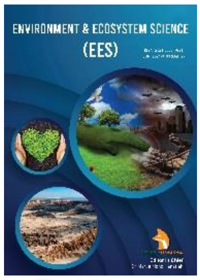
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0882 (Print)
ISSN: 2521-0483 (Online)
CODEN: EESND2

Environment & Ecosystem Science (EES)

DOI: http://doi.org/10.26480/ees.02.2021.143.151



CrossMark

RESEARCH ARTICLE

ENVIRONMENTAL IMPACTS OF SHRIMP FARMING IN CHAKARIA UPAZILA OF COX'S BAZAR IN BANGLADESH

Md. Humayain Kabir*, Delwar Hossain

Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh
****Corresponding Author Email: mhkabir@cu.ac.bd***

ARTICLE DETAILS

Article History:

Received 08 August 2021
Accepted 12 September 2021
Available online 21 October 2021

ABSTRACT

Aquaculture has become one of the fastest-growing economic sub-sectors of the Bangladesh economy, providing protein-rich food, the source of employment and foreign currency earnings. Therefore, shrimp farming is very much common in the brackish water which affects the coastal natural ecosystem and livelihood of the coastal communities, prticularly in Chakaria Upazila of Cox's Bazar district. Due to rapid and unplanned growth of this farming, socio-ecological systesms has been changing. This study aims to assess shrimp farming's environmental, social, and economic impacts in Chakaria upazila in Bangladesh. Soil sample was collected to determine the environmental impacts of shrimp farming. Besides, we selected the shrimp farmers, rice producers, and alternative shrimp-rice producers through simple random sampling. Purposive sampling was conducted to choose the other stakeholders. A semi-structured questionnaire was developed for interviewing different stakeholders. We found that, because of the high economic benefit, high production rate in short time, and availability of brackish water, the people in this Upazila are attracted to continue the shrimp farming. As a result, mangrove forest and agricultural land converted into shrimp farming. Our soil analysis showed that organic matter content in was low (0.25-3.56%). In addition to this, most people suffer from water-borne diseases during the flooding period. We also found clear evidene of shortage of safe drinking water due to salinity intrusion in grounwater. The tendency of raring livestock such as cow, goat, and buffalo decreased due to insufficient grazing land. The study also revealed that some internal conflicts exist between different stakeholders in Chakararia Upazila. Most local shrimp fry collectors collect fry from the tidal river and use an unscientific traditional method which was harmful for the other aquatic fish population. Poor quality of larvae supply from hatchery caused various diseases in cultivated ghers and ponds. The findings from this study provide useful information for sustainable coastal zone management in Bangladesh to build a more resilient coastal communities.

KEYWORDS

Shrimp farming, coastal livelihoods, Bangladesh, social and environmental impacts.

1. INTRODUCTION

Millions of people in Bangladesh rely on fisheries and aquaculture for a living, and they contribute a sizable amount of the animal protein consumed. The fishery and aquaculture business, particularly shrimp farming, has a key economic, environmental, and social role in securing money, jobs, and nutrient facilities for food security in Bangladesh. The Black Tiger Shrimp (*Penaeus monodon*), often known as Bagda, is one of Bangladesh's most important exported fish, accounting for about 87 percent of all fish exported (DoF, 2014; DoF, 2017). Since the late 1970s, almost 15000 ha of land in Cox's Bazar district has been transferred to the account for shrimp farming. Shrimp farming practices have resulted in a loss of crop production, a loss of many indigenous flora species, drinking water and fuelwood shortage, and are expected to worsen in the near future (Karim, 2002). Toxic materials are gradually polluting soil sub-surface through which carry these dangerous compounds and have great potentiality to cause health hazards.

Although intensive brackish water shrimp farming is not widely practised in Bangladesh, there is an extensive traditional farming method practised in the country's coastal region. These areas are located in Khulna, Satkhira, Bagerhat in the southwestern region and greater Chittagong in the southeastern part. Shrimp farming is generally practised in rotation with rice or salt in the selected areas of Chakaria Upazila, Cox's Bazar. Some of

Quick Response Code	Access this article online	
	Website: www. environecosystem.com	**DOI:** 10.26480/ees.02.2021.143.151

Cite the Article: Md. Humayain Kabir, Delwar Hossain (2021). Environmental Impacts of Shrimp Farming in Chakaria Upazila of Cox's Bazar in Bangladesh. *Environment & Ecosystem Science, 5(2): 143-151.*

the farms are very large, covering an area of 80 hectares and the average being 16 hectares. The major species of shrimp that are farmed in that area is *Bagda chingri*. The farmers traditionally cultivate shrimp and fish by entrapping them in low-lying coastal areas with the construction of embankments. Starting in the late1950's, many low-lying coastal areas have been employed under the "Coastal Embankment Project" to prevent saline water intrusion so that paddy could be grown in those areas (Ahmed, 2001). In recent years, shrimp farming has been extended even to non-poldered regions, and to some extent in areas where mangrove forest have been cleared off.

