An Extra Grain of Salt: Ocean Salinity, Early-Life Health, and Adaptation in Bangladesh[*]

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Abstract

We present evidence on the effects of *in utero* exposure to climate change induced high salinity levels on children's anthropometric outcomes. Leveraging six geo-referenced waves of the Bangladesh Demographic and Health Surveys merged with gridded data on ocean salinity, ocean chemistry and weather indicators (temperature, rainfall and humidity) from 1993 to 2018, we find that a one standard deviation increase in *in utero* salinity exposure leads to a 0.11 standard deviation decline in height-for-age. Effects on weight-for-height and weight-for-age for a similar magnitude increase in salinity are 0.13 and 0.15 standard deviations, respectively. Analyses of parental investments and health-seeking behaviors demonstrate that there are relatively few compensating actions along these dimensions to attenuate the detrimental effects of salinity, especially among poorer households. Using satellite-sourced datasets on agriculture and land-use, we find that increasing salinity constrains farmers' land use choices. In particular, the effects of salinity on child health mainly originate in areas with lower agricultural intensity caused by the progressive salinization and erosion of productive lands. These results highlight the costs of climate shocks on early-life health outcomes in susceptible populations.

Key Words: Ocean salinity, early-life health, climate change, height-for-age, weight-for-height, weight-for-age, children, adaptation, Bangladesh

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1. Introduction

The effects of climate change, particularly coastal and tidal flooding, sea level rise, and shoreline recession, are becoming more salient in Bangladesh, a low-lying vulnerable country. The coastal belt is particularly susceptible to the natural hazards of climate change including seawater intrusion and the progressive salinization of agricultural lands, which impacts cropping intensity, yields, livelihoods, and human health. While there is growing evidence that climate change contributes to the prevalence of acute and chronic nutritional deficiency among vulnerable populations, there is still a need for a more accurate assessment of the effects, and of the potential channels of transmission that cause these impacts to generate disproportionately heavier health burdens for resource-constrained women and children. We address this research gap by analyzing the impact of *in utero* exposure to higher salinity levels on children's nutritional status as measured by anthropometric measures.

To study how the variation in salinity levels during pregnancy shapes health in early-life, we construct a novel dataset linking gridded data on salinity, weather, and ocean chemistry variables, and child health outcomes. We obtain geo-referenced monthly data on sea water salinity and other variables related to the health of the ocean at a resolution of 0.083^0 x 0.083^0 (each degree corresponding to approximately 8 kilometers), from January 1993 to December 2019, from the Copernicus Marine Environment Monitoring Service (CMEMS). We then combine this data with children's standardized anthropometric measures (height-for-age, weight-for-height, and weight-for-age z-scores) from six geo-referenced waves of the Bangladesh Demographic and Health Surveys (BDHS), and match monthly local variation in salinity levels to birth histories. An advantage of using ocean salinity measures is that respondents are unlikely to be fully aware of changing circumstances in ocean waters that distant from on-shore, and thus less likely to modify

their compensatory behavior correspondingly (Armand and Taveras 2021). This makes this measure more exogenous than something like river salinity, which is likely to be directly experienced in close proximity. However, although ocean measures do have this advantage, increasing seawater intrusion into coastal areas and the concomitant rise in salinity inland has led to the adoption of some adaptation mechanisms in agriculture, as we demonstrate in detail below.

We leverage a saturated model that controls for unobserved heterogeneity including location-specific seasonality and regional trends, while conditioning on a host of child, mother, and household controls. We exploit exogenous variation in average salinity levels nine months preceding the child's month of birth, measured as deviations from long-run month and annual trends, to identify impacts on child health outcomes. We find that greater *in utero* salinity exposure leads to significant effects on the probability that a child suffers from chronic and acute nutritional deficiency. A one standard deviation increase in *in utero* salinity leads to a 0.11 standard deviation decline in the child's height-for-age z-score (representing approximately 6.10% of the mean), while also increasing the prevalence of stunting and severe stunting by 0.7 and 1.3 percentage points, respectively. We find that increased salinity adversely impacts wasting and weight-for-age as well. These results withstand a battery of robustness checks using alternative measures of exposure, nonlinear specifications, and additional ocean chemistry controls. We ensure that our results are not driven by selective fertility or migration. Overall, we document that exposure to salinity *in utero* negatively impacts the health of very young children.

We then undertake a careful exploration of the possible mechanisms to gain insights into the channels through which salinity affects early-life outcomes. We first examine heterogeneity in the effects across different sub-groups. We find larger negative effects for girls, children of higher parity, and for children whose mothers were not employed. We then use information on parental

investments and health-seeking behavior to evaluate whether investments react to salinity exposure. In this, we are guided by the literature on how parental investments may respond to early-life shocks (Almond and Mazumder 2013, Adhvaryu and Nyshadham 2016), and the fact that the effects of prenatal shocks may be confounded by parental actions (Barker 1995, Currie and Almond 2011). We find that at least in terms of prenatal and antenatal care (vaccinations, number of antenatal visits, iron supplementation during pregnancy, skilled prenatal care, skilled attendance at birth, and institutional delivery), there are few corresponding compensating behaviors that attenuate the detrimental effects of salinity.

To evaluate how variations in agricultural intensity may mediate effects, we use two complementary gridded data sources on agricultural and land-use variables. We first document the importance of land use mediators, and show that increasing salinity constrains farmers' land use choices. We find that increased salinity reduces reliance on irrigated croplands that are potentially more profitable. The negative effects of salinity on child health is primarily attributed to the sample of children resident in clusters experiencing lower agricultural intensity (reduced pasture area, grazing area, rice area and total rainfed area) due to the progressive salinization of lands.

Our study contributes to the body of work that considers the effects of *in utero* shocks on early-life health outcomes, human capital, and cognition (Almond 2006, Bleakley 2007, Almond and Currie 2011, Almond and Mazumder 2011, Banerjee et al. 2010, Rocha and Soares 2015, Wilde et al. 2017, Adhvaryu 2019, Armand et al. 2021). It also speaks to a strand of this literature that quantifies the effects of climate change on a range of outcomes (Barreca 2012, Burgess et al. 2013, Deschenes and Greenstone 2011, Molina and Saldarriaga 2017), and that evaluates how environmental factors determine outcomes that affect economic development (Dell et al. 2012, Maccini and Yang 2009). However, our study is unique in that it focuses on country-specific

ground realities to analyze effects of climate change using high resolution temporal and spatial variation in ocean salinity. While most studies consider either temperature or rainfall alone, we trace-out the impacts of rising salinity while conditioning on climate-induced changes in other measures of ocean chemistry including ocean pH, as well as land-based weather measures on temperature, rainfall and humidity. The strength of our paper also lies in the use of a novel database that provides scope to understand the impacts of climate change on human health, while providing the richness of information required to disentangle parental, agricultural, and selection effects in the context of a developing country.

Experts agree that the deleterious effects of global warming will exacerbate preexisting vulnerabilities and inequalities. The results of our study on the scarring effects of salinization on fetal health further underlines this fact. Understanding how climate change related shocks impair child health is important given that we understand such childhood shocks have long-lasting consequences on human capital attainment (Currie and Vogl 2013, Edwards 2017), and in order to focus attention on engineering effective coping strategies in environments with low resources and adaptive capacities.

2. Background

2.1. Climate change and salinity in Bangladesh

Bangladesh, a low-lying deltaic country with a flat topography, is home to one of the largest populations vulnerable to climate change. Criss-crossed by the Brahmaputra, the Ganges, and the Meghna rivers, and located at the tip of the Bay of Bengal, the country is continuously subject to sea level rise, tidal surges, shoreline recession, strong cyclones, and riverbank erosion (Rahman et al. 2014). Coastal areas along the Bay of Bengal covering about 3.22 million hectares (Rahman et al. 2011), more than 30% of the country's cultivable land (Rasel et al. 2013) and home to around

11.80 million poor people located across 19 districts (Dasgupta et al. 2018), are particularly susceptible to seawater intrusion and increased salinity levels.[1]

The southwest coastal region, lying about 1.5 meters above mean sea-level, is most threatened by climate-induced increases in water salinity. Annual mean sea-level data for the period 1983-2003 from the Permanent Service for Mean Sea Level (PSMSL) shows that sea-level in the southwest coastal region has increased by 122 mm between 1983 and 2003, with a yearly average increase of roughly twice the global average of 3 mm per year over this 20-year period.[2] As a result, salt intrusion is rapidly increasing in coastal areas. A report from the Soil Resource Development Institute (SRDI, 2010) from the Ministry of Agriculture shows that the amount of salt-affected area (measured in hectares) during four decades (1973-2009) in coastal areas has increased by 26.7%. Storm surges, the flow of saline groundwater during the dry season coupled with insufficient rainfall to lower saline concentrations, warmer temperature that increases evaporation, and tidal inundation in the wet season, all affect salinity (Baten et al. 2015, Dasgupta et al. 2016). These in turn impact the quality of livelihoods, agricultural yields, cropping intensity, biodiversity, and human health.[3]

Higher salinity levels distort normal cropping patterns and impede agricultural productivity and economic development.[4] Heavy reliance on the agricultural sector implies that saltwater intrusion has significant ecological and socioeconomic implications, with possible spillover effects for the rest of the economy. Hossain et al. (2018) identifies the main coastal

[1] The Bureau of Statistics in Bangladesh, the World Food Programme, and the World Bank, carried out a poverty-mapping exercise to estimate the vulnerable population in coastal areas (Dasgupta et al. 2018).
[2] The data used is for station ID 1451 (Hiron Point, Bangladesh). More information can be obtained from psmsl.org. The data authority for this source is the Bangladesh Inland Water Department of Hydrography, Transport Authority.
[3] Mahmuduzzaman et al. (2014) analyze the causes of salinity intrusion in the coastal region of Bangladesh. In addition to its critical geographic location and to climate change induced factors, sedimentation is a major cause of increased salinity in the coastal belt.
[4] The agricultural sector (agriculture, forestry, and fishing, value added) contributed 12.7 percent of Bangladesh's GDP in 2019, and employed 38.3 percent of the labor force (WDI, World Bank 2021).

communities affected by salt intrusion. Crop farmers, Sundarbans (mangroves) – dependent communities, and landless agricultural laborers, are all vulnerable. Increased salinization causes drinking water shortages, food insecurity, degradation of soil quality, unemployment, reduction in tree coverage, and the depletion of fish resources, posing serious threats to public health, primary production, and aquaculture (Dasgupta et al. 2015). Baten et al. (2015) explains that irrigated water demand is impacted by saltwater intrusion in surface water while Rahman et al. (2011) considers the impact of salinity on agro-biodiversity in three coastal, rural villages of Bangladesh to find that the use of brackish water for irrigation limits the cultivation of rice and vegetables in the dry season.

2.2. Increased salinity exposure and human health

Increased salinity in the coastal belt of Bangladesh has nutritional consequences for everyone, especially women and children. The shortage of grazing land and fodder crops leads to lower milk production, less cattle-rearing, reduced stock of freshwater fish species, and other agro-biodiversity changes that affect households' diet (Alam et al. 2017). The loss of income pushes vulnerable households into poverty. Exposure to high levels of salt through drinking, bathing, and the expansion of shrimp farming to compensate for the loss of livelihoods causes several health problems which are exacerbated by nutritional deficiencies. These include gestational hypertension, acute respiratory infections, diarrheal diseases, and negative consequences on mother-child health in a region already suffering from chronic malnutrition. Khan et al. (2011) for instance, analyzes the link between drinking water salinity and maternal health in Dacope in southwestern coastal Bangladesh and finds that pregnant women had relatively higher rates of pre-eclampsia and gestational hypertension. Dasgupta et al. (2016) documents the association between mother's salinity exposure in the last month of pregnancy and infant mortality. Nahian et al. (2018)

documents the correlation between water salinity and health care crises in coastal Bangladesh, while Joseph et al. (2019) find a U-shaped association between drinking water salinity and infant and neonatal mortality in Bangladesh.

3. Data

We describe the sources of our data in this section. We also provide summary statistics for the main variables used in the analysis, and consider the distribution and seasonality of ocean salinity.

3.1. Children's health outcomes

We use 6 rounds of geo-referenced Demographic and Health Survey (BDHS) for Bangladesh: years 1999, 2004, 2007, 2011, 2014, and 2017. The BDHS is a stratified two-stage nationally representative sample. In the first stage, enumeration areas (EAs) are randomly chosen from the Population and Housing Census of Bangladesh, and are used as the sampling frame, with stratification by region.[5] In the second stage, within the selected EAs (or clusters), a number of households are randomly selected to be surveyed. We use anthropometric measures (height-for-age z-score (HAZ), weight-for-height z-score (WAH), and weight-for-age z-score (WAZ)) for all children aged 0-5, collected in households within which women of reproductive age (15-49 years) were interviewed. We create indicator variables for stunting, wasting, and undernutrition using these measures. We also complement the early childhood outcomes with additional child and household characteristics and other health-related measures. We use the geographic location of each surveyed cluster over rounds to match children by month and year of birth to the geo-coded salinity and weather data at the month and year level. We use this sample to estimate the impact of *in utero* salinity exposure on the health markers of very young children.

[5] Bangladesh has 8 administrative divisions: Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, and Sylhet. Each division is further divided into *zilas*, and *zilas* in turn contain *upazilas.*

3.2. Identifying BDHS coastal communities

To identify the BDHS clusters that are most likely to be affected by rising seawater salinity, we use a measure of proximity to the ocean's shore. For each cluster, we calculate the minimum distance between the cluster's location and the closest shoreline, using the Global Self-Consistent, High Resolution Geography Dataset (GSHHG) (Wessel and Smith 1996). Following the literature, we define coastal communities as those living within 100 km from the ocean, and we classify households living in clusters within 40 km from the ocean as being the most vulnerable communities directly exposed to climate change induced increases in ocean salinity.[6] Figure 1 depicts the location of all clusters in our sample. There are 1000 unique clusters in our sample of coastal communities and 630 unique clusters in the sample of vulnerable coastal communities.

3.3. Ocean salinity and chemistry

Our ocean salinity and chemistry data comes from the Copernicus Marine Environment Monitoring Service (CMEMS), which is drawn from both satellite Earth Observation and *in-situ* (non-space) data.[7] The gridded dataset has a spatial resolution of 0.083° x 0.083° (approximately 8 km × 8km), for the period January 1993 to December 2019.[8] We obtain monthly measures on seawater salinity, seawater temperature, sea surface height (surface value), eastward and northward seawater velocity, and the ocean's pH levels over these years.[9] Specifically, our salinity metric measures the amount of dissolved salts in parts per thousand and is commonly reported in

[6] We here follow Armand and Taveras (2021) who provide an empirical assessment of rising acidification on early-childhood mortality.
[7] We use the global ocean 1/12° physical reanalysis (*GLORYS12V1*) product: "global ocean eddy-resolving reanalysis covering the altimetry".
[8] The "*Global_Reanalysis_PHY_001_030*" product contains three datasets (the 3D daily mean fields, monthly mean fields, and monthly climatology mean fields). We use the dataset containing monthly mean fields. For more information on the validation methodology and series of diagnostics used for the dataset, see Drevillon (2018).
[9] The original file format is the Network Common Data Form (NetCDF) and NetCDF-4. We process these files in Python to obtain month-year level data from January 1993 onwards. All variables considered here are on the same regular grid points.

practical salinity units (psu) (parts per thousand = psu). We match these data to the geolocation of clusters using the month and year of birth of each child using inverse distance weighting (IDW). This is elaborated below.

