respond to expanded supply in the peak-catch period. If children's disease resistance is positively related to maternal nutrition during the late gestation and early nursing periods, then we should observe better health outcomes for children born during the peak-catch period.

Our general health impact model is specified as follows:

$$(3)\ H_i = \beta_0 + \beta_1 f_i + \beta_2 e_i + \beta_3 m_i + \beta_4 F_i + \beta_5 E_i + \beta_6 W_i + \beta_7 S_i + \beta_8 Y_{2014}$$
$$+ \sum_{j=7}^{12} \gamma_j M_j + \sum_{k=1}^{191} \delta_k C_{ik} + \mu P_i + \sum_{m=2006}^{2014} \theta_m BY_{im} + \varepsilon_{int}$$

where
H_i	=	Health indicator
		Deceased (1 if occurred; 0 otherwise),
		Recent diarrhea (1 if occurred; 0 otherwise)
		Recent fever (1 if occurred; 0 otherwise)
		Recent cough (1 if occurred; 0 otherwise)
f_i	=	Child fish intake during the previous 24 hours (Yes = 1; 0 otherwise)
e_i	=	Child eggs intake during the previous 24 hours (Yes = 1; 0 otherwise)
m_i	=	Child meat intake during the previous 24 hours (Yes = 1; 0 otherwise)
F_i	=	1 if female; 0 if male
E_i	=	Years of mother's education
W_i	=	Household asset count
S_i	=	Child size at birth (included in mortality risk estimation)
Y_{2014}	=	1 if survey year is 2014; 0 if year is 2011)
M_j	=	Dummy variable for survey month j
C_{ik}	=	Dummy variable for location grid cell k (see Figure 1)
P_i	=	Dummy variable for birth period (1 if September - December; 0 otherwise)
BY_{im}	=	Dummy variable for birth year m

5.1 Mortality Risk

Table 9 reports our results for child mortality risk. We focus particularly on two elements: (1) different types of animal-source food consumption which, as noted above, should be interpreted as reflecting individual preferences after controlling for all previously-identified socioeconomic, temporal and spatial factors; (2) birth during the peak-catch season (September - December), when mothers' fish intake should increase.

We find a large, negative, highly-significant impact for fish consumption preference. The other two animal-source foods also have negative estimated impacts, but the parameters are smaller in absolute

value and fail to meet the standard criteria for statistical significance. Per our prior expectation, we also find a large, negative, highly-significant impact for birth during the peak-catch period.

We find that female children have lower mortality rates than male children, ceteris paribus. Mother's education, family asset ownership and child size at birth do not have significant effects. Reported child deaths yield a higher mortality rate for the 2014 survey, but survey month has no impact on the results. In contrast, the birth-year results are strong and declining as public health services improve.

To assess their quantitative significance, we use our probit results to estimate differential mortality rates within a centrally-located grid square with typical population density (Figure 8, square outlined in light blue). We perform the prediction for a mother with no education who resides in a household whose asset count is zero; the mean child size at birth for this education and asset ownership group; survey year 2014; birth year 2012; the first six survey months (dummy values 0 for the survey months included in the result); and zero consumption preference for eggs and meat.

We produce four predictions: with and without fish consumption preference and peak-catch-season birth, respectively. Table 10 presents our results, which suggest substantial impacts. The estimated mortality rate is 72.3 per 1,000 for children born in this locale during the off-peak-catch season to mothers with no fish preference (beyond the structurally-determined factors, per model (1)). With no change in fish preference, the estimated mortality rate declines to 32.4 per 1,000 for a child born during the peak-catch season. In contrast, children born to mothers with fish preference have predicted mortality rates of 31.5 per 1,000 in the off-peak season and 12.3 in the peak-catch season.

In summary, our results suggest a remarkable 83% decrease in the child mortality rate (from 72.3 to 12.3) produced by two elements related to fish consumption. We believe that this should be viewed as an outer-bound estimate, because our interpretation depends on the following assumptions: (1) the fish consumption result reflects individual preferences, not other factors that cannot be observed;

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Table 9: Probit results - child mortality rate[a]

Protein Intake	Parameter Estimates		Survey Month	Parameter Estimates
Fish	-0.400		July	0.12
	(3.62)**			(0.24)
Eggs	-0.186		August	-0.022
	(1.44)			(0.04)
Meat	-0.244		September	0.173
	(1.48)			(0.33)
			October	0.217
Characteristics				(0.41)
Female	-0.278		November	0.262
	(3.10)**			(0.48)
Mother's Education	0.021		December	0.576
	(1.45)			(1.01)
Household Assets	-0.021			
	(0.69)		Survey Year 2014	2.809
Size at Birth	0.081			(7.98)**
	(1.42)			
			Birth Year	
Peak-Catch Birth	-0.388		2006	5.347
	(3.96)**			(9.33)**
			2007	5.032
Constant	-6.389			(9.54)**
	(6.92)**		2008	5.081
				(9.66)**
			2009	4.806
				(9.01)**
			2010	3.963
				(7.63)**
			2011	2.927
				(6.71)**
			2012	2.127
				(5.47)**
			2013	0.836
				(2.15)*