In the surrounding area of Cox's Bazar in Chittagong, shrimp culture started as a rotation with solar salt production- a traditional enterprise. In the early seventies, along with the growing demand in the international market, the price of shrimp culture started to get rise in nearby mangrove and other low-lying areas. Gradually, it spreads to other districts such as Noakhali, Barishal, and Patuakhali. In 1979-80, the total area under shrimp culture in Bangladesh was 26,315.79 ha (65000 acres). In 1984, it increased to an estimated area of 62,756 ha (155,000 acres) (Haque, 1984).

After the deterioration of natural forests from Chakaria Sundarbans, some fisher families and some middle-class Muslim families started small-scale fisheries there. They used to block some portion of *Khals* or *Charas* by giving earthen embankments for fishing purposes. After one or two months, it produced a lot of fish. This system helped some be prosperous within a short period and attracted others due to the conversion of all the depressions, lowlands, khals and channels under aquaculture. This water-logging condition hindered the natural regeneration of various mangrove species. The remaining trees were also cleared for this traditional farming (Kamal, 2001).

In recent times, shrimp is widely cultured in Chakaria (Cox's Bazar district). In these areas, shrimp is cultivated by indigenous methods, i.e., traditional extensive trapped method. The coverage of areas under shrimp cultivation is gradually increased year by year with the rise in demand for shrimp in the international market. The biodiversity, mangrove forests are facing devastating impacts due to excess shrimp culture. So, being aware of the local community about different categorical consequences already they are facing this study will be helpful for them. The climatic condition and geographic location of the Chakaria regions are very much favourable for shrimp farming.

Shrimp farming has been causing severe threats to ecological systems of coastal Bangladesh, such as deterioration of soil and water quality, depletion of mangrove forest, a decrease of local variety of fish and shellfish, saline water intrusion in groundwater, surface water pollution and change of surface and sub-surface hydrology (Kabir & Iva, 2014). The recent expansion of shrimp cultivation has caused severe depletion of forest cover in the Chakaria-Sundarbans, and hence led to a near-complete loss of mangrove forest and biodiversity (Shahid & Islam, 2002). Groundwater salinization and saline water intrusion in surrounding areas have caused serious ecological and socioeconomic damage in the coastal environment. Salinity has been dubbed as a silent poison to coastal Bangladesh due to extensive shrimp farming (Kabir & Iva, 2014). However, there is a significant research gap in an in-depth analysis of shrimp farming's environmental and social impact in Chakaria, Bangladesh. Therefore, this study aims to assess shrimp farming's environmental, social, and economic effects and suggest eco-hydrological ways to minimize its potential adverse effects.

2. Materials and Methods

2.1 Description of the study area

Chakaria is an Upazila, sub-unit of local administration, of Cox's Bazar District in the Division of Chittagong, Bangladesh (Figure 1). Chakaria Upazila, with an area of 970.32 km^2, is bounded by Lohagara, Banshkhali and Lama Upazilas on the north, Cox's Bazar Sadar, and Ramu Upazilas on the south, Lama and Naikhongchhari Upazilas on the east, Maheshkhali and Kutubdia Upazilas on the west. The Upazila is surrounded by the Matamuhuri, Bara Matamuhuri, Maheshkhali and Kutubdia Channel. This Upazila is more vulnerable to natural disasters such as cyclone, coastal flooding. The Maiskhal channel and Matamuhuri Khal bound the Chakaria Sundarban to the west and Medi Khal to the east. To the north, it is extended up to Malumghata. The Matamuhuri has divided the Chakaria Sundarbans into two different parts. The west side of the Matamuhuri is Rampur, and the east side is known as Charandwip (Chowdhury, 1964).

Chakaria's climate is classified as tropical. Most months of the year are marked by significant rainfall. In Chakaria, the average maximum annual temperature is 29.9° C, and the average yearly minimum temperature is 21.7^0 C. The average annual precipitation is 250 mm, and the annual average humidity is about 79.3%. One of the main economic activities in the coastal zone is aquaculture. In 2002 and 2003, the fisheries subsector contributed 5.23 per cent of the GDP. A vast network of river systems, beels (natural depressions), baors (dead river sections), floodplains and ponds provide opportunities for both capture and culture fisheries in this Upazila (Ahsan, 2013). Soils contain some water-soluble salts. About 53% of the coastal areas are affected by salinity. Agricultural productivity in this Upazila is relatively poor compared to the country's average crop production. Soil Salinity causes an unfavourable environment and hydrological situation that restrict the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are tidal flooding during the wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline groundwater during the dry season (November-May) (Haque, 2006). Huntington (2003) also noted that those areas with clay soils rich in Calcium (Ca^+) and Magnesium (Mg^+) ions are better at resisting saline intrusion. The soil salinity rate in this Upazila is very much high.