3.4. Weather data

Since other features of weather are likely to be correlated with both children's health and salinity levels, we include a series of climatic variables in our analyses.[10] We obtain weather data from the Bangladesh Meteorological Department (BMD). The BMD maintains historical records of all meteorological events and archives weather and climate data. We obtain station-month-year level data for all 35 stations across Bangladesh from 1970 to 2019, which includes data on minimum and maximum temperature, rainfall, and humidity.[11]

To transform the ocean and weather data from the station level to the cluster level, we use IDW methods following the environmental economics literature (e.g., Mendelsohn et al. 1994, Deschenes and Greenstone 2011, Zhang et al. 2017). We calculate the weighted average of the weather data for the 5 closest stations for each cluster, weighing each point by the inverse of the squared distance from the cluster's centroid. Thus, for each month and year, we estimate each cluster's weather data at that point in time as the weighted average of stations' data readings, with the weights being inversely proportional to squared distances so that each station has a local

[10] The literature suggests that climate change affects the distribution of several climatic variables, and that any model that attempts to evaluate the distributional effects of climate change will most likely produce biased results due to omission of a set of other climatic variables. Barreca (2012) for instance, finds that humidity, like temperature, is an important determinant of mortality. Zhang et al. (2017) finds that omitting humidity tends to over-predict the cost of climate change on crop yields.

[11] Auffhammer et al. (2013) and Zhang et al. (2017) highlight the importance of having a continuous weather record (and thus few missing observations) when averaging station-data across space to ensure relatively lower loss of weather variation when fixed-effects are used in the empirical model. Although these data do not have a lot of missing values, we complete the series for the relatively few missing observations by using IDW spatial interpolation methods.

influence that diminishes with distance.[12] We also interpolate using 1, 3, and 10 closest stations to test for robustness. We assign these weighted averages to each cluster and include the average minimum and maximum temperature, rainfall (and interaction terms with temperature), and humidity in the month and year of birth in all regressions to account for their potentially confounding influences.

3.5. Summary statistics

Table 1 provides summary statistics for the sample that is most vulnerable, that is, within 40 kms of the coastline. The outcomes of interest are continuous for HAZ, WAH, and WAZ. The binary variables *stunted* and *severely stunted* equal to one if child HAZ falls below -2 and -3 standard deviations, respectively. Similarly, *wasted* and *severely wasted* are binary variables that equal one if child WAH falls below -2 and -3 standard deviations, respectively. *Underweight* and *severely underweight* are constructed from WAZ in a similar fashion, following the World Health Organization guidelines. In Panel A, the mean HAZ is -1.80, and approximately 45% and 19% of children aged 0-5 years are stunted and severely stunted, respectively. The mean for WAH and WAZ are -0.91 and -1.67, respectively, and almost 15% and 39% of children in this sample are wasted or underweight, respectively.[13]

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[12] Let c denote a DHS cluster, i a station, and n_c is the number of stations that relate to cluster c (we choose $n_c = 5$). Let d_{ic}^2 be the squared distance between cluster c and station i. We thus define the weight W_{ic} as follows:

$$W_{ic} = \frac{\frac{1}{d_{ic}^2}}{\sum_{k=1}^{n_c} \frac{1}{d_{kc}^2}} \quad for\ d_{ic} \geq o, and\ for\ any\ i, c$$

Thus, temperature $\bar{T}_c$ at cluster c equals to:

$$\bar{T}_c = \sum_{i=1}^{n_c} W_{ic} T_{ic}, \qquad \text{with} \sum_{i=1}^{n_c} W_{ic} = 1$$

where T_{ic} is the temperature at station i related to cluster c. Simply, T_{ic} is weighted by the inverse of the squared distance given the mean temperature at station i (see De Mesnard (2013) for more details for the use of the IDW method in models estimating pollution impact, for instance).

[13] Figure A1 in the appendix shows that there is substantial heterogeneity in the nutritional status of children across sub-districts in Bangladesh.

In Panel B, average salinity level during the 9 months preceding the child's month of birth, is 12.59 psu, with a standard deviation of 4.40.[14] Ocean's pH has an average of 8.20. Panel C reports the summary statistics for weather-related variables used as controls in all our regressions. Panel D provides information on the characteristics of children, mothers and fathers in our sample. Half of the children are male, and the average child's age is 29.31 months. The average birth order is 2.69, and the average mother's age at first birth is 17.95 years. Estimates reveal that 24% and 26% of mothers and fathers in our sample had no education, respectively. In 87% of cases, the head of the household is male.

3.6. The distribution and seasonality of ocean salinity

The kernel densities for average surface salinity levels in panels A and B of Figure 2 provide evidence of climate-induced change in ocean salinity over time. Panel A considers the kernel densities for salinity levels for ocean points associated with clusters within 100 km of the ocean for two periods: 1995-2002 and 2011-2018. Panel B includes salinity for ocean points associated with the sampled vulnerable coastal clusters living within 40 km of the ocean for the same two periods. In both panels, there is a right shift in the distribution of ocean salinity over time. The fact that both panels look similar suggests that much of this change in coastal communities arises among those that are most vulnerable, as expected.[15]

Ocean salinity clearly varies with the onset and end of the monsoon period. Panel A of Figure 3 shows the seasonal variation in salinity (the average for each month over the years) for

[14] The WHO recommends no more than 5 grams of salt per day but there is no clear translation between this metric and recommended salinity exposure in practical salinity units. Nasrin et al. (2020) notes various categories for salinity levels based on optimal conditions for crop growth and soil quality: low saline (0.5 to 5 psu), moderate saline (5 to 18 psu) and high saline (18 to 30 psu). An average of 12.59 psu in the 9 months preceding the child's month of birth thus falls in the moderate category, based on these benchmarks.

[15] The rise in salinity exposure is evident in the raw data as well. Over the 1994-1999 years, 1383 children in our sample were exposed to *in utero* ocean salinity that exceeded 13 psu (rounded average salinity level in the 9 months preceding birth). However, this number rose to 4117 children in the 2000-2010 decade, and was 2910 children in the 2011-2018 time-span.

ocean points matched to coastal clusters. We observe differences in salinity levels over the pre- and post-monsoon seasons; in particular, salinity increases in the post-monsoon period (October) through the pre-monsoon month of May, after which it declines. Surface salinity in coastal waters is higher in the dry season due to lower rainfall and river discharge, which allow saline water to intrude further upstream in major rivers through tidal effects and stronger estuarine exchange flows (Baten 2015, Shammi et al. 2019, Dasgupta et al. 2015). In addition to the monsoons, increases in the ice melting of the Himalayas during May through October generates a higher upstream flow of freshwater and higher river water discharge, and thus reduces salinity in the coastal areas (Mahmuduzzaman et al. 2014). Our empirical methodology outlined below is cognizant of these seasonal changes in salinity levels.

Panel B of Figure 3 shows the distribution of ocean salinity for ocean points matched to all sampled coastal clusters. The distribution is mostly skewed to the right, but there is also variation in levels across clusters. The distribution also reveals that the identifying variation stems from the majority of clusters and not just from a few outliers. Taken together, Figures 2 and 3 show that ocean salinity exhibits considerable variation across clusters and over time.

4. Empirical Strategy

To test for the effects of variation in *in utero* salinity on early-life health, we employ the following specification:

$$y_{icdmt} = \beta salinity_{cdmt} + X'_{icdmt}\gamma + \mu_d + \sigma_m + \lambda_t + \eta_{mt} + \theta_{dm} + \Phi_{dt} + \epsilon_{icdmt} \qquad (1)$$

y_{icdmt} is the health outcome for child *i*, born in month *m* in year *t*, and whose mother was surveyed in cluster *c* in district *d*.[16] As noted above, we consider two sets of areas for analyses - coastal

[16] We initially wanted to include cluster fixed-effects in our models but these were so many over the six years of BDHS data we use that the models took extensive time to converge given that their interactions with month and year of birth are also included. As we note above, there are more than 1000 unique clusters when we consider all coastal

communities within 100 km, and within 40 km from the ocean. We consider the effects of salinity exposure in the 9 month *in utero* phase, and construct $salinity_{cdmt}$ as the average value of ocean salinity (constructed from the 5 closest stations, as described above) in the 9 months preceding the child's month of birth in cluster *c* as our variable of interest.[17] β is the coefficient of interest, and it is expected to be negative for HAZ, WAH and WAZ, and positive when the binary indicators for stunting, wasting, and underweight are considered.

X_{icdmt} is a vector of controls including child, mother, and household characteristics, and time-varying weather and other ocean chemistry controls that could potentially be correlated with salinity while also determining part of the variation in early-life health. More specifically, we include child's age, gender, and birth order, mother's age at first birth, a dummy variable that equals one if the mother is uneducated, a dummy variable that equals one if the father is uneducated, mother's height, and the gender of the household head.[18] In terms of other ocean and land measures, we include time-varying climatic variables: minimum and maximum temperature, rainfall, the interaction between minimum/maximum temperature and rainfall, and humidity. We also control for ocean pH (Armand and Taveras 2021), and consider additional variables including seawater velocity, seawater temperature, and sea surface height in our robustness analysis.

Equation (1) includes a series of temporal and spatial fixed-effects to control for unobserved heterogeneity in seasonality and in regional trends.[19] District fixed-effects (μ_d) account for the unobserved time-invariant characteristics specific to the districts in which the

communities, and 630 unique clusters in the vulnerable coastal communities. Instead, we have 19 unique district fixed-effects in the sample of vulnerable communities, additionally interacted separately with month and year of birth as equation (1) notes (over 700 fixed-effect parameters).

[17] We assume a gestation period of 9 months but have checked sensitivity when we extend to 10 months (see Table A2, also discussed below).

[18] We run extensive heterogeneity checks with wealth measures below; in this baseline model, parents' (especially father's) educational level proxies for household wealth.

[19] Hence, we estimate the impact of deviations in salinity from long-run seasonality and regional trends at the location of birth (as in Armand et al. 2021).

clusters are surveyed. We include month of birth fixed-effects (σ_m) to account for other seasonal factors. Year of birth fixed-effects (λ_t) and year by month fixed-effects (η_{mt}) are included to control for idiosyncratic changes common across clusters. We also include district fixed-effects interacted with month of birth (θ_{dm}) to control for local seasonal variation, and Φ_{dt} which are district-year of birth fixed-effects to control for district-specific trends in cohort nutritional status, and thus for any local annual patterns in health outcomes. The presence of these fixed-effects implies that we estimate the impact of deviations in ocean salinity over long-run month and year trends, facilitating causal interpretation of our estimates (Dell et al. 2014). ϵ_{icdmt} is the idiosyncratic error term. Regressions are weighted so estimates may be interpreted as representative and we report standard errors clustered at the cluster level. The identifying assumption is that there are no omitted variables that could be correlated with both the salinity measure and with child health outcomes, so that exposure to salinity levels *in utero*, conditional on the other variables in the models, is as good as random. Identification of the parameter of interest, β, therefore stems from exogenous (unanticipated) variations in salinity exposure net of district-specific monthly and annual trends, as noted above.

Since oceanic variables are likely correlated, we expect multicollinearity to be an issue. To alleviate concern while not jeopardizing statistical consistency, we employ a double-lasso variable selection strategy to guide our selection of climatic and oceanic variables (Belloni et al. 2014). The double-lasso strategy works in two steps: the first step regresses the treatment variable (in our case ocean salinity) on the full set of control variables in a lasso regression; the second step regresses the outcome variable on the treatment variable and the selected set of variables from the first step. The double-lasso strategy provides a robust model selection framework that selects a smaller subset of control variables from a wider set of potential control variables (Belloni et al. 2014).

We implement the double-lasso estimator on the within-40km-to-ocean sample with all nine outcome variables using three different selection methods: full cross-validation, adaptive selection, and plugin-adaptive selection. All variables in our main model are included in the double-lasso selection, demeaned with the same set of saturated fixed-effects.[20] We force household controls and salinity to always remain in the model, leaving oceanic and weather variables to be selected. We are unable to apply weights in the double-lasso regression, and as such could not use post-lasso inference methods directly.

Table A1 presents results from running the double-lasso algorithm on 27 candidate models and specifications (3 selection methods for each of the 9 outcome variables). Although sea surface temperature and sea surface heights are selected, we exclude them because of their strong correlation with salinity (the correlation coefficients are large and both significant at the 1% level). We include pH as a control for ocean chemistry, noting that ocean acidification negatively impacts shrimp farming, an important adaptation alternative.[21] The set of local weather variables, although selected in fewer model, are included in all specifications given their low correlation with salinity and because they may be more accurate gauges of conditions in inland areas within 100 kms of the coast.

5. Results

5.1. The effects of *in utero* salinity exposure

In Table 2, we present results from the regression in equation (1). In Panel A, we restrict the sample to the vulnerable coastal area (DHS clusters living within 40 km of the ocean), and in

[20] Demeaning is accomplished by extracting the residuals from the regression y = 1 + fixed effects. As recommended in Luo et al. (2017), we double-checked the residuals obtained from the demeaning regression and found that the within-group means are minimal (i.e., close to zero and much smaller than the original standard deviation of the variable). Thus this should not be a concern empirically.

[21] North wind velocity is another ocean measure that is selected in this method. However, given its low correlation with ocean salinity (correlation coefficient is only -0.05), its inclusion is unlikely to change our results in any meaningful way.

Panel B, we restrict the sample to all DHS clusters living in the coastal area, that is within 100 km of the ocean. Focusing on the coefficients in Panel A, we see consistently negative effects of ocean salinity on children's anthropometric indicators. In column (1), a one standard deviation (SD) increase in *in utero* salinity leads to a 0.11 SD decline in the child's HAZ (representing approximately 6.10% of the mean).[22] In columns (2) and (3), the results are in line with expectations – *in utero* salinity exposure has significant effects on the probability that the child is stunted and severely stunted. A one unit increase in salinity increases the prevalence of stunting and severe stunting by 0.7 and 1.3 percentage points, respectively. Taken together, results in columns (1) to (3) in Panel A show that *in utero* salinity exposure has significant implications for children's health. When the sample is restricted to all coastal communities in Panel B, while the coefficients are of smaller magnitudes, the negative impacts of salinity exposure are still evident.

In columns (4) to (6), we consider WAH and binary variables for wasted and severely wasted. Column (4) of Panel A indicates that the effect of a one SD increase *in utero* salinity leads to a 0.13 SD decrease in WAH (representing about 14.00% of the mean), with significant effects evident also for the prevalence of wasting and severe wasting. As above, corresponding estimates in Panel B are lower.