[a] **Grid location results excluded for brevity**

Observations: 4,761
Absolute value of t statistics in parentheses [* significant at 5%; ** significant at 1%]

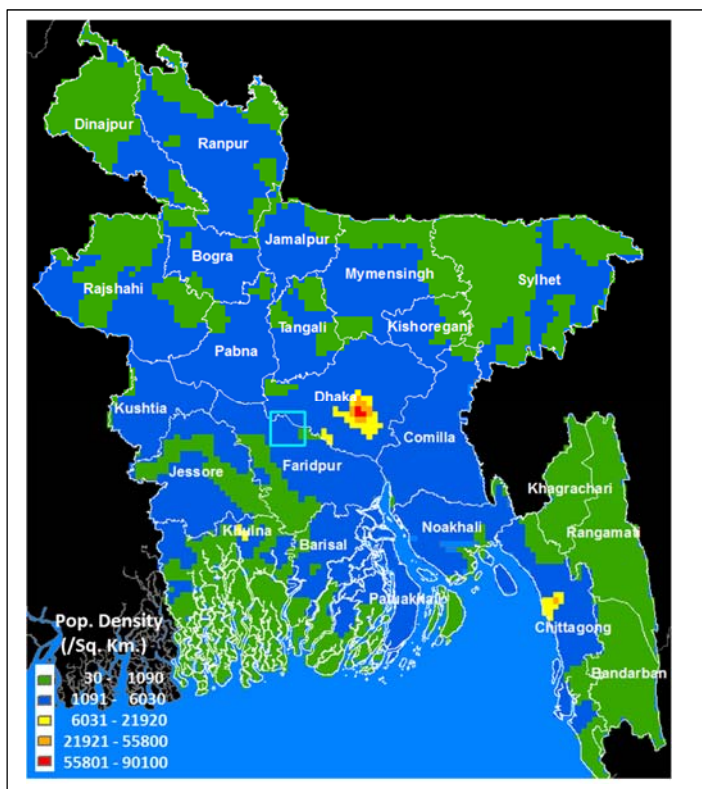**Figure 8: Area selected for predictive assessment of child mortality**

**Table 10 : Fish consumption elements and child mortality rate
(per thousand)**

Fish Preference	Off-Peak Birth	Peak-Catch Birth
0	72.3	32.4
1	31.5	12.3

(2) individual preferences have remained constant over the period covered by our database; (3) our result

for birth during the peak-catch season reflects increased fish supply, not other unobserved factors.

Despite these cautionary notes, we believe that our results support the following proposition:

Children's mortality risk in Bangladesh is substantially lower if they are born during the peak-catch

season, to mothers with strong fish consumption preference.

5.2 Childhood Illness

We also consider the impact of animal-source food intake on the incidence of childhood illness, as reported in the DHS surveys. Our exercise tests the impact of consumption of animal-source foods, particularly fish, on resistance to common childhood infections. We focus on the reported occurrence of diarrhea, fever and coughing immediately before the survey date.

As before, we consider the roles of fish consumption preference and fish supply during the birth period, after controlling for the socioeconomic, temporal and spatial determinants of fish intake during the survey period. We perform probit estimation on a stacked panel data set drawn from DHS 2011 and 2014. The dependent variable is the occurrence of illness, defined as diarrhea, fever or coughing. Our independent variables replicate those in the child mortality model (Table 9). We also introduce dummy variables to allow for variation in mean incidence rates across illness categories.

Our results (Table 11) indicate that child health status is strongly affected by socioeconomic status: Both mother's education and household asset ownership have negative, highly-significant effects on illness incidence. Our results also suggest that female children have lower illness incidence, ceteris paribus. After controlling for the socioeconomic, temporal and spatial determinants of consumption of animal-source foods, we find that fish consumption preference has a negative, significant impact on illness. As before (Table 9), we find no significant impact for the intake of other animal-source foods. And again, we find a lower incidence rate for children born during the peak-catch period (September - December).

To assess the quantitative significance of these results, we replicate our simulation strategy for child mortality. We use the probit results reported in Table 11 to predict incidence rates for children with birth year 2012 whose mothers reside in the grid square identified in Figure 8; have no formal education; belong to a household with zero tabulated assets; and have zero consumption preference for eggs and

meat. We produce four predictions: with and without fish consumption preference and peak-catch season birth, respectively. Table 12 presents the results.