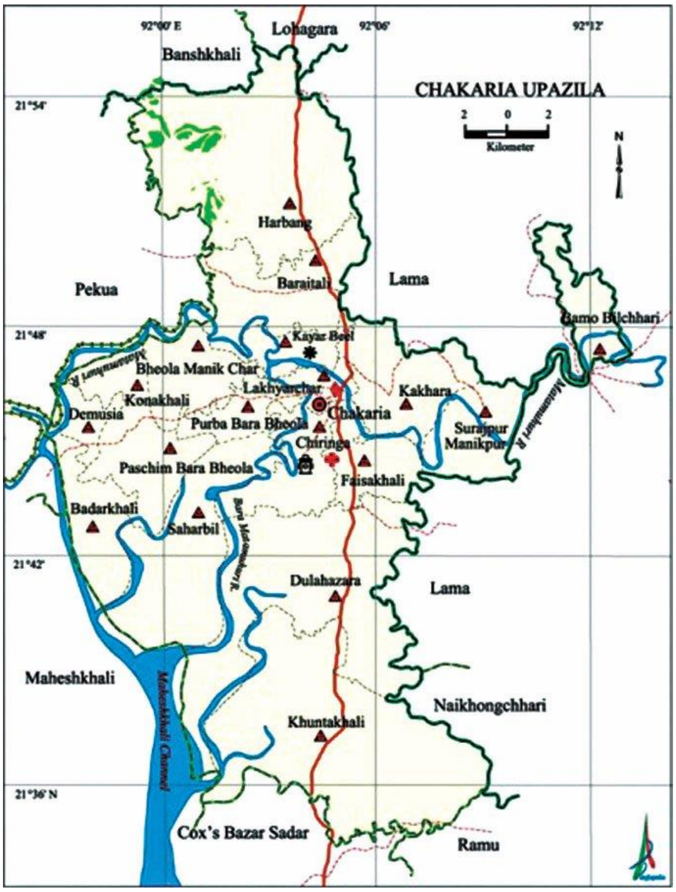


Figure 1: Map of the study area (Banglapedia, 2004).

2.2 Sampling

The study was conducted in Chakaria Upazila. To assess the impacts of shrimp farming, ten categories of stakeholders who are directly or indirectly dependent on shrimp farming were selected (Table 1).

Table 1: Sampling design and distribution of shrimp farming stakeholders

Sl. No	Stakeholders	Sample size	Description
1	Shrimp farmers	30	Year-round only shrimp farming
2	Alternate rice and shrimp prawn farmers	20	After rice culture; shrimp-prawn culture together
3	Rice farmers	20	Rice farming in shrimp growing area
4	Depot owners	5	Depot: Local shrimp processing factory
5	Depot workers	5	Workers in the shrimp processing factory
6	Shrimp farm labourers	20	The labourers are working either the whole day and night or part-time
7	Faria-Shrimp traders	10	Buying shrimp from shrimp farm and selling it to the depot
8	Land lessors	10	Leasing their land to the rich shrimp farm
9	Shrimp larvae collectors	10	They collect the Post Larvae (PL) from the river and the hatchery
10	Fisheries Officer	1	Working at Upazila Fishery Office
Total stakeholders		131	

A simple random sampling technique was applied to select rice farmers, shrimp farmers, and alternate rice and shrimp-prawn farmers. Firstly, the list of rice farmers, shrimp farmers, and the alternate rice and shrimp-prawn farmers were collected from the Upazila Fishery Office of the Chakaria Upazila, and then random number table was used for selecting the sample units. The purposive sampling method selected shrimp farm labourers, depot owners, depot workers, shrimp seed collectors, and land lessors.

On the other hand, stratified sampling method was used to collect soil samples. In this method, we selected 7 unions out of 18 unions randomly in where shrimp farming is mainly practiced. These unions are Demusia, Badarkhali, Dulahazara, Fasiakhali, Saharbil, Paschim Bara Bheola, and Konakhali. By selecting the first sampling point randomly, all the other samples were selected systematically at every 1 km distance (Figure 2). Random sampling was also conducted to collect the water samples of different sources in selected unions. Water samples were collected by 100 ml beaker, then recorded the multimeter's p^H, TDS, and conductivity. The soil samples were also collected by using auger instrument. In the laboratory pH, conductivity and organic matter of collected soil samples were recorded.