In columns (7) to (9), the dependent variables relate to WAZ. The results again support the hypothesis that variation in *in utero* salinity levels have detrimental effects on children's health. Higher *in utero* salinity levels are associated with lower WAZ, and a higher prevalence of children who are underweight and severely underweight. Since WAZ in particular is a composite measure

[22] The coefficient on salinity exposure in column (1) of Table 2 is -0.025. We multiply this coefficient by the standard deviation of salinity (4.40) in order to obtain the 0.11 SD decline. We then consider this effect with respect to the mean of HAZ (-1.80) to get the percentage value of 6.1%.

of both chronic and acute nutritional deficiency, the negative effects indicate that increased salinity has especially harmful consequences on the likelihood that children are malnourished.

5.2. Robustness checks for the main results

5.2.1. Alternative measures of *in utero* salinity exposure

We construct alternative measures of *in utero* exposure (following Adhvaryu et al. 2020) to underline the robustness of our main results. We focus on the results for vulnerable coastal areas (within 40 km of the ocean) henceforth but results for all coastal communities (with 100 km of the ocean) are available upon request. In Panel A of Table A2 in the appendix, the results on child health outcomes remain robust when we use the sum of monthly salinity values (in logs) for the 9 months prior to birth as the source of variation. In Panel B, we retain average *in utero* salinity but also control for the number of months in which salinity exceeded the cluster's mean (by at least one standard deviation) as a measure of intensity. The estimates for the main variable of interest are in the same ballpark as those from the main analysis. In Panel C, we use the standard deviation of salinity for the 9 months before birth as the variable of interest. The results suggest that higher salinity dispersion is also associated with deteriorating child health outcomes, with significant effects on the likelihood that the child is severely stunted, severely wasted, underweight, and severely underweight. We exclude the southwestern districts from the sample of vulnerable coastal areas in Panel D, given the exceptionally high levels of salinity there. The coefficients still match our *a priori* expectation that increased *in utero* salinity exposure leads to deteriorating child health. In panel E, we assume a gestation period of 10 months; overall, our main results do not change.

5.2.2. Additional controls for potential confounders

In Table A3, we augment our baseline specification with additional controls including seawater temperature, sea surface height, and for seawater velocity. Our main results remain unaltered.

5.2.3. Nonlinear specification

In Table A4, we replace our variable of interest with binary variables constructed using the sample distribution of salinity in the vulnerable coastal area to account for non-linearities in salinity effects. In Panel A, we condition on an indicator variable that equals one if salinity is greater or equal to the 50th percentile value.[23] The results suggest that children exposed to above median *in utero* salinity levels are more likely to experience worse health. In Panel B, we use quartiles of salinity exposure and include three binary variables that each equals one if the child experienced *in utero* salinity levels in the second, third, or fourth quartile.[24] The results show that relative to lower quartile exposure (the omitted category), children in the third and fourth quartiles have lower HAZ, WAH, and WAZ, and higher prevalence of severe stunting, wasting, and underweight. In Panel C, we exclude the southwestern districts from the sample in Panel B. In general, the coefficients are again of larger magnitude in the higher quartiles.

5.2.4. Effects by trimester

We disaggregate the exposure variable by trimester to understand whether there are gestational periods in which the effects of salinity are more pronounced.[25] The results are presented in Table A5. Stunting is mainly caused by exposure to salinity in the second trimester: a one SD increase in salinity decreases HAZ by 0.18 SDs, increases the chance of stunting by 0.80

[23] This corresponds to a salinity of 11.3 psu in the data.
[24] For the lower quartile, salinity ≤ 9.3 psu, second quartile: 9.3-11.3 psu, third quartile: 11.3-15.4 psu, and for the top quartile: ≥ 15.4 psu.
[25] This involves estimating a variant of our baseline model in equation (1), where $\beta salinity_{cdmt}$ is replaced with three variables for the mean salinity exposure during the first, second, and third trimesters.

percentage points, and the chance of severe stunting by 1.01 percentage points. Wasting is mainly caused by exposure to salinity in the first trimester: a one SD increase in salinity exposure in the first trimester decreases WAH by 0.16 SDs. The results on underweight suggest that second trimester exposure matters. The second trimester is when the fetus is in advanced stages of physical and neurological development while the third trimester is when most of the weight gain occurs. Hence impacts on HAZ and WAZ are consistent with this course of development. However, exposure over the full gestational cycle is likely correlated, and hence we are reluctant to state which trimester matters the most for these outcomes.

5.2.5. Timing of exposure: Controlling for salinity before conception and after birth

As a falsification test, we check that impact of salinity matters only in the *in utero* period.[26] In Figure A2, we present results estimating the effects of salinity during the pregnancy period by including average salinity levels 1-2 months before conception (10-11 months before birth), 3-4 months before conception (12-13 months before birth), during the month of birth, and 1 trimester after birth. We note that exposure before or after pregnancy does not have significant effects for most of the outcomes. In HAZ and severe stunting, *in utero* salinity exposure in the month of birth has a marginally significant effect.

5.2.6. Spatial spillover effects

We estimate spatial spillovers of salinity impacts on children's outcomes by generating dummy variables for each cluster indicating their distance to the coast in 10 km distance bands, starting from within 10 km to 90-100 km. We then replace the single salinity metric in equation (1) with interaction terms between these distance bands and salinity exposure.

[26] This falsification test is similar to Molina and Saldarriaga (2017) and Armand and Taveras (2021).

Results are presented in Figure 4. We find that the effects of salinity on children's health are larger in clusters closer to the ocean. For instance, the impact of salinity on both WAH and WAZ are negative and significant in most clusters that are within 50 kms of the coast, and insignificant beyond 50 kms. For severe stunting and severe wasting, the effect is significant within 70 kms of the coast. Across the board, the magnitude of the effect decreases over distance, which aligns with the expectation that communities nearer the coast are more vulnerable.

6. Heterogeneity, Mechanisms and Adaptations

6.1. Heterogeneous effects of salinity exposure

We explore heterogeneity in the impacts of *in utero* exposure on health by child, maternal, and locational characteristics. As we note above, these analyses focus on the most vulnerable households living within 40 km of the ocean. Results are presented in Tables 3 and 4. In Panel A of Table 3, we estimate impacts by gender of the child. The results using sub-samples restricted to female children point to larger negative effects in many of the outcomes. Gender heterogeneity may be explained by several factors. It could be that there exist gender-biased early childhood health investments by parents (Bharadwaj et al. 2020) in favor of boys (a possibility that we explore below). The decline in income caused by progressive salinization could differentially impact prenatal care and health-seeking behavior, affecting girls' health disproportionately (also explored below). Second, it could be that the relative vulnerability of male fetuses to adverse shocks leads healthier boys to survive to term and then to depict better health outcomes post-birth (Gualtieri and Hicks 1985, Kraemer 2000, Sanders and Stoecker 2015). We check this possibility as well below. Finally, gender-biased parental investments consistent with son-preference is also a possibility (Asadullah et al. 2020).

In Panel B, we consider the heterogeneous effects of salinity across birth orders. The results suggest that while salinity has a detrimental impact on all children, in general, children of higher parity are more negatively affected relative to first-born children. This result is likely due to intrafamily resource constraints such that when the number of children in the household increases, parental investments decrease (Becker and Tomes 1976; Li et al. 2008).[27]

We then use mother's height as an indicator of mother's health in Panel C. We split the sample by median mother's height, and document some evidence that children of relatively shorter mothers are more negatively impacted. In Panel D, we run separate regressions for the sample of children whose mothers work outside of the home versus those whose mothers are not engaged in this manner. We obtain significance mostly for children whose mothers do not work. Children of unemployed mothers are potentially more exposed to the health damages of salinity. Working mothers who are likely educated may have access to knowledge on how to protect their children, or have recourse to more effective mitigation strategies.

In Table 4, we consider sub-samples created based on location characteristics. In Panel A, we find that the response of outcomes to salinity is greater in areas with population density below the sample median. The results in Panel B, where we use total built-up area (measuring the number of towns, cities, and other buildings in squared km per grid cell) as a proxy for urbanization, lend support to these findings.[28] Children in more 'built-up' coastal areas are less affected.

6.2. Early childhood health investments

We test whether the effect of salinity on child health is intensified or mitigated by compensating behaviors of parents (Almond and Mazumder 2011). In Panel A of Table 5 we

[27] We show that the negative effects of salinity on prenatal care and at birth investments are more pronounced for non-first born children in the following section.
[28] The data is available from HYDE 3.2, a data source on which we elaborate further in the paper.

examine the impact of salinity on post-birth vaccinations. The coefficients are negative suggesting that increased exposure reduces early childhood investments. In results discussed below, we find that these negative impacts originate mainly in the relatively poorer households, which is suggestive of an income channel. Water and soil salinization leads to crop failure, destroys employment opportunities, resulting in lower agricultural incomes. This could hinder health-related investments in both the prenatal and postnatal stages. Increased opportunity cost of maternal time (Bhalotra et al. 2010, Bharadwaj et al. 2020) due to livelihood losses could also explain the fall in vaccination rates.[29]

In Panel B of Table 5, we consider effects on the number of antenatal visits, prenatal care, medical assistance during delivery, and institutional delivery. In columns (1) and (2), we find that higher salinity reduces the number of antenatal visits and lowers the likelihood of receiving iron tablets during pregnancy.[30] In columns (3) to (6), the dependent variable equals one if prenatal care and medical assistance at birth came from either a doctor or a nurse, respectively. Again, effects are negative. In column (7), *'Delivery: at home'* equals one if the mother reports that she gave birth at home. Greater salinity raises the likelihood of home birth. As we note below, these results mainly arise in among the relatively poorer households. These results underline that mothers in resource-constrained households at least are unable to rely on such investments (similar to Banerjee and Maharaj 2020).

Indeed, differences in parental investments in prenatal and postnatal healthcare drive part of the effects. In Table A6, we re-estimate the impact of salinity presented in Table 2, conditioning

[29] The literature provides mixed evidence on health shocks, compensating behaviors and parental investments. Molina and Saldarriaga (2017) finds negative effects of heat shocks on medical assistance at birth in the Andean region. Armand and Taveras (2021) does not observe any significant effect of ocean pH on antenatal and delivery investments. Adhvaryu et al. (2019) finds that health investments reduce the effects of *in utero* dust exposure in West Africa.
[30] The number of antenatal visits also determines the use of nutrient supplementation during pregnancy (Gebremedhin et al. 2014).

on these variables. We find that receiving antenatal checkups and prenatal assistance from doctors significantly improves children's outcomes, and the effects of salinity become smaller and insignificant for most outcomes.

Given evidence on the importance of gender and birth order (Baird et al. 2011), we examine whether the effects of salinity on health-seeking behavior are homogeneous along these dimensions. The results are reported in Table A7. We find that little differential impacts in Panel A. In Panel B, mostly the sub-sample of non-first-born children are affected.

6.3. Agricultural and biodiversity-related losses

Increased salinity in the coastal belt affects child health through its negative impacts on agriculture, biodiversity, and on the availability of fresh water for consumption (Dasgupta et al. 2015). Significant reductions in agricultural yields, accompanied with ground water and soil quality degradation have profound impacts on livelihoods (Khanom 2016).[31] The loss of native species, the fall in agricultural productivity as well as reductions in the availability of agricultural land, all contribute to heightened food insecurity.[32]

We examine empirically the agricultural and bio-diversity related adaptation mechanism, guided by the intuition that salinization of agricultural lands may have cascading effects on health via impacts on crop systems, aquaculture, livestock, homestead agro-forestry, and land use, both in the short and longer-term (Costinot et al. 2016, Waldinger 2022). We use two complementary data sources that provide gridded agricultural/land-use variables in order to undertake this exercise.

[31] This has caused aquaculture to boom over the past few decades as coastal communities adapt to increased salinity by relying more on shrimp cultivation. This in turn worsens the soil salinity problem further as brackish water invades surrounding areas, and leads to a fall in the number of indigenous rice varieties (Rahman et al. 2011).

[32] Ziaul Haider et al. (2013) studies the impact of salinity on farmers' livelihood strategies. The study finds that while salinity motivates adaptations such as shrimp cultivation, other land-use activities, and changes in agricultural patterns, detrimental effects on agricultural income and employment opportunities still result, leading to lower living standards.

The first is the annual land cover classifications for the period 1993-2019 provided by the Copernicus Land Monitoring Service (CLMS) with a spatial resolution of 300 m (0.002778^0). These are consistent with the annual land cover maps from 1992-2015 produced by the ESA-CCI LC project (Defourny et al. 2017). Using the coordinates of each DHS cluster, we create multiple buffer zones of varying distances and count the total number of each land-use class within each buffer zone to track land-use pattern changes over space and time.[33] Figure A3 presents an example of the procedure for the 1999 clusters. It shows the land cover map for 1993 superimposed on a shapefile containing the coordinates of the clusters in 1999. The geolocation of clusters is then used to match birth histories (based on the child's birth year) with land-use patterns.

We augment equation (1) with additional land use mediators, including the share of land within a given buffer for rainfed crops, irrigated crops, forests, saline flooded forests (mangroves), wetland, shrubland, and urban settlement. Table 6 presents the results. We find that after including these land use variables, the effect of salinity reduces in magnitude and significance. For example, we find an 84.00% decrease in the magnitude of the salinity coefficient on HAZ after conditioning on land use patterns (the coefficient becomes insignificant). This indicates that land use is an important mediating factor for salinity's effects on children's health.

We then examine how salinity exposure may drive land use decisions, aiming to shed further light on the agricultural mechanism. To do so, we explain annual land use patterns from 1993-2019 for each 30 km buffer from the cluster's center with ocean salinity, pH, average weather

[33] We create buffer zones of 5 km, 10 km, 20 km and 30 km, but report results only for 30 km given space constraints. All results are available on request. Further, to proxy for agricultural cultivated area, we use the IPCC classes representing rainfed cropland and irrigated cropland. To proxy for forestry area, we aggregate the IPCC classes representing tree cover (broad-leaved, needle-leaved, evergreen and deciduous). We also focus on the tree cover flooded with saline water, and on other land-use classes for shrub land, grassland, sparse vegetation, other bare areas, and water. For further details, see the correspondence between the IPCC land categories used for the change detection and the LCCS legend used in the land cover classes provided by the Land Cover Climate Change Initiative - Product User Guide v2. Issue 2.0.

conditions, and the full set of fixed-effects from our baseline specification in equation (1). Table A8 presents the results. We find that higher salinity levels are associated with less land used for irrigated crops and more for rainfed crops. This is in line with evidence in Shelley et al. (2016), where coastal farmers fallow for the winter dry season (*boro*) and plant rainfed agriculture in the wetter monsoon (*aman*) season to cope with salinity exposure. The transition from winter irrigated to monsoon rainfed agriculture is often coupled with using salinity-resistant traditional rice varieties which have significantly lower yields (Shelley et al. 2016). We also find significant land use responses moving from forests to shrubland when facing higher salinity levels. Taken together, this is further evidence that increasing salinity constrains farmers' land use choices, possibly deterring the planting of profitable crops such as irrigated rice with detrimental effects on agricultural income.

To substantiate the above findings with more evidence that the agricultural channel is a plausible one explaining the salinity-child health nexus, we use the *History Database of the Global Environment – HYDE 3.2* (Goldewijk et al. 2017) to build indicator variables to proxy for the intensity of agricultural activities.[34] We use the available data from 2000 to 2017 and process the geospatial files for the gridded land use data (available at the 5 by 5 minutes resolution). We thus obtain annual data for total land used for grazing, for pasture, for total rain-fed agricultural area, total rain-fed agricultural area devoted to the production of rice, and total rain-fed agricultural area for other crops (except rice), all measured in squared km per grid cell.[35] We then consider the heterogeneous effect of salinity on child health by the intensity of these agricultural activities.