Table 11: Probit results - child illness rate[a]

Protein Intake	Parameter Estimates		Survey Month	Parameter Estimates
Fish	-0.066		July	-0.18
	(2.48)*			(1.46)
Eggs	0.005		August	-0.303
	(0.19)			(2.45)*
Meat	-0.042		September	-0.218
	(1.17)			(1.74)
			October	-0.147
Characteristics				(1.16)
Female	-0.084		November	-0.283
	(3.86)**			(2.19)*
Mother's Education	-0.018		December	-0.483
	(5.26)**			(3.53)**
Household Assets	-0.016			
	(2.09)*		Birth Year	
			2009	0.241
Peak-Catch Birth	-0.071			(3.82)**
	(2.63)**		2010	0.292
				(7.19)**
Constant	0.036		2011	0.146
	(0.19)			(3.65)**
Diarrhea Adjustment	-1.27		2012	0.093
	(41.54)**			(1.57)
Fever Adjustment	0.084		2013	0.177
	(3.60)**			(4.60)**

[a] **Grid location results excluded for brevity**

Observations: 18,008
Absolute value of t statistics in parentheses [* significant at 5%; ** significant at 1%]

Table 12: Child illness incidence by fish preference and birth season (%)

	Birth Month		
	Off-Peak	Peak-Catch	Max Change (%)
Diarrhea			
Fish Preference			
0	8.7	7.6	
1	7.7	6.7	-23.0%
Fever			
Fish Preference			
0	49.8	46.9	
1	47.1	44.3	-11.0%
Cough			
Fish Preference			
0	46.4	43.6	
1	43.8	41.0	-11,6%

For diarrhea, the predicted incidence rate is 8.7% for children born during the off-peak season to mothers with no fish preference (beyond the structurally-determined factors, per model (1)). With no change in fish preference, the rate declines to 7.6% for a child born during the peak-catch season. For mothers with fish preference, the incidence rates are 7.7% and 6.7% respectively for children born in the off-peak and peak-catch seasons. In comparison with the worst case (no fish preference, off-peak birth), the best case (fish preference, peak-catch birth) has an incidence rate 23.7% lower.

Fever and cough have much higher mean incidence rates than diarrhea, but similar patterns of variation with fish preference and season of birth. From worst to best case, the incidence rates for fever and cough fall by 11.0% and 11.6% respectively.

6. Summary and Conclusions

In this paper, we have analyzed 36,491 case histories drawn from individual and household records in the Bangladesh Demographic and Health Surveys for 2000, 2004, 2007, 2011 and 2014. We address three related questions: What are the socioeconomic determinants of consumption of animal-source foods? Among animal-source foods, what are the socioeconomic determinants of the fish share? What are the impacts of consumption of animal-source foods (fish, meat, eggs) on child mortality and resistance to infectious disease? The paper focuses particularly on fish consumption and its health effects for children in their first years of life. Critical factors examined include maternal education, family economic status, child gender, and temporal/spatial variations in fish supply.

We find that maternal education and family economic status are highly-significant determinants of animal-source food intake, along with annual, seasonal and local-area fish supply conditions. After controlling for these factors, we find that children's animal-source food intake is gender-neutral. Our results for the fish share of animal-source food consumption assign significant roles to family economic status, maternal education and seasonal and spatial variations in fish supply. The importance of fish supply for poverty alleviation is highlighted by another finding: The share of fish in consumption of animal-source foods is highest for the poorest households, and declines significantly with income. By implication, programs that increase fish supply and lower fish prices will have a significant impact on intake of animal-source foods, particularly for the poorest households.

We also find a highly-significant, negative relationship between maternal education and the share of fish in animal-source food consumption. In the lowest income groups, mothers shift strongly toward meat and eggs as their education level increases, suggesting a perverse "status bias" against fish despite their lower cost and health advantages.

We assess the implications for child health by estimating the impact of fish consumption on the child mortality rate and the incidence of three common disease symptoms: diarrhea, fever and coughing. After controlling for socioeconomic, temporal and spatial determinants of animal-source foods and fish consumption, we focus on two additional factors: (1) mothers' individual preference for fish consumption; and (2) maternal fish consumption during the immediate pre- and post-partum periods. Our results suggest that both factors have large effects on child mortality risk and significant effects on childhood disease symptoms.[10]

In summary, our results highlight the critical role played by fish supply in maternal and child animal-source food consumption, the fish share of that consumption, and children's health status in Bangladesh. They suggest that programs which promote fish supplies during the off-peak season may significantly improve child health outcomes, particularly in the poorest, least-educated households. Even for those households, however, we find that schooling has a strong and perverse "status bias" effect: As mothers' formal education increases, they shift away from fish toward other sources of animal-source foods that are both more costly and less healthy. This suggests a potentially-important role for public education about the benefits of fish as an animal-source food.

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[10] Identification of components in fish with desired effects on child nutrition and health is a subject for future research.

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