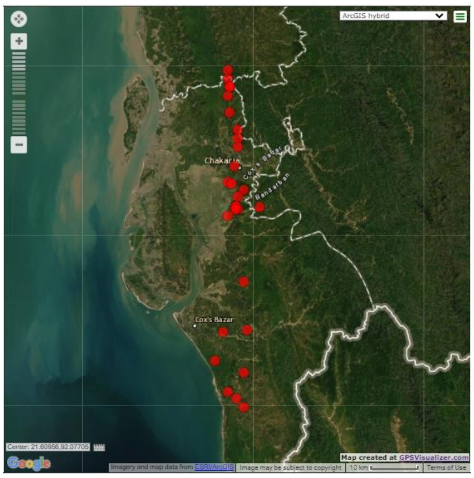


Figure 2: Geo-location of soil and water sample (map source: Google Earth)

2.3 Questionnaire design and survey of the study area

A reconnaissance survey was conducted in September 2018 before collecting relevant data and information related to shrimp culture. After then, a questionnaire was prepared consisting of different components of impact assessment. Both open and closed forms of questions were used to collect data, and necessary suggestions to mitigate different impacts. Simple and logically sequenced questions were included in the questionnaire to ascertain the opinion of the selected stakeholders. We collected primary data through the in-person interview. The primary data collection period was December 2018 to February 2019.

2.4 Secondary data and information collection

Along with primary data, secondary data and information were collected from different relevant sources. Previous socioeconomic and environmental conditions, mangrove status, salinity, and other problems were collected from relevant books and journals, Export Promotion Bureau (EPB), Department of Fisheries (DoF), relevant thesis, reports, official records, newspaper, and library.

2.5 Data processing and analysis

Collected information obtained from the survey was accumulated, grouped and interpreted according to the objectives and research questions. Some data have contained numeric and narrative facts. The collected data were then edited, summarized and tabulated and analyzed by Microsoft Excel and Statistical Package for Social Science (SPSS). The collected water and soil samples were tested in the laboratory at the Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.

2.6 Analysis of soil parameters

2.6.1 Soil p^H Test (Horneck et al.,, 2011)

Equipment: Beaker, Collected soil sample, Deionized water, Stirrer, p^H meter

Procedure:

I. Weight 20 g of soil sample into a 100 mL beaker.

II. Add 20 mL of deionized (DI) water and place on a stirrer to mix for 30 minutes.

III. Cover and let stand for an hour.

IV. After then we recorded the p^H of collected soil samples by p^H meter.

2.6.2 Soil Conductivity Test

Equipment: Beaker, Collected soil sample, Deionized water, Stirrer, Conductivity meter.

2.6.3 Soil Organic Matter Test(McCauley et al., 2009)

Equipment: Soil sample, Muffle furnace, Balance, Porcelain dish.

Data Analysis:

I. Determine the mass of the dry soil.

$$M_D=M_{PDS}-M_P$$

II. Determine the mass of the ashed (burned) soil.

$$M_A=M_{PA}-M_P$$

III. Determine the mass of organic matter

$$M_O = M_D - M_A$$

IV. Determine the organic matter (content).

$$OM = (M_O/M_D)*100$$

3. Results and Discussion

3.1 Environmental impacts

3.1.1 Impacts on water quality

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purposes.

3.1.1.1 Water p^H

In the study, water quality parameters has varied significantly. Figure 3 shows that the pH value of shrimp farms varied from 7.3 to 7.8. This indicates that the p^H value is found to be almost neutral or slightly alkaline. Generally, coastal water p^H range from 6.0-8.4 (Benneyworth et al., 2016). The groundwater p^H varies from 7.1 to 7.5 in which p^H standards for drinking water is 6.5-8.5. The present study revealed that the p^H value of drinking water is within the standard limit. Also, the surface water p^H value ranges between 7.4 to 7.9, which are within a permissible limit (6.5-8.5).

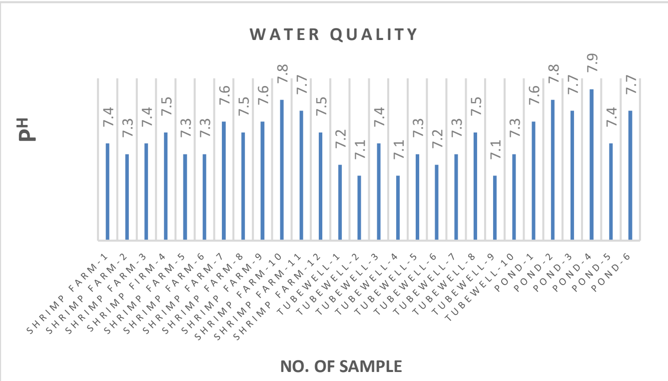


Figure 3: Comparative levels of water p^H in different locations of Chakaria Upazila

3.1.1.2 Water conductivity

Electrical conductivity is a measure of the saltiness of the water and is measured on a scale from 0 to 50,000 µS/cm. In Chakaria, the conductivity range of shrimp farms was in between 3001-3951 µS/cm (Figure 4). This represents that the shrimp farms water is very much saline and not recommended for drinking or domestic purposes. Also, the conductivity range of ponds was between 982-2230 µS/cm, which standards range is between 800-2500 µS/cm. Therefore, the study revealed that the groundwater is slightly saline in some union.