[34] The database provides gridded time series of population and land use from 10,000 B.C to 2017 A.D. The data is available for time intervals 100 years apart until 1700, then 10 years apart till 2000, and in 1 year intervals from 2000-2017.

[35] Note that this reduces the sample size since we cannot match the data for children in the BDHS who were born between 1994-1999 as annual data are only available from 2000 onwards.

Figure 5 reports the coefficients on salinity exposure when different sub-samples are used based on indicator variables for below or above median values for pasture area, grazing area, rice, and rain-fed cultivated area. Children born in clusters experiencing lower agricultural activities (below median) face more pronounced negative health effects. We note also in Figure 5 that the extent and intensity of rainfed agricultural land devoted to rice production and to other crops clearly drives the effects of salinity on child health. Coefficients on salinity exposure for *"rice area"* and *"total rainfed area"* in this figure are mostly statistically significant when the samples are restricted to children born in clusters experiencing below median agricultural activities in their year of birth. Thus the agricultural mechanism is important in explaining the effects of salinity.

6.4. Wealth as a mediator

We end this section by analyzing the influence of wealth in mediating the impacts of salinity. The BDHS data has a wealth indicator that classifies households in quintiles of the wealth distribution across rounds, and is constructed using information on assets owned. Since agricultural losses in particular are likely to be concentrated among those who own land (the relatively richer households), we create a binary variable that equals one for households in the top two quintiles of wealth, zero otherwise (the land use measure in BDHS has too many missing values). This indicator thus distinguishes the richest households in the distribution. We begin by investigating the effect of salinity exposure on these households and results are presented in Table A9. These show that salinity has a significant negative effect, that is, salinity exposure reduces the likelihood that households are in these richest quintiles of the wealth distribution.

Given the strong effect of salinity on wealth, we expect that conditioning on the household wealth indicator in the main results of Table 2 will reduce the impact of salinity on outcomes. Results presented in Table A10 confirm this to be the case. Whereas the salinity coefficient was

significant in eight of the nine outcomes in Table 2, it is significant in a reduced five outcomes in Table A10. Additionally, the household wealth indicator has strong and significant impacts across all columns in this table, as expected.

Finally, we analyze variations in parental investments, health-seeking behavior and prenatal care by wealth status. That is, we differentiate results presented in Table 5 by the wealth status of households using the constructed wealth measure discussed above. These results are shown in Table A11 and reveal that many of the significant results in Table 5 arose among the poorer households in the wealth distribution, as we noted above. Among the richer households, there is very little evidence that salinity affects vaccinations, prenatal car or at-birth investments in the most vulnerable coastal communities.

7. Selective fertility and migration

We address concerns related to selection. Existing research suggests that the long-term effects of early-life shocks involve boys' culling and girls' scarring (Catalano and Bruckner 2006, Liu et al. 2014), and the higher vulnerability of male fetuses can lead to excess male mortality in response to negative health shocks (Sanders and Stoecker 2015). In Table A12, we test for significant effects of salinity on the probability that the child is male conditional on the initial set of controls in equation (1), for vulnerable clusters within 40 km of the ocean. In column (1), we find that salinity has no effect on the probability that the child is male. In column (2), we consider the impact of salinity while controlling for the salinity level in the month of conception. In column (3), we consider average exposure for 2-9 months during gestation, and in column (4), we include both salinity in the month of conception and in months 2-9.[36] In column (5), we consider a

[36] Bratti et al. (2021) perform a similar analysis in their study of the impact of prenatal exposure to heat waves in Sub-Saharan Africa.

nonlinear specification by including quartiles of salinity levels. Overall, the results in Table A12 indicate that salinity does not predict male gender.

We next consider selection on parental characteristics. We demonstrate in Table A13 that maternal characteristics do not correlate with salinity exposure (these tests for selection are motivated by Buckles and Hungerman (2013) and guided by insights in Wilde et al. (2017)). The maternal characteristics considered are mother's education (6 and 12 years or less of education) in columns (1) and (2), height in column (3), a dummy variable that equals one if she is currently working in column (4), mother's age, age at the time of first delivery, and the age difference with the household's head (columns (5), (6), and (7) respectively). There are mostly no significant impacts for selective fertility.

To allay concerns related to selection from population sorting, we restrict the sample to children of mothers who have resided in the current place of residence for more than 9 years (the median number of years of residence) in Table A14. We note first that the majority of our sample (approximately 67%) has remained resident in the same area for this extended period of time. Consistent with this, our estimates remain essentially unchanged.

8. Conclusion

This paper empirically demonstrates the harmful consequences of rising ocean salinity on the health of very young children in coastal Bangladesh. We employ geo-referenced data on salinity merged with child health outcomes from 6 waves of the Bangladesh Demographic Health Surveys to evaluate how variations in *in utero* salinity exposure affects children nutritional status using anthropometric measures of health. Our baseline strategy leverages a saturated fixed-effects model that allows us to exploit exogenous variations in salinity over time and space (deviations from long run district-specific means), while controlling for the effects of district-specific

seasonality and other local trends. Our main results indicate that a one standard deviation increase in *in utero* salinity exposure decreases HAZ scores by approximately 6.10% relative to the mean, while increasing the prevalence of stunting and severe stunting. Similar effects are obtained for weight-for-height and weight-for-age. We underline the validity of our results with various robustness and specification checks.

Heterogeneity tests reveal that effects are more pronounced for girls, children of higher parity, and for children whose mothers are unemployed. We demonstrate that higher salinity levels are associated with lower early childhood investments in prenatal and post-birth stages, mostly among poorer households. The lack of compensating behaviors suggests that parental investments in early-life are not mitigation strategies. Where we do find evidence for adaption is in our analysis of agricultural land use using satellite-sourced information. Here we find suggestive evidence that salinity affects the scale and intensity of agricultural activities, with possible deleterious consequences on incomes, food security and nutritional intake. We document the importance of land use mediators and provide evidence that increasing salinity constrains farmers' land use choices.

These findings have important implications for coastal communities in Bangladesh and elsewhere as climate changed induced increases in salinity exposure generate irreversible environmental crises. A comprehensive assessment of the effects of rising salinity on early-life health and on the behavioral responses that are triggered is essential to highlight possible adaptation measures to increase resilience and to minimize catastrophic fallouts on human health, income and well-being.

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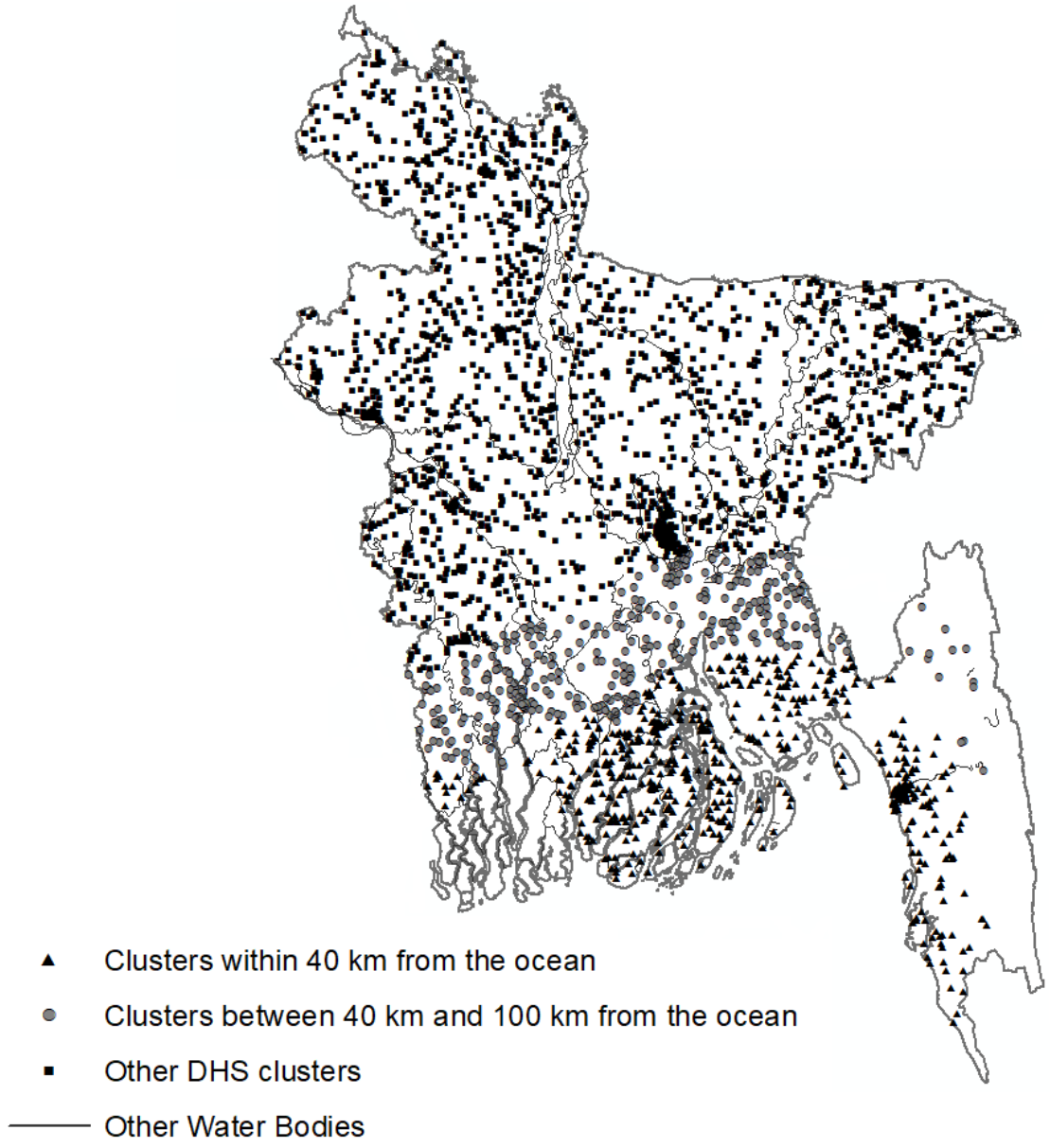
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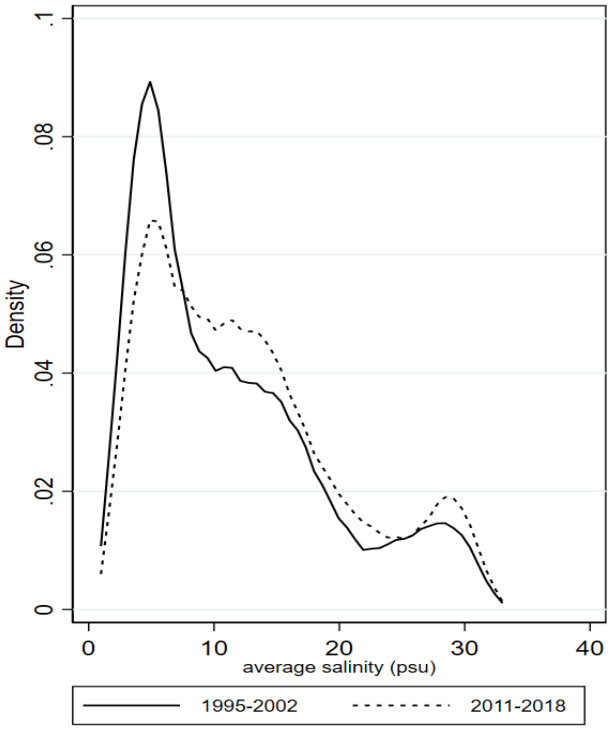
Figure 1: BDHS Coastal Communities



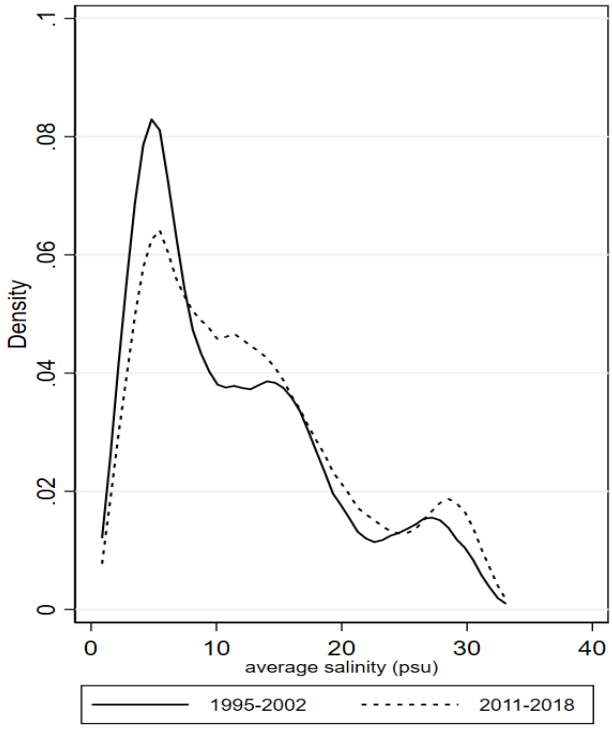
Notes: Figure 1 shows the location of all BDHS clusters in our sample. The black triangles represent coastal clusters that are within 40 km from the ocean. The gray circles represent coastal clusters that are between 40 km and 100 km from the ocean. The black squares represent all the other DHS clusters. Data citation: Wessel, P., and Smith, W. 1996. A Global Self-consistent, Hierarchical, High-resolution Shoreline Database, *Journal of Geophysical Research*, 101, 8741-8743

Figure 2: Kernel Densities of Salinity 1995-2018

Panel A: All Coastal Communities



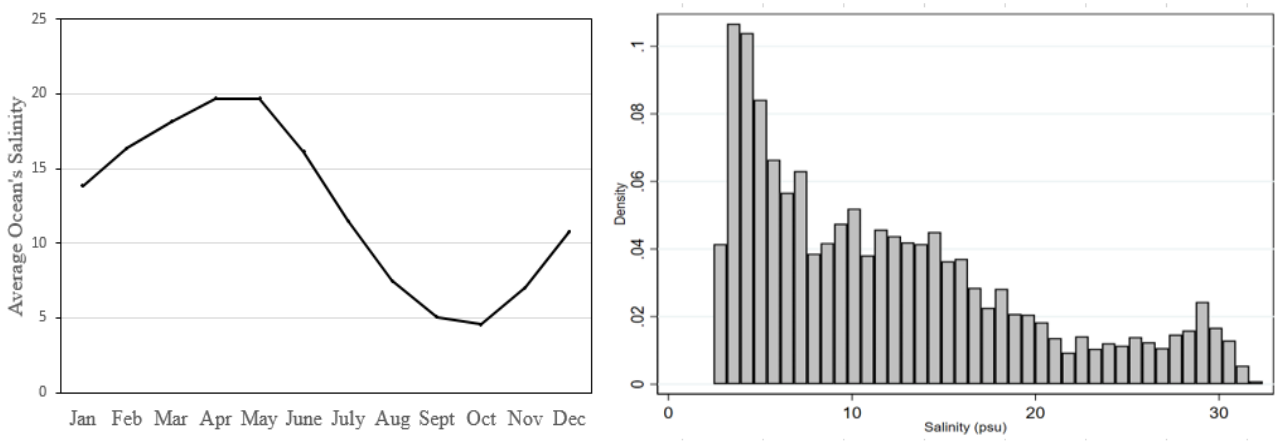
Panel B: Vulnerable Coastal Communities



Notes: Authors' calculations using the Copernicus Marine Environment Monitoring Service (CMEMS) for two periods. Panel A shows the kernel density for ocean's salinity for clusters within 100 km of the ocean (coastal communities). Panel B shows the kernel density for ocean's salinity for clusters within 40 km of the ocean (vulnerable coastal communities). To match the gridded salinity data to the cluster level, we use the IDW method as explained in the text.

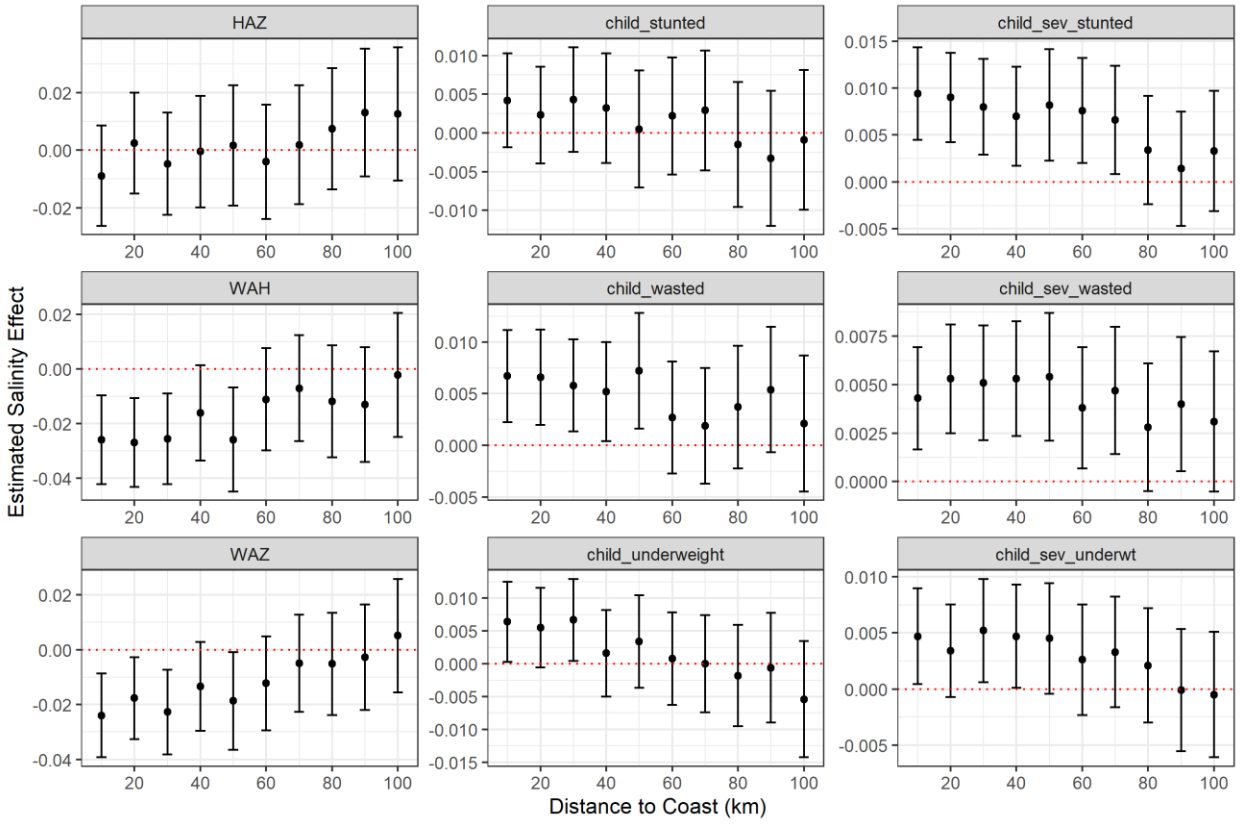
Figure 3: The Seasonality and Distribution of Salinity in Coastal Communities

Panel A: The Seasonality of Salinity **Panel B: The Distribution of Salinity**



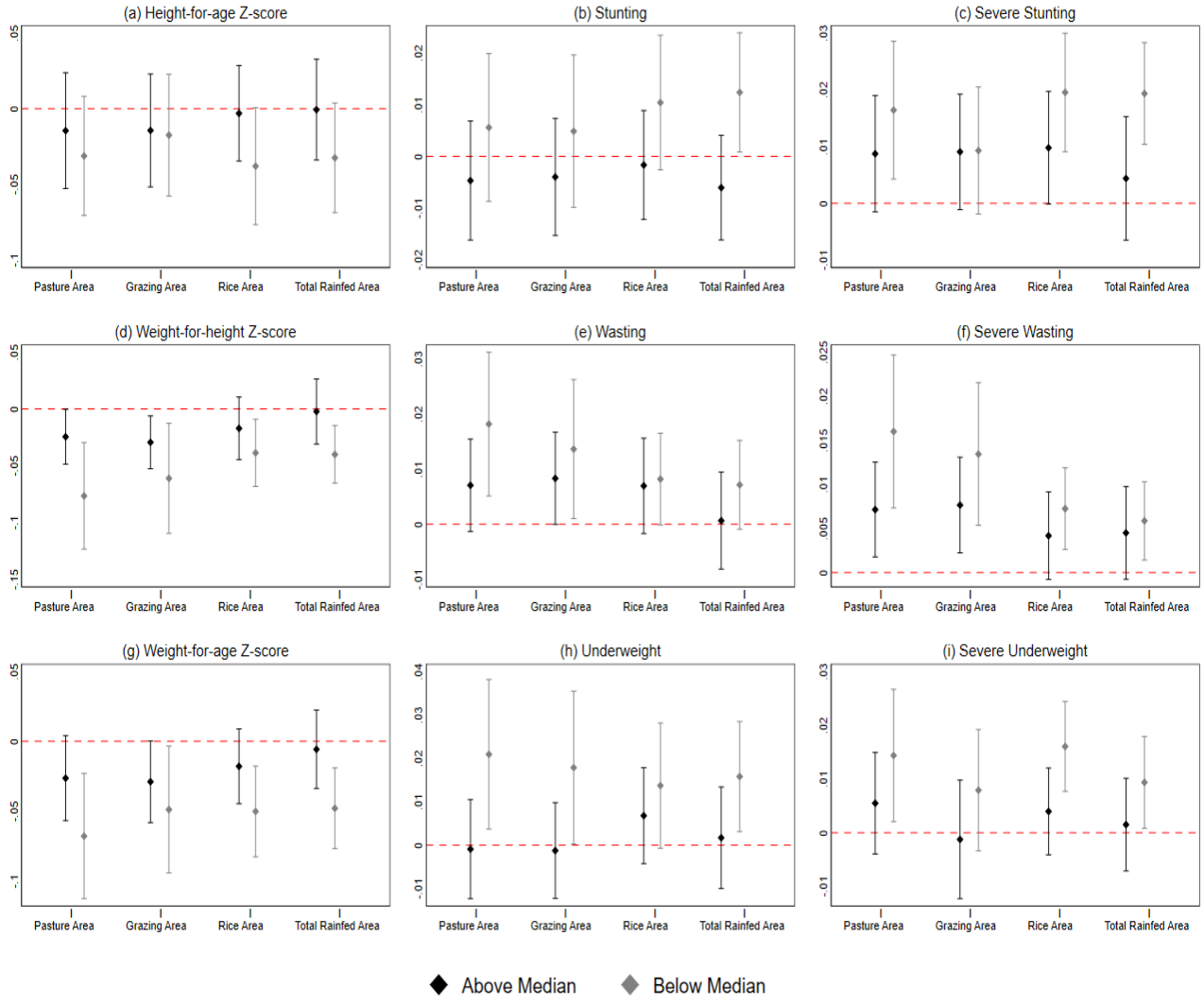
Notes: Authors' calculations using the Copernicus Marine Environment Monitoring Service (CMEMS). Panel A shows the seasonality of salinity (average salinity for each month over all the years) for all coastal communities in our data (ocean points matched to clusters in all coastal communities). Panel B shows the distribution of salinity in the data for all coastal communities. To match the gridded salinity data to the cluster level, we use the IDW method as explained in the text.

Figure 4: The Spatial Spillover of Salinity Exposure on Child Health Outcomes



Notes: The panel shows the spatial spillover of *in utero* salinity impact on health outcomes by distance to the coastline. Each sub-panel represents one regression model, which include the interaction between salinity and distance bands indicating the distance between the cluster and the coastline. All regressions include child, mother, household, and weather controls, and ocean's pH levels used in the main regression analysis. The same set of spatial and temporal fixed-effects are used. Please see Table 1 for details on dependent variables and controls. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. 90% confidence intervals are reported.

Figure 5: Heterogeneous Effects of Salinity Exposure on Child Health Outcomes, By Intensity of Agricultural Activities



Notes: The panel shows the heterogeneous effects of salinity while *in utero* on health outcomes by intensity of agricultural activities as proxied by indicator variables for below or above sample median values for pasture area, grazing area, rice, and rain-fed cultivated area. Estimates are from equation (1). Each coefficient is computed in separate regressions where the sample is restricted to the corresponding group. All regressions include child, mother, household, and weather controls, and ocean's pH levels used in the main regression analysis. The same set of spatial and temporal fixed-effects are used. Please see Table 2 for details on dependent variables and controls. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. Confidence intervals are reported at 90% level.

Table 1: Summary Statistics

	Mean	Std. Deviation
	(1)	(2)
Panel A: health outcomes		
Height-for-age z-score (HAZ)	-1.804	1.417
Stunting (HAZ < 2 SD)	0.451	0.498
Severe stunting (HAZ < 3 SD)	0.190	0.392
Weight-for-height z-score (WAH)	-0.910	1.130
Wasting (WAH < 2 SD)	0.146	0.353
Severe wasting (WAH < 3 SD)	0.032	0.177
Weight-for-age z-score (WAZ)	-1.671	1.153
Underweight (WAZ < 2 SD)	0.390	0.488
Severe underweight (WAZ < 3 SD)	0.119	0.323
Panel B: ocean chemistry variables		
Seawater salinity (psu)	12.591	4.396
Ocean's pH level	8.199	0.045
Panel C: weather-related variables		
Minimum temperature (deg. celcius)	18.691	1.660
Maximum temperature (deg. celcius)	33.872	0.797
Rainfall (mm, logs)	5.360	0.402
Humidity (%)	81.274	2.466
Panel D: Child, mother, household controls		
Child's age (months)	29.307	17.298
Child is male	0.503	0.500
Child birth order	2.691	1.794
Mother's age at first birth	17.950	2.957
Mother's height	150.895	5.328
Mother has no education	0.240	0.420
Father has no education	0.260	0.440
Head of household is male	0.871	0.335

Notes: The data sources include the BDHS 1999, 2004, 2007, 2011, 2014, and 2017, and the Copernicus Marine Environment Monitoring Service (CMEMS). The sample is restricted to coastal communities living within 40 km of the ocean.

Table 2: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Sample of DHS Coastal Clusters Within 40 km									
salinity exposure	-0.025*	0.007*	0.013***	-0.029**	0.007**	0.006***	-0.035***	0.011**	0.005
(in utero)	(0.013)	(0.004)	(0.004)	(0.011)	(0.003)	(0.002)	(0.012)	(0.005)	(0.004)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
Mean of dependent variable	-1.804	0.451	0.190	-0.910	0.146	0.033	-1.672	0.39	0.119
R-squared	0.323	0.278	0.227	0.169	0.151	0.162	0.268	0.218	0.182
Panel B: Sample of DHS Coastal Clusters Within 100 km									
salinity exposure	-0.007	0.004	0.009***	-0.026***	0.007**	0.005***	-0.023**	0.007*	0.005*
(in utero)	(0.011)	(0.004)	(0.003)	(0.009)	(0.003)	(0.002)	(0.010)	(0.004)	(0.003)
Observations	12,544	12,544	12,544	12,544	12,544	12,544	12,544	12,544	12,544
Mean of dependent variable	-1.727	0.422	0.167	-0.837	0.134	0.029	-1.574	0.353	0.102
R-squared	0.299	0.255	0.216	0.164	0.131	0.115	0.263	0.204	0.164
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. Panel A considers the sub-sample of DHS clusters that are within 40 km of the ocean while Panel B considers the sub-sample of DHS clusters that are within 100 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Table 3: The Heterogeneous Effects of Salinity on Child Health Outcomes, Based on Child and Maternal Characteristics

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A:	**Sub-Sample: Male Children Only**								
salinity exposure	-0.001	0.004	0.001	-0.040**	0.005	0.005**	-0.027*	0.006	0.006
(in utero)	(0.017)	(0.006)	(0.005)	(0.016)	(0.005)	(0.002)	(0.015)	(0.007)	(0.004)
Observations	3,933	3,933	3,933	3,933	3,933	3,933	3,933	3,933	3,933
	Sub-Sample: Female Children Only								
salinity exposure	-0.033*	0.008	0.022***	-0.024	0.012**	0.008**	-0.040***	0.014**	0.007
(in utero)	(0.018)	(0.006)	(0.005)	(0.016)	(0.005)	(0.003)	(0.015)	(0.007)	(0.005)
Observations	3,904	3,904	3,904	3,904	3,904	3,904	3,904	3,904	3,904
Panel B:	**Sub-Sample: First Born Children Only**								
salinity exposure	-0.026	0.008	0.002	-0.017	0.013*	0.008**	-0.031	0.005	0.002
(in utero)	(0.026)	(0.010)	(0.007)	(0.023)	(0.007)	(0.004)	(0.021)	(0.009)	(0.006)
Observations	2,411	2,411	2,411	2,411	2,411	2,411	2,411	2,411	2,411
	Sub-Sample: Non-First Born Children								
salinity exposure	-0.027*	0.006	0.015***	-0.035***	0.007*	0.007***	-0.041***	0.014**	0.010**
(in utero)	(0.015)	(0.005)	(0.005)	(0.013)	(0.004)	(0.003)	(0.013)	(0.006)	(0.004)
Observations	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429
Panel C:	**Sub-Sample: Mother's height (below median)**								
salinity exposure	-0.012	0.006	0.011**	-0.050***	0.006	0.006**	-0.041***	0.009	0.009**
(in utero)	(0.018)	(0.006)	(0.005)	(0.017)	(0.004)	(0.003)	(0.015)	(0.006)	(0.004)
Observations	3,899	3,899	3,899	3,899	3,899	3,899	3,899	3,899	3,899
	Sub-Sample: Mother's height (above median)								
salinity exposure	-0.028	0.007	0.013**	-0.015	0.009*	0.005*	-0.028	0.011	0.001
(in utero)	(0.019)	(0.006)	(0.006)	(0.016)	(0.005)	(0.003)	(0.017)	(0.008)	(0.006)
Observations	3,940	3,940	3,940	3,940	3,940	3,940	3,940	3,940	3,940