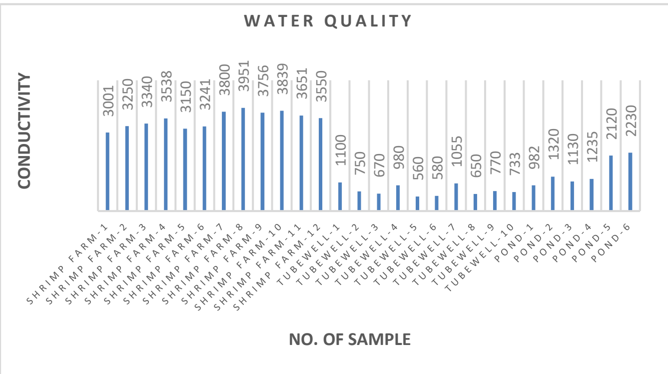


Figure 4: Levels of water conductivity in different locations of Chakaria Upazila

3.1.1.3 Water TDS

The TDS range of shrimp farms was between 1450-2200 mg/l (Figure 5). This indicates that the water of the shrimp farm is very much saline. Generally, TDS value for brackish water range from 1000-10,000 mg/ /l and TDS for freshwater range from 0-1000 mg/l (Sylus & Ramesh, 2015). TDS value of tube well also ranges from 380-756 mg/l in which the value of the standard of TDS is < 600 mg/l. Also, the Household ponds TDS range is between 370-670 mg/l. Therefore, the study revealed that drinking water is slightly saline in Chakaria near the coastline.

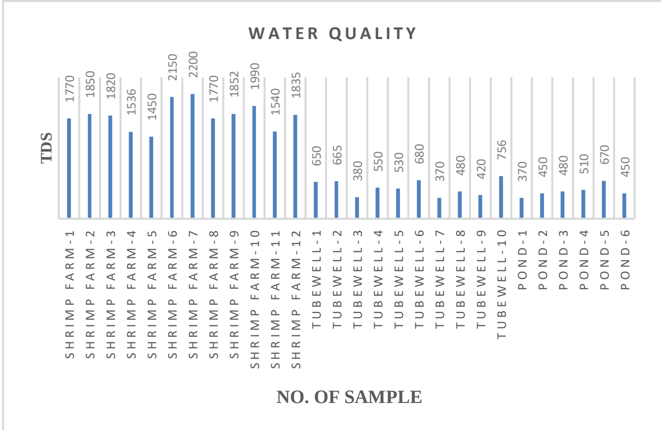


Figure 5: Levels of water TDS in different locations of Chakaria Upazila

3.1.2 Impacts on soil quality

3.1.2.1 Soil p^H

Soil pH is considered one of the major variables in the soil as it affects many chemical processes. In Chakaria, the soil p^H range from 6.6 to 7.6 (Figure 6). A previous study (2006) conducted in the southeast coastal region of Bangladesh revealed that coastal soil pH range from 6.0-8.4 and alkaline due to salinity intrusion (Haque, 2006). Moreover, the study indicates that agricultural soil is slightly acidic and alkaline, and also household's soil is somewhat acidic. But the shrimp cultivated soil is moderately saline.