Panel D:				**Sub-Sample: Working Mothers**					
salinity exposure	-0.036	0.023**	0.012	-0.025	0.012	0.010*	-0.038	0.018	-0.001
(in utero)	(0.032)	(0.010)	(0.009)	(0.030)	(0.008)	(0.005)	(0.027)	(0.013)	(0.008)
Observations	1,485	1,485	1,485	1,485	1,485	1,485	1,485	1,485	1,485
				Sub-Sample: Non-Working Mothers					
salinity exposure	-0.028*	0.005	0.014***	-0.022*	0.006	0.005*	-0.033**	0.009	0.006
(in utero)	(0.016)	(0.005)	(0.004)	(0.013)	(0.004)	(0.003)	(0.014)	(0.006)	(0.004)
Observations	6,305	6,305	6,305	6,305	6,305	6,305	6,305	6,305	6,305

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth) for different sub-samples used in separate regressions. The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS, are weighted, and include the same set of fixed-effects included in equation (1). Robust standard errors are clustered at the DHS cluster level. We consider DHS clusters within 40 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Table 4: The Heterogeneous Effects of Salinity on Child Health Outcomes, Based on Locational Characteristics

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A	**Sub-Sample: Population Density (Below Median)**								
salinity exposure	-0.026	0.004	0.014**	-0.027*	0.002	0.006*	-0.036**	0.004	0.007
(in utero)	(0.018)	(0.006)	(0.006)	(0.015)	(0.004)	(0.003)	(0.015)	(0.006)	(0.006)
	Sub-Sample: Population Density (Above Median)								
salinity exposure	-0.022	0.009	0.006	-0.031	0.006	0.010**	-0.032	0.017	0.004
(in utero)	(0.026)	(0.010)	(0.007)	(0.028)	(0.008)	(0.005)	(0.027)	(0.011)	(0.006)
Panel B	**Sub-Sample: Built-Up Areas (Below Median)**								
salinity exposure	-0.036*	0.007	0.015**	-0.030*	0.010*	0.008**	-0.045**	0.008	0.008
(in utero)	(0.020)	(0.006)	(0.006)	(0.016)	(0.005)	(0.003)	(0.018)	(0.007)	(0.005)
	Sub-Sample: Built-Up Areas (Above Median)								
salinity exposure	0.027	-0.016*	-0.001	0.000	0.003	0.004	0.019	-0.015	0.002
(in utero)	(0.029)	(0.010)	(0.008)	(0.034)	(0.011)	(0.005)	(0.030)	(0.011)	(0.007)

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth) for different sub-samples used in separate regressions. The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS, are weighted, and include the same set of fixed-effects included in equation (1). Robust standard errors are clustered at the DHS cluster level. We consider DHS clusters within 40 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Table 5: The Impact of Salinity on Parental Investments, Health-Seeking Behavior and Prenatal Care

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel A: Sample of DHS Coastal Clusters Within 40 km						
	Early Investments in Child Health: Vaccination Received						
	Polio 1	Polio 2	BCG	DPT 1	DPT 2	Measles	Tetanus
salinity exposure	-0.006*	-0.011**	-0.004	-0.005	-0.011**	-0.011**	-0.012*
(in utero)	(0.003)	(0.005)	(0.003)	(0.004)	(0.005)	(0.005)	(0.007)
Observations	7,410	7,389	7,408	7,408	7,408	7,384	4,198
R-squared	0.316	0.377	0.269	0.315	0.371	0.505	0.263
	Panel B: Sample of DHS Coastal Clusters Within 40 km						
	Prenatal Care and At Birth Investments						
	No. of antenatal visits	Received iron tablet	Prenatal care: Doctor	Prenatal care: Nurse	Assistance at birth: Doctor	Assistance at birth: Nurse	Delivery: at home
salinity exposure	-0.139***	-0.017**	-0.017***	-0.006*	-0.008**	-0.013***	0.017***
(in utero)	(0.031)	(0.007)	(0.005)	(0.003)	(0.004)	(0.005)	(0.005)
Observations	5,857	3,672	5,856	5,856	6,845	6,845	7,920
R-squared	0.364	0.339	0.370	0.180	0.283	0.325	0.397
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. Panel A considers the sub-sample of DHS clusters that are within 40 km of the ocean, and the dependent variables are coded as 1 if the child has received the type of vaccination presented in each column. In Panel B, we consider the same sample of coastal communities, and the dependent variable is continuous in column (1) for the number of antenatal visits. The other outcome variables in columns (2) to (7) are binary variables that equal to one if the mother received iron tablet during pregnancy, prenatal care, assistance at birth, and if delivery happened at home, respectively . ***p<0.01, **p<0.05, *p<0.1

Table 6: The Effects of Salinity Exposure on Child Health Outcomes Conditioning on Land Use Variables

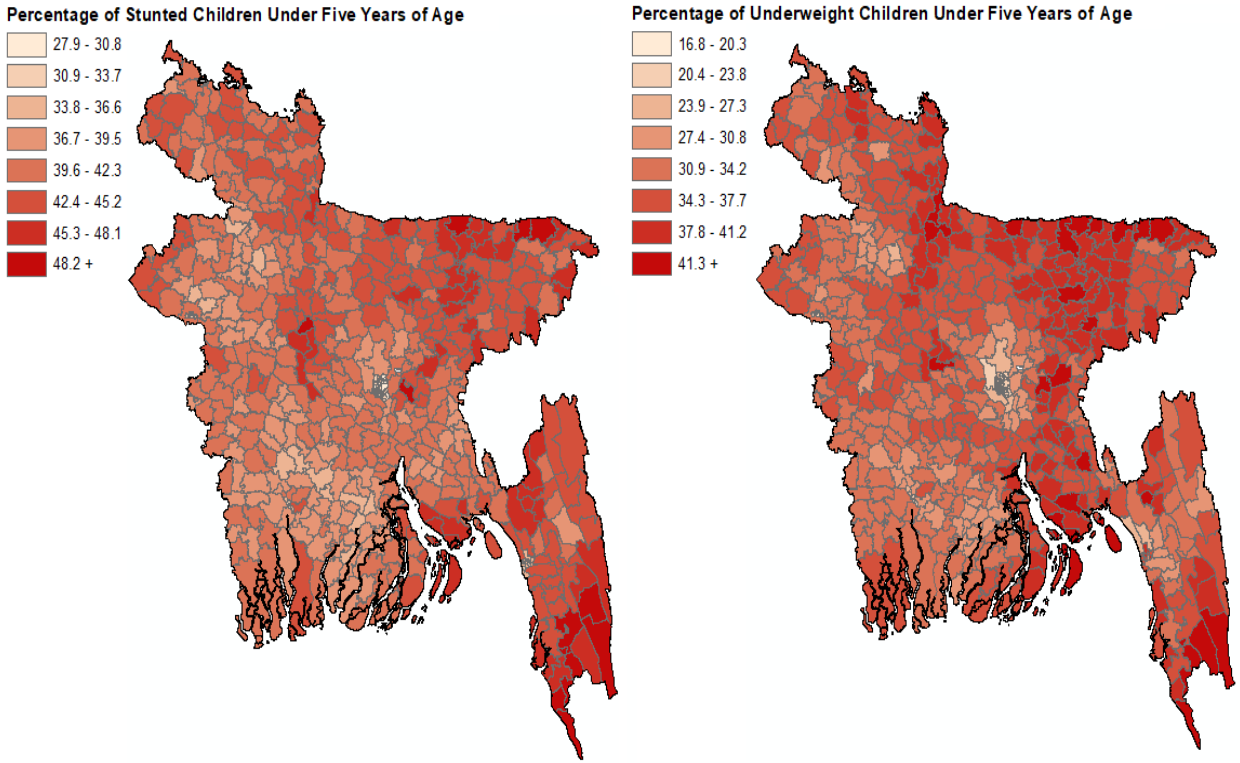
	Dependent Variables:								
	HAZ	Stunted	Severely Stunted	WAH	Wasted	Severely Wasted	WAZ	Underweight	Severely Underweight
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample of DHS Coastal Clusters Within 40 km								
salinity exposure	-0.004	0.001	0.008**	-0.026*	0.008**	0.005**	-0.021	0.006	0.000
(in utero)	(0.014)	(0.005)	(0.004)	(0.014)	(0.004)	(0.002)	(0.013)	(0.005)	(0.003)
rainfed cropland	1.187*	-0.189	-0.213	0.012	-0.093	-0.253***	0.781	-0.226	-0.170
	(0.608)	(0.215)	(0.153)	(0.517)	(0.163)	(0.082)	(0.520)	(0.210)	(0.154)
irrigated cropland	0.350	-0.050	-0.069	-0.234	0.105*	0.019	0.075	0.041	-0.044
	(0.217)	(0.078)	(0.065)	(0.184)	(0.053)	(0.029)	(0.177)	(0.071)	(0.052)
forest	2.394***	-0.521*	-0.688***	0.813	-0.160	-0.375***	2.038***	-0.812***	-0.380*
	(0.710)	(0.273)	(0.212)	(0.653)	(0.186)	(0.096)	(0.592)	(0.251)	(0.199)
saline flooded forest (mangroves)	0.062	0.060	-0.145	0.212	-0.006	-0.095	0.320	-0.133	-0.206*
	(0.655)	(0.240)	(0.158)	(0.529)	(0.160)	(0.066)	(0.495)	(0.199)	(0.123)
wetland	-21.338	4.942	-0.466	16.989	-5.426	0.610	-2.308	-2.362	-2.696
	(16.145)	(6.061)	(4.636)	(14.020)	(4.007)	(2.016)	(13.332)	(5.911)	(3.811)
shrubland	-1.095**	0.399**	0.334**	-0.323	0.094	0.274***	-1.010	0.346*	0.341***
	(0.538)	(0.201)	(0.147)	(0.664)	(0.131)	(0.090)	(0.652)	(0.206)	(0.128)
urban settlement	2.645	-1.168	0.735	1.574	-0.538	0.185	2.273	-1.664	-0.245
	(2.900)	(1.125)	(0.791)	(2.971)	(0.769)	(0.425)	(2.755)	(1.057)	(0.610)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.326	0.279	0.232	0.170	0.152	0.168	0.272	0.222	0.186

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. The land use variables here represent the share of land within a 30 km buffer from each cluster. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We consider the sub-sample of DHS clusters that are within 40 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Appendix

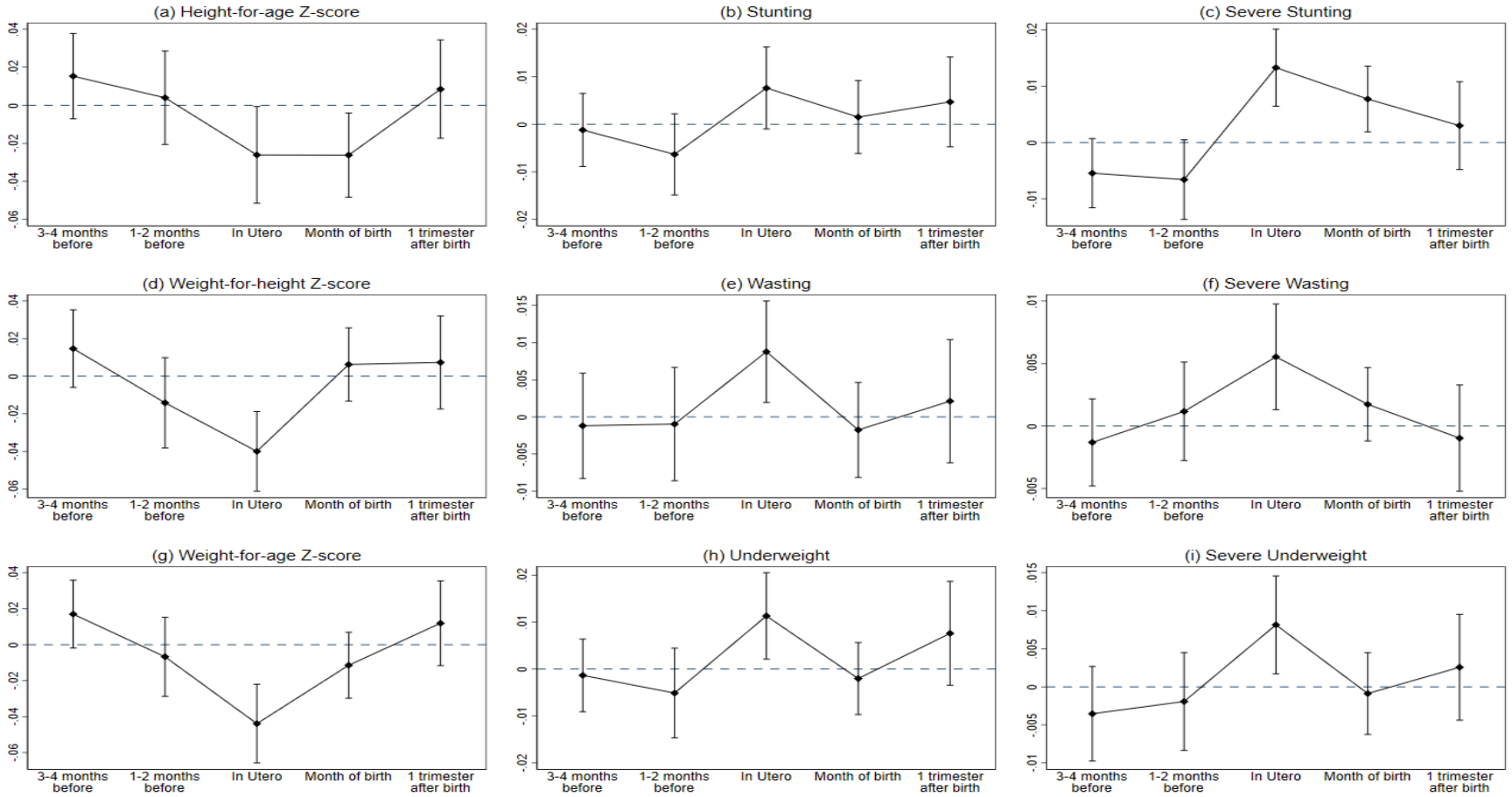
Figure A1: The Nutritional Status of Children in Bangladesh

Panel A **Panel B**



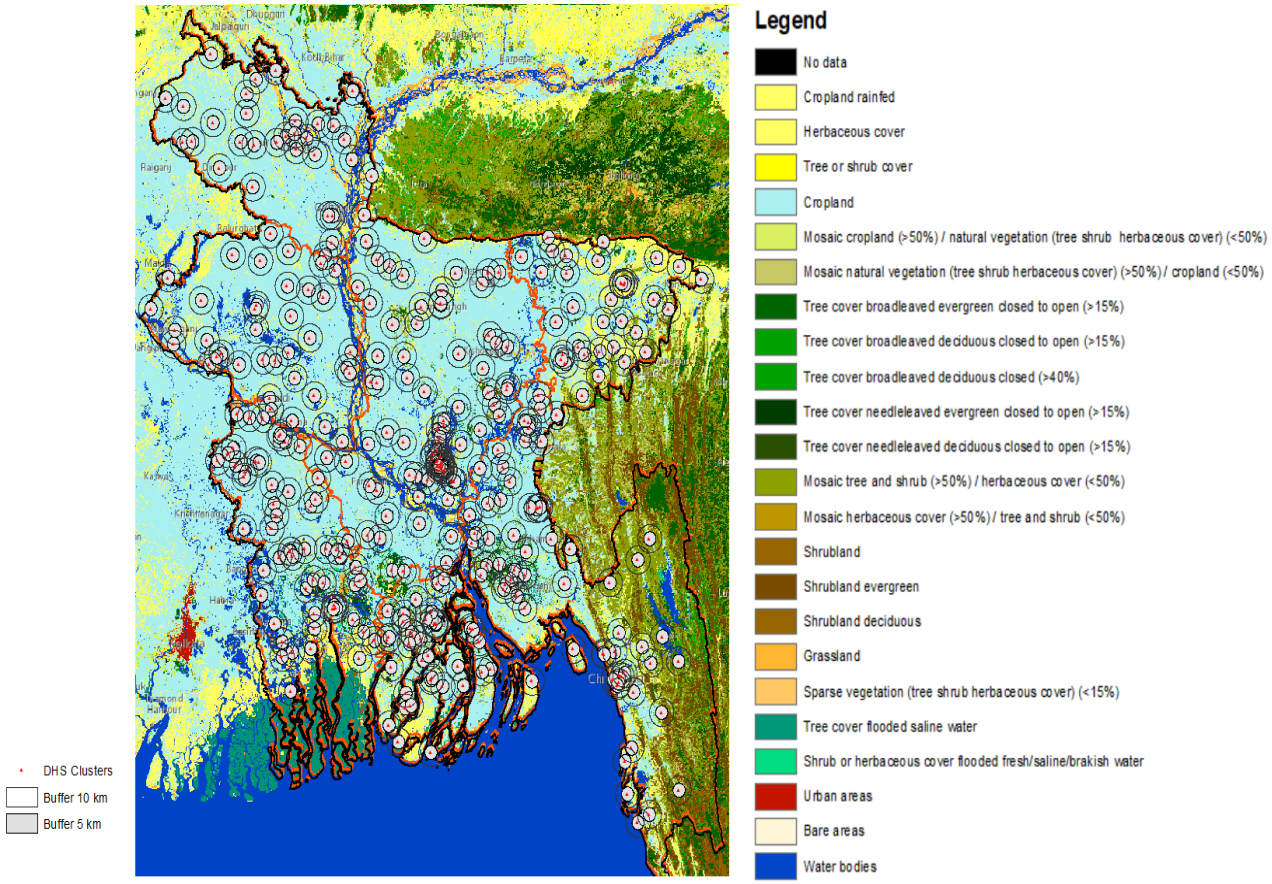
Notes: Panel A shows the percentage of stunted children under five years of age at the *upazila* (sub-district) level in 2012 in Bangladesh, while Panel B shows the percentage of underweight children under five years of age at the *upazila* (sub-district) level in 2012. The data is available from the Food and Agriculture Organization (FAO), and uses the 2012 Undernutrition Maps of Bangladesh.

Figure A2: The Effects of Salinity During Pregnancy on Child Health Outcomes, Controlling for Salinity Levels Before Conception and After Birth



Notes: The data shows the coefficients of salinity exposure (at different times in the baseline specification). We augment equation (1) with controls for the average salinity levels 1-2 months before conception, 3-4 months before conception, in the month of birth, and one trimester after birth. The sample is restricted to DHS clusters that are within 40 km from the ocean. We use the same set of controls, spatial and temporal fixed-effects as reported in Table 2. Confidence intervals are reported at 90% level. The timing of exposure is shown on the horizontal axis, and corresponding point estimates are shown on the vertical axis.

Figure A3: Land-Cover Classification



Notes: This shows the land cover map for 1993, and the location of the DHS clusters as of 1999. We also show buffers of 5 km and 10 km drawn around each cluster to obtain an estimate of land cover use. Data citation: Defourny, P., Lamarche, C., Bontemps, S., De Maet, T., Van Bogaert, E., Moreau, I., Brockmann, C., Boettcher, M., Kirches, G., Wevers, J., Santoro, M., Ramoino, F., & Arino, O. (2017). Land Cover Climate Change Initiative - Product User Guide v2. Issue 2.

Table A1: Double-Lasso Selection of Oceanic and Weather Controls

Variable	Frequency Selected (out of 27 models)	Probability Selected	Correlation with Salinity
	Oceanic Physics and Chemistry		
	(1)	(2)	(3)
Sea Surface Height	27	100%	-0.92
Sea Surface Temperature	27	100%	0.79
North Wind Velocity	18	67%	-0.05
pH	12	44%	-0.29
East Wind Velocity	2	7%	0.24
	Weather		
Cumulative Rainfall	11	41%	0.23
Average Humidity	6	22%	-0.15
Maximum Temperature	4	15%	-0.04
Minimum Temperature * Cumulative Rainfall	3	11%	0.39
Maximum Temperature * Cumulative Rainfall	2	7%	0.21
Minimum Temperature	2	7%	0.33

Note: Double-Lasso selection on oceanic and weather variables on the 40km-from-ocean sample. 27 double-Lasso models are estimated on 9 outcome variables (HAZ, stunted, severely stunted, WAH, wasted, severely wasted, WAZ, underweight, and severely underweight) using three different criteria of selection (cross-validated, adaptive, and plugin adaptive). Ocean salinity and household characteristics are always included in the double-lasso model. All variables are demeaned by the same set of saturated fixed-effects through extracting the residual from the regression y = 1 + fixed-effects. Column 2 reports the number of times a variable is included in the double-Lasso selection; Column 3 reports the probability that a variable is selected out of 27 candidate models. Column 4 reports the empirical correlation between the variable and ocean salinity after demeaning.

Table A2: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes Using Alternative Measures of Exposure and Additional Controls

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A:	**Sample of DHS Coastal Clusters Within 40 km**								
accumulated salinity levels (logs)	-0.332*	0.089	0.174***	-0.347**	0.097**	0.093***	-0.448***	0.144**	0.082*
(past 9 months)	(0.174)	(0.056)	(0.051)	(0.148)	(0.044)	(0.029)	(0.152)	(0.064)	(0.046)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.228	0.169	0.151	0.163	0.268	0.219	0.182
Panel B:	**Sample of DHS Coastal Clusters Within 40 km**								
salinity exposure	-0.026*	0.007*	0.013***	-0.027**	0.007*	0.006**	-0.035***	0.011**	0.005
(in utero)	(0.013)	(0.004)	(0.004)	(0.011)	(0.004)	(0.002)	(0.012)	(0.005)	(0.004)
number of months with above	0.015	-0.004	0.002	-0.029	0.017**	0.008	-0.012	0.006	0.013
cluster mean	(0.036)	(0.012)	(0.010)	(0.034)	(0.008)	(0.005)	(0.031)	(0.012)	(0.008)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.227	0.169	0.151	0.163	0.268	0.219	0.182
Panel C:	**Sample of DHS Coastal Clusters Within 40 km**								
standard deviation of salinity	-0.035*	0.007	0.018***	-0.030*	0.005	0.010***	-0.043**	0.014*	0.012**
(for the 9 months before birth)	(0.021)	(0.007)	(0.006)	(0.018)	(0.006)	(0.004)	(0.018)	(0.007)	(0.005)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.277	0.227	0.168	0.150	0.162	0.267	0.218	0.182
Panel D:	**Sample of DHS Coastal Clusters Within 40 km (excluding southwestern districts)**								
salinity exposure	-0.028*	0.007	0.013***	-0.026**	0.006*	0.007***	-0.035***	0.012**	0.007*
(in utero)	(0.014)	(0.005)	(0.004)	(0.012)	(0.004)	(0.002)	(0.013)	(0.005)	(0.004)
Observations	7,152	7,152	7,152	7,152	7,152	7,152	7,152	7,152	7,152
R-squared	0.328	0.279	0.235	0.171	0.155	0.173	0.274	0.219	0.192
Panel E:	**Sample of DHS Coastal Clusters Within 40 km**								
salinity exposure	-0.025*	0.006	0.012***	-0.030***	0.008**	0.006***	-0.036***	0.012**	0.006
(in utero - assume 10 months)	(0.014)	(0.004)	(0.004)	(0.012)	(0.004)	(0.002)	(0.012)	(0.005)	(0.004)

Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.227	0.169	0.151	0.162	0.268	0.218	0.182

Notes: All regressions include child, mother, household controls, weather controls, and pH used in the main regression analysis. The same set of spatial and temporal fixed-effects are used. Please see Table 2 for details on dependent variables and controls. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. ***p<0.01, **p<0.05, *p<0.1.

Table A3: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes Controlling for Ocean Chemistry Variables

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample of DHS Coastal Clusters Within 40 km								
	Controlling for Other Ocean Chemistry Variables								
salinity exposure	-0.023*	0.007	0.014***	-0.028**	0.008**	0.007***	-0.034***	0.011**	0.006
(in utero)	(0.014)	(0.005)	(0.004)	(0.012)	(0.004)	(0.002)	(0.012)	(0.005)	(0.004)
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We consider the sub-sample of DHS clusters that are within 40 km of the ocean. The additional ocean chemistry variables are: sea temperature, sea surface height, and eastward seawater velocity. ***p<0.01, **p<0.05, *p<0.1

Table A4: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes Using Nonlinear Specifications

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Sample of DHS Coastal Clusters Within 40 km (Using below/above median sample value of salinity)									
salinity exposure	-0.145**	0.030	0.036**	-0.149***	0.036**	0.039***	-0.206***	0.069***	0.043***
(in utero) above median	(0.062)	(0.022)	(0.018)	(0.057)	(0.018)	(0.012)	(0.054)	(0.022)	(0.016)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.226	0.169	0.151	0.164	0.268	0.219	0.183
Panel B: Sample of DHS Coastal Clusters Within 40 km (Using quartiles of salinity)									
salinity exposure	-0.030	0.012	0.046**	-0.013	0.014	0.024**	-0.016	0.002	0.011
(in utero) second quartile	(0.064)	(0.023)	(0.020)	(0.064)	(0.020)	(0.010)	(0.059)	(0.025)	(0.018)
salinity exposure	-0.171*	0.038	0.072***	-0.156**	0.046*	0.059***	-0.217***	0.069**	0.052**
(in utero) third quartile	(0.087)	(0.029)	(0.027)	(0.076)	(0.025)	(0.016)	(0.076)	(0.031)	(0.023)
salinity exposure	-0.159	0.059	0.117***	-0.214**	0.066**	0.058***	-0.246**	0.092**	0.049
(in utero) fourth quartile	(0.111)	(0.038)	(0.033)	(0.100)	(0.032)	(0.020)	(0.100)	(0.042)	(0.033)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.227	0.169	0.151	0.165	0.268	0.219	0.183
Panel C: Sample of DHS Coastal Clusters Within 40 km (Using quartiles of salinity and excluding southwestern districts)									

salinity exposure	0.008	-0.012	0.019	-0.073	0.018	0.027**	-0.034	0.015	0.003
(in utero) second quartile	(0.071)	(0.025)	(0.022)	(0.067)	(0.020)	(0.011)	(0.064)	(0.026)	(0.019)
salinity exposure	-0.101	0.006	0.056**	-0.154**	0.037	0.050***	-0.172**	0.060**	0.038*
(in utero) third quartile	(0.079)	(0.027)	(0.026)	(0.074)	(0.023)	(0.013)	(0.071)	(0.030)	(0.021)
salinity exposure	-0.214**	0.048	0.077**	-0.240**	0.051*	0.056***	-0.305***	0.111***	0.066**
(in utero) fourth quartile	(0.106)	(0.034)	(0.033)	(0.094)	(0.030)	(0.019)	(0.097)	(0.039)	(0.029)
Observations	7,152	7,152	7,152	7,152	7,152	7,152	7,152	7,152	7,152
R-squared	0.328	0.279	0.234	0.171	0.155	0.174	0.275	0.220	0.193

Notes: All regressions include child, mother, household controls, weather controls, and pH used in the main regression analysis. The same set of spatial and temporal fixed-effects are used too. Please see Table 1 for details on dependent variables and controls. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. ***p<0.01, **p<0.05, *p<0.1

Table A5: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes By Trimester

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample of DHS Coastal Clusters Within 40 km								
salinity exposure *(in utero)* 1st trimester	0.009	-0.004	-0.001	-0.022**	0.005*	0.003	-0.008	0.003	0.001
	(0.010)	(0.004)	(0.003)	(0.010)	(0.003)	(0.002)	(0.009)	(0.004)	(0.003)
salinity exposure *(in utero)* 2nd trimester	-0.026**	0.008**	0.010***	-0.004	-0.001	-0.001	-0.020**	0.006	0.004
	(0.011)	(0.004)	(0.003)	(0.009)	(0.003)	(0.001)	(0.009)	(0.004)	(0.003)
salinity exposure *(in utero)* 3rd trimester	-0.006	0.002	0.002	-0.003	0.004	0.004***	-0.006	0.002	0.000
	(0.010)	(0.003)	(0.003)	(0.009)	(0.003)	(0.001)	(0.008)	(0.004)	(0.003)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.323	0.278	0.228	0.169	0.151	0.163	0.268	0.219	0.182

Notes: All regressions include child, mother, household controls, weather controls, and pH used in the main regression analysis. The same set of spatial and temporal fixed-effects are used. Please see Table 1 for details on dependent variables and controls. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. ***p<0.01, **p<0.05, *p<0.1.