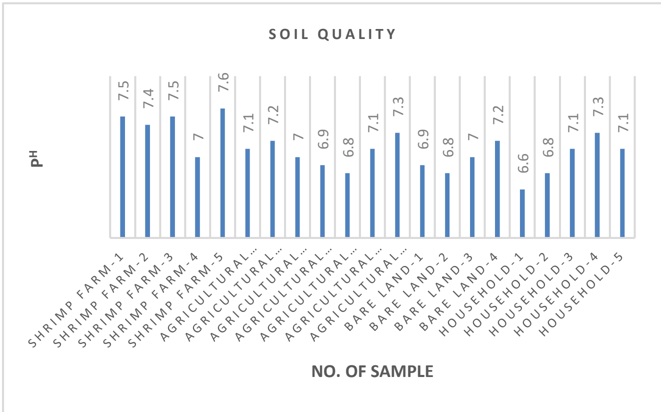


Figure 6: Levels of soil p^H in different locations of Chakaria Upazila

3.1.2.2 Organic matter

Soil organic matter is the basis of soil fertility. It releases nutrients for plant growth, promotes the soil's structure, biological and physical health, and is a buffer against harmful substances. A typical soil should contain 4 to 6 per cent organic matter for normal functioning in a sustainable crop production system. But the coastal soil organic matter content is pretty low (1.0-2.5%) (Haque, 2006). The study revealed that most of the village's soil organic matter content is pretty low and range from 0.25-3.56% (Figure 7). This is clearly indicating that the organic matter content is fluctuating in agricultural and bare lands. This represents that the soil is not good for paddy or other crop production because of fewer nutrients in the soil.

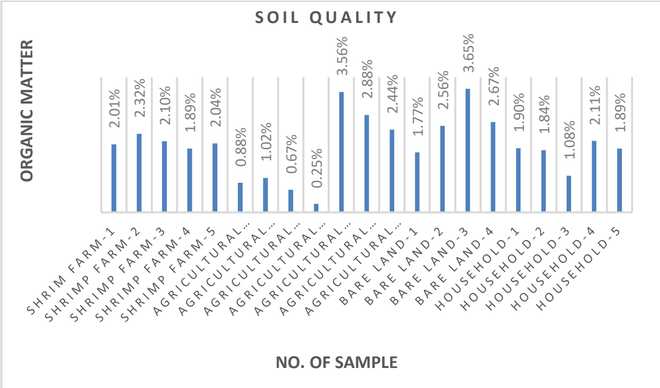


Figure 7: Levels of soil organic matter in different locations of Chakaria Upazila

3.1.2.3 Conductivity

Conductivity is another important parameter for soil quality. It indicates the presence of salinity in the soil. High conductivity affects soil quality and plants togrow. The study revealed that the conductivity is very much high (ranges from 1055-1537 µS/cm) in shrimp cultivated farms soil (Figure 8). The lowest conductivity is observed in the household's soil. Generally, coastal soil conductivity range from 600-1500 µS/cm (Haque, 2006). Moreover, the soil of shrimp farms is moderately saline, and agricultural land is slightly saline (standards permissible limit < 600 µS/cm).

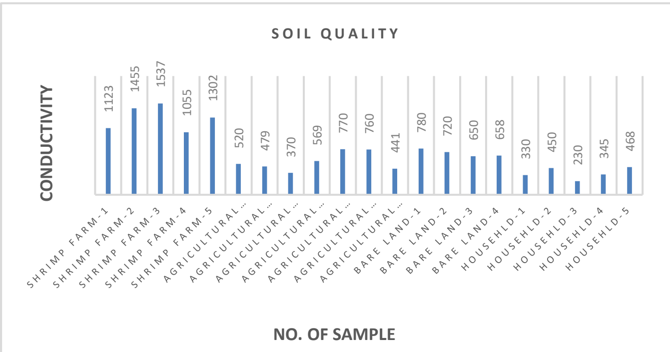


Figure 8: Levels of conductivity in different locations of Chakaria Upazila

3.1.3 Human disease

Our survey report that the people of Chakaria Upazila was highly affected by diarrhoea during the flooding period (Figure 9). The percentage of cholera was also high. People sometimes affected by other diseases due to salinity intrusion in household ponds and tube well. The condition becomes acute during the flooding period.

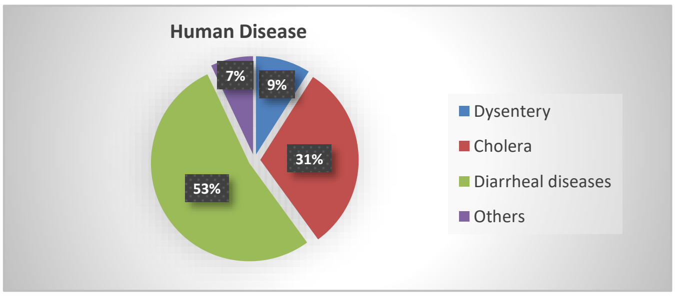


Figure 9: Human diseases due to shrimp farming in Chakaria Upazila

3.1.4 Impact on livestock

Shrimp farming in Chakaria Upazila has an influence on the livestock resources. Our findings showed that the percentage of the domestic cow is lower than others (Figure 10). Salinity intrusion in the agricultural field and conversion of grazing land into shrimp culture are the main driven forces of decreasing traditional animals. However, the people would like to feeding buffalo and duck because of muddy land and available ponds.

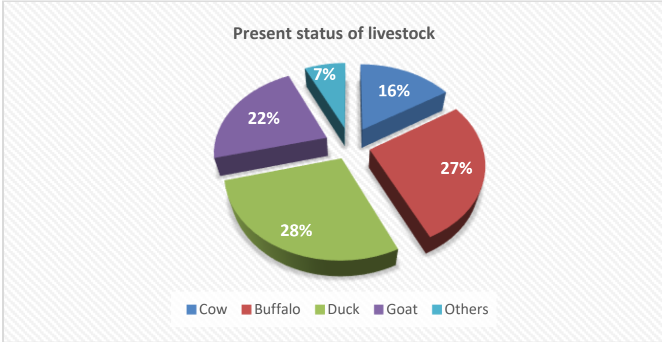


Figure 10: Present status of livestock resources in Chakaria Upazila, Cox's Bazar

3.1.5 Main driving forces of fish population depletion

Catching of fish fry from saline tidal areas, lagoons, canals, and creeks provides an important livelihood and sources of income for the lack of coastal zone residents, including women and children. Our study revealed that these activities are causing great harm to the fish population. Larvae of different fishes and other aquatic species are being caught with the larvae of shrimp. The larvae of fish and other aquatic organisms are killed due to the unscientific collection process and small meshed mosquito nets near the shoreline.

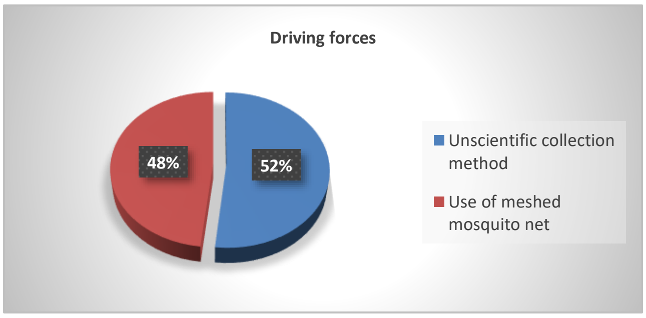


Figure 11: Driving forces of fish population declination in Chakaria Upazila, Cox's Bazar

3.1.6 Economic Impacts

3.1.6.1 Monthly personal income

Shrimp farming is profitable economy. The finding demonstrated that the economic status of depot owners, land lessors and some farmers was higher than other stakeholders. Most of the land lessors lease land from the local government and lease their issued land to the local shrimp farmers for 1 or 2 years. In that case, Shimp labourers sometimes deprived of their rightful wages. Rice farmers near the shrimp farms are not economically satisfied because of saline water intrusion, particularly during the harvesting period.

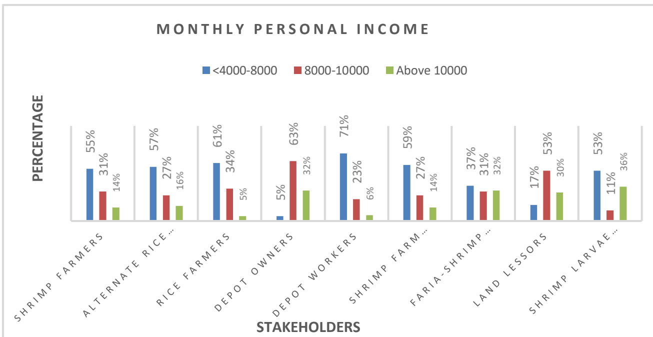


Figure 12: Impact of shrimp farming on the monthly income of different stakeholders in Chakaria

We also found that about 65% of people are economically satisfied with conducting shrimp aquaculture (Figure 13). However, 35% of people don't allow shrimp aquaculture due to excess salinity intrusion in their crop fields and their household ponds.

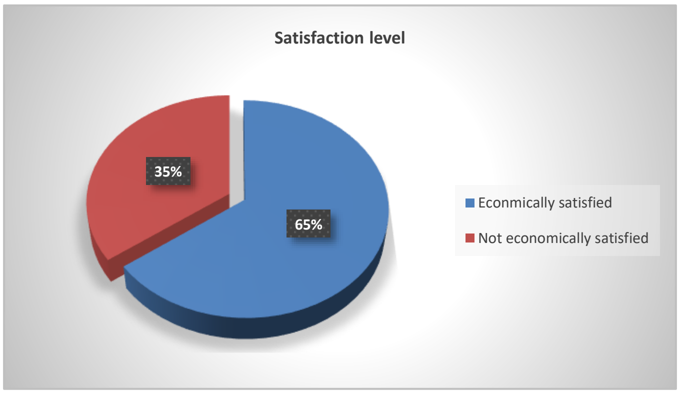


Figure 13: Economic satisfaction of shrimp farming practitioners in Chakaria Upazila, Cox's Bazar

3.1.7 Social impacts

3.1.7.1 Social conflicts

The internal conflicts were found, based on the respondent's opinion, from the different shrimp farming stakeholders, as depicted in table 1. Around 15 per cent Faria, shrimp farmers and depot owners opined that they have internal conflicts about buying and selling rate of shrimps in the shrimp farms and depots (Figure 14). Around 31 per cent of rice producers and shrimp farmers agreed that they have conflicts about the paddy culture in their area because paddy cannot grow in saline water. Shrimp farming is not so profitable for the marginal rice farmers due to their scarcity of land; even if they want to do shrimp culture, they do not get adequate saline water from the narrow canals controlled by local politically powerful farmers. About 23 per cent of livestock producers and shrimp farmers claimed that they have internal conflicts because of decreasing grazing land for shrimp culture.

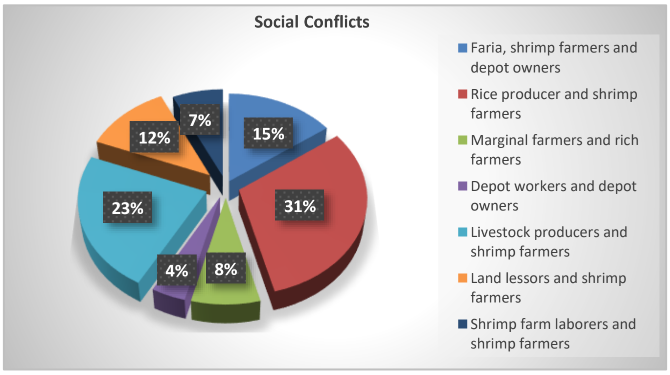


Figure 14: Social conflicts between different stakeholders of shrimp farming in Chakaria

To analyze the relationship of existing conflicts between different stakeholders and other social factors, we developed a model using the following equation.

Y= A+B1X1+B2X2+B3X3+B4X4+B5X5+………… +BNXN (Mostafa, 1989)

Here, Y = Existing conflicts between different stakeholders (Dependent variable)

A = Intercept

B = Co-efficient

X = Independent variables such as low salary of shrimp labourers, encroachment, poor quality of larvae, feed cost, seasonal disease, post-larvae cost, insufficient saline water supply upstream.

Table 2: Factors affecting social conflicts among stakeholders of shrimp farming in Chakaria

	Co-efficient	P-Value
Intercept	1.639	0.00
Low salary of shrimp labourers	0.017	0.836
Encroachment	0.189	0.341
Poor quality of larvae	-0.621	0.026
Feed cost	0.713	0.029
Seasonal disease	-0.096	0.879
Postlarvae cost	-0.081	0.731
Insufficient saline water supply from upstream	0.362	0.046

Here, the p-value is used in the context of null hypothesis testing to quantify the statistical significance of the evidence. We found that p-value of shrimp labourers, encroachment, seasonal disease, and post-larvae cost was not statistically high. On the other hand, p-value of poor quality of larvae, feed price and insufficient saline water supply was statistically significant. Here, we conclude that the regression line of social conflicts statistically depends on poor quality of larvae, feed cost, and insufficient saline water supply.

Our final regression model is:

Existing conflicts (Y) = 1.639 – 0.621* Poor quality of larvae + 0.713* Feed cost + 0.362* Insufficient saline water supply from upstream.

3.1.7.2 Modelling of potential impacts of shrimp culture

A model was developed to analyze the relationship with potential impacts of shrimp culture in selected farms and other socioeconomic factors.

Y= A+B1X1+B2X2+B3X3+B4X4+B5X5+………..+$B_N X_N$(Mostafa, 1989)

Here, Y = Potential impacts of shrimp culture in farms (Depended variable)

A = Intercept

B= Co-efficient

X= Independent variables i.e., Income, Manure type, Manure amount, Level of education, Energy use, Farming method.

Table 3: Factors affecting the potential impacts of shrimp culture

	Co-efficient	p-Value
Intercept	0.99	0.00
Manure type	-0.042	0.144
Manure amount	0.216	0.044
Energy use	0.071	0.365
Farming method	0.557	9.26E-06
Production	0.217	0.047
Income	0.347	0.02

We found that p-value of manure type, and energy use was not statistically significant. However, the p-value of Manure amount, Income, Farming method and Production were statistically significant. Therefore, the regression line of potential impacts of shrimp culture statistically depends on Manure amount, Income, Farming method, and Production.

Table 4: Summary of regression statistics

Multiple R	0.627
R Square	0.714
Adjusted R Square	0.308
Significant F	0.001

From our analysis it is revealed that R square value is 0.714, which statistically explained the response variable variation is about 71% (statistically significant). The considerable F-value (<0.05) indicates that the predicted regression line is statistically significant.

The resultant regression equation is:

Potential