Table A6: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes Controlling for Prenatal Care and At Birth Investments

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
salinity exposure	-0.017	0.001	0.007	-0.026	0.007	0.004	-0.029*	0.003	0.005
(in utero)	(0.016)	(0.006)	(0.005)	(0.017)	(0.005)	(0.003)	(0.015)	(0.007)	(0.005)
no. of antenatal visits	0.055***	-0.013***	-0.006	0.034**	-0.004	-0.001	0.057***	-0.013***	-0.005*
	(0.015)	(0.005)	(0.004)	(0.014)	(0.004)	(0.002)	(0.013)	(0.005)	(0.003)
received iron tablet	-0.115*	0.016	0.013	-0.088	0.023	0.014*	-0.118**	0.040*	0.023
	(0.065)	(0.021)	(0.018)	(0.055)	(0.015)	(0.008)	(0.052)	(0.022)	(0.016)
prenatal care: doctor	0.230***	-0.075***	-0.058***	0.062	-0.029*	-0.021**	0.165***	-0.064***	-0.053***
	(0.073)	(0.024)	(0.020)	(0.058)	(0.017)	(0.009)	(0.063)	(0.024)	(0.017)
prenatal care: nurse	0.051	-0.029	-0.007	0.023	-0.012	0.001	0.048	-0.080***	-0.018
	(0.092)	(0.033)	(0.022)	(0.077)	(0.021)	(0.013)	(0.075)	(0.030)	(0.019)
assistance: doctor	0.118	-0.048	0.028	-0.003	0.001	0.001	0.089	0.017	-0.018
	(0.101)	(0.039)	(0.028)	(0.097)	(0.025)	(0.014)	(0.091)	(0.037)	(0.024)
assistance: nurse	0.121	-0.036	-0.037	0.120	0.000	0.008	0.122	-0.029	0.018
	(0.090)	(0.034)	(0.023)	(0.080)	(0.022)	(0.010)	(0.075)	(0.031)	(0.022)
delivery: at home	0.029	-0.006	0.010	-0.083	0.033*	0.004	-0.043	0.062**	0.028
	(0.073)	(0.027)	(0.020)	(0.062)	(0.020)	(0.009)	(0.061)	(0.027)	(0.019)
Observations	3,669	3,669	3,669	3,669	3,669	3,669	3,669	3,669	3,669
R-squared	0.410	0.348	0.295	0.235	0.219	0.175	0.353	0.293	0.239
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

District x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. ***p<0.01, **p<0.05, *p<0.1

Table A7: The Impact of Salinity on Parental Health Investments, Health-Seeking Behavior, and Prenatal Care, By Gender and Birth Order

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel A: Sample of DHS Coastal Clusters Within 40 km						
	Early Investments in Child Health: Vaccination Received						
	Polio 1	Polio 2	BCG	DPT 1	DPT 2	Measles	Tetanus
	Male Children Only						
salinity exposure	-0.007*	-0.012**	-0.004	-0.004	-0.011**	-0.015**	-0.008
(in utero)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.006)	(0.010)
	Female Children Only						
salinity exposure	-0.006	-0.010*	-0.006	-0.006	-0.011*	-0.006	-0.020**
(in utero)	(0.004)	(0.006)	(0.004)	(0.004)	(0.006)	(0.007)	(0.008)
	First Born Children Only						
salinity exposure	-0.008*	-0.015**	-0.009**	-0.009*	-0.016**	-0.010	-0.004
(in utero)	(0.004)	(0.007)	(0.004)	(0.005)	(0.007)	(0.007)	(0.012)
	Non-First Born Children Only						
salinity exposure	-0.006	-0.009*	-0.003	-0.004	-0.010*	-0.014**	-0.014*
(in utero)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.006)	(0.007)
	Panel B: Sample of DHS Coastal Clusters Within 40 km						
	Prenatal Care and At Birth Investments						
	No. of antenatal visits	Received iron tablet	Prenatal care: Doctor	Nurse	Assistance at birth: Doctor	Nurse	Delivery: at home
	Male Children Only						
salinity exposure	-0.140***	-0.012	-0.019**	-0.002	-0.009*	-0.017**	0.020***
(in utero)	(0.043)	(0.011)	(0.007)	(0.005)	(0.005)	(0.006)	(0.006)
	Female Children Only						
salinity exposure	-0.150***	-0.025**	-0.017***	-0.009**	-0.006	-0.009	0.013**
(in utero)	(0.039)	(0.011)	(0.007)	(0.005)	(0.005)	(0.006)	(0.006)
	First Born Children Only						
salinity exposure	-0.183***	-0.001	-0.011	-0.005	0.001	-0.012	0.023**
(in utero)	(0.057)	(0.016)	(0.010)	(0.007)	(0.008)	(0.011)	(0.010)
	Non-First Born Children Only						
salinity exposure	-0.146***	-0.022***	-0.021***	-0.006*	-0.010**	-0.014***	0.018***
(in utero)	(0.035)	(0.008)	(0.006)	(0.004)	(0.004)	(0.005)	(0.005)

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth) for different sub-samples used in separate regressions. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth,

a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS, are weighted, and include the same set of fixed-effects included in equation (1). Robust standard errors are clustered at the DHS cluster level. Panel A considers the sub-sample of DHS clusters that are within 40 km of the ocean, and the dependent variables are coded as 1 if the child has received the type of vaccination presented in each column. In Panel B, we consider the same sample of coastal communities, and the dependent variable is continuous in column (1) for the number of antenatal visits. The other outcome variables in columns (2) to (7) are binary variables that equal to one if the mother received iron tablet during pregnancy, prenatal care, assistance at birth, and if delivery happened at home, respectively. ***p<0.01, **p<0.05, *p<0.1

Table A8: The Effects of Salinity Exposure on Land Use Decisions

	Dependent Variables: Share of land within a given buffer for:						
	rainfed cropland	irrigated cropland	forest	saline flooded forest	wetland	shrubland	urban settlement
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
annual salinity exposure	0.0071***	-0.0225***	-0.0005	0.0039***	-0.0001***	0.0091***	-0.0013***
	(0.0012)	(0.0030)	(0.0010)	(0.0007)	(0.0000)	(0.0018)	(0.0002)
annual pH exposure	0.4414***	-0.4841	0.2131	0.4562***	0.0188***	1.1418***	-0.2159***
	(0.1191)	(0.3024)	(0.1332)	(0.1147)	(0.0045)	(0.2261)	(0.0272)
annual rainfall	0.0003***	-0.0010***	-0.0000	0.0002***	0.0000	-0.0001	-0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
annual humidity	-0.0014	0.0154***	-0.0143***	-0.0040***	-0.0005***	-0.0051***	-0.0023***
	(0.0029)	(0.0058)	(0.0025)	(0.0012)	(0.0001)	(0.0014)	(0.0003)
annual max temperature	-0.0182**	0.2034***	0.0481***	-0.0061	0.0018***	0.0196***	-0.0001
	(0.0071)	(0.0190)	(0.0068)	(0.0043)	(0.0003)	(0.0065)	(0.0009)
annual min temperature	-0.0363***	0.2370***	0.0536***	-0.0017	0.0013***	0.0267***	-0.0004
	(0.0089)	(0.0211)	(0.0092)	(0.0055)	(0.0004)	(0.0078)	(0.0012)
annual dry temperature	-0.0109	-0.3456***	-0.1078***	0.0177***	-0.0021***	-0.1200***	0.0029
	(0.0200)	(0.0294)	(0.0206)	(0.0068)	(0.0007)	(0.0168)	(0.0032)
Observations	16,536	16,536	16,536	16,536	16,536	16,536	16,536
R-squared	0.6974	0.7911	0.6459	0.6106	0.6723	0.7830	0.8478

Notes: This table shows the impact of annual oceanic and local weather variables on land use choices. Each observation represents a 30-km buffer zone centered around a cluster that is within 40 km from the ocean. Dependent variables are percentages of land within the 30-km buffer that are devoted to those land use categories. All independent variables are aggregated by calendar year to match with the temporal interval of the dependent variables. All regressions include the same set of fixed-effects as in equation (1). Robust standard errors presented in parenthesis, clustered at the cluster by year level. ***p<0.01, **p<0.05, *p<0.1

Table A9: The Effects of Salinity Exposure on Wealth

	Dependent Variable: Top Two Wealth Quintiles (1)
	Sample of DHS Coastal Clusters Within 40 km
salinity exposure	-0.053***
(in utero)	(0.007)
Observations	7,978
R-squared	0.284
Weather controls	✓
Ocean chemistry control (pH)	✓
District, year of birth, month of birth FE	✓
Year of birth x month of birth FE	✓
District x month of birth FE	✓
District x year of birth FE	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variable in column (1) is a binary variables that equal to one if the household is in the top two wealth quintiles. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We consider the sub-sample of DHS clusters that are within 40 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Table A10: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes Conditional on Wealth Quintiles

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample of DHS Coastal Clusters Within 40 km								
salinity exposure	-0.007	0.001	0.009**	-0.023*	0.006*	0.006**	-0.021*	0.006	0.003
(in utero)	(0.013)	(0.004)	(0.004)	(0.012)	(0.004)	(0.002)	(0.012)	(0.005)	(0.004)
top two highest wealth quintiles	0.438***	-0.145***	-0.098***	0.135***	-0.038***	-0.010*	0.348***	-0.121***	-0.056***
	(0.042)	(0.015)	(0.011)	(0.042)	(0.011)	(0.006)	(0.041)	(0.017)	(0.010)
Observations	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920	7,920
R-squared	0.337	0.290	0.237	0.171	0.153	0.163	0.281	0.228	0.186
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. ***p<0.01, **p<0.05, *p<0.1

Table A11: The Impact of Salinity on Parental Health Investments, Health-Seeking Behavior, and Prenatal Care, By Wealth Quintile

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel A: Sample of DHS Coastal Clusters Within 40 km						
	Early Investments in Child Health: Vaccination Received						
	Polio 1	Polio 2	BCG	DPT 1	DPT 2	Measles	Tetanus
	Sample: in lower wealth quintiles						
salinity exposure	-0.009**	-0.013**	-0.004	-0.006	-0.013*	-0.018***	-0.016**
(in utero)	(0.004)	(0.006)	(0.004)	(0.005)	(0.006)	(0.006)	(0.008)
	Sample: top two wealth quintiles						
salinity exposure	0.002	-0.000	-0.001	-0.000	-0.002	0.007	0.005
(in utero)	(0.004)	(0.006)	(0.005)	(0.004)	(0.006)	(0.006)	(0.011)
	Panel B: Sample of DHS Coastal Clusters Within 40 km						
	Prenatal Care and At Birth Investments						
	No. of antenatal visits	Received iron tablet	Prenatal care: Doctor	Prenatal care: Nurse	Assistance at birth: Doctor	Assistance at birth: Nurse	Delivery: at home
	Sample: in lower wealth quintiles						
salinity exposure	-0.086***	-0.017*	-0.012*	-0.009**	-0.002	-0.004	0.011**
(in utero)	(0.029)	(0.010)	(0.007)	(0.003)	(0.003)	(0.004)	(0.005)
	Sample: top two wealth quintiles						
salinity exposure	-0.170**	-0.002	-0.007	-0.013	0.004	-0.005	0.008
(in utero)	(0.075)	(0.015)	(0.011)	(0.008)	(0.011)	(0.011)	(0.009)

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth) for different sub-samples used in separate regressions. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS, are weighted, and include the same set of fixed-effects included in equation (1). Robust standard errors are clustered at the DHS cluster level. Panel A considers the sub-sample of DHS clusters that are within 40 km of the ocean, and the dependent variables are coded as 1 if the child has received the type of vaccination presented in each column. In Panel B, we consider the same sample of coastal communities, and the dependent variable is continuous in column (1) for the number of antenatal visits. The other outcome variables in columns (2) to (7) are binary variables that equal to one if the mother received iron tablet during pregnancy, prenatal care, assistance at birth, and if delivery happened at home, respectively. ***p<0.01, **p<0.05, *p<0.1

Table A12: The Effects of Salinity Exposure on Child's Gender

	Dependent Variable: Probability that the Child is Male				
	(1)	(2)	(3)	(4)	(5)
	Sample of DHS Coastal Clusters Within 40 km				
salinity exposure	-0.001	-0.003			
(in utero)	(0.004)	(0.006)			
salinity exposure		0.002		0.002	
(in month of conception)		(0.004)		(0.004)	
salinity exposure			-0.001	-0.003	
(2-9 months during gestation)			(0.004)	(0.005)	
salinity exposure					0.018
(in utero) second quartile					(0.028)
salinity exposure					0.001
(in utero) third quartile					(0.031)
salinity exposure					-0.024
(in utero) fourth quartile					(0.040)
Observations	7,920	7,920	7,920	7,920	7,920
R-squared	0.131	0.131	0.131	0.131	0.131
Child, mother, household controls	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓

Notes: This table shows the impact of salinity on the probability that the child is male. The dependent variable is a dummy variable that equals to one if the child is male. The child, mother, household controls include the child's age (in months), child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We use the sub-sample of DHS clusters that are within 40 km of the ocean.***p<0.01, **p<0.05, *p<0.1

Table A13: The Effects of Salinity Exposure on Mother's Characteristics

	Dependent Variables:						
	mother's education					mother 's	age
	<= 6 years	<= 12 years	mother's height	mother employed	mother's current age	age at delivery	difference with head
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Sample of DHS Coastal Clusters Within 40 km						
salinity exposure	0.001	0.001	0.103*	-0.002	0.080	0.057	0.028
(in utero)	(0.006)	(0.002)	(0.061)	(0.005)	(0.053)	(0.049)	(0.159)
Observations	7,978	7,978	7,933	7,978	7,978	7,978	7,978
R-squared	0.144	0.100	0.126	0.211	0.148	0.130	0.141
Child, mother, household controls	×	×	×	×	×	×	×
Weather controls	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓
District, year of birth, month of birth FE	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth) on mother's characteristics. The dependent variables in columns (1) and (2) are binary variables that equal to one if the mother has 6 and 12 years or less of education, respectively. The dependent variables in columns (3), (5), (6), and (7) are continuous. The dependent variable in column (4) is a binary variable that equals to one if the mother is currently working. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We the sub-sample of DHS clusters that are within 40 km of the ocean. ***p<0.01, **p<0.05, *p<0.1

Table A14: The Effects of Salinity Exposure During Pregnancy on Child Health Outcomes, Not Recently Migrated Sample

	Dependent Variables:								
	HAZ	Stunted (HAZ < 2 SD)	Severely Stunted (HAZ < 3 SD)	WAH	Wasted (WAH < 2 SD)	Severely Wasted (WAH < 3 SD)	WAZ	Underweight (WAZ < 2 SD)	Severely Underweight (WAZ < 3 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample of DHS Coastal Clusters Within 40 km (Restricted to Households Resident In the District for More than 9 years)								
salinity exposure *(in utero)*	-0.035**	0.012**	0.016***	-0.034***	0.007*	0.006**	-0.044***	0.013**	0.009**
	(0.016)	(0.005)	(0.005)	(0.013)	(0.004)	(0.002)	(0.013)	(0.006)	(0.004)
Observations	5,318	5,318	5,318	5,318	5,318	5,318	5,318	5,318	5,318
R-squared	0.355	0.310	0.272	0.218	0.200	0.227	0.300	0.259	0.221
Child, mother, household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weather controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ocean chemistry control (pH)	✓	✓	✓	✓	✓	✓	✓	✓	✓
District, yr of birth, mthb of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year of birth x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x month of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
District x year of birth FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the coefficients of salinity exposure (measured as the average level 9 months prior to birth). The dependent variables in columns (1), (4), and (7) for height-for-age z-score, weight-for-height z-score, and for the weight-for-age z-score, respectively, are continuous. Dependent variables in columns (2), (5), and (8) are binary variables that equal to one if the child is stunted, wasted, and underweight, respectively, while in columns (3), (6), and (9), the binary variables equal to one if the child is severely stunted, severely wasted, and severely underweight, respectively. The child, mother, household controls include the child's age (in months) and gender, child birth order, mother's age at first birth, a dummy variable that equals to one if the mother has no education, a dummy variable that equals to one if the father has no education, mother's height, and the gender of the household head. Weather controls include minimum and maximum temperature, rainfall (in logs), the interaction between minimum and maximum temperature and log of rainfall, and humidity. We also control for the ocean's pH levels. All regressions are OLS and are weighted. Robust standard errors are clustered at the DHS cluster level. We consider the sub-sample of DHS clusters that are within 40 km of the ocean, with children whose parents have resided in the current place of residence for greater than 9 years (median number of years). ***p<0.01, **p<0.05, *p<0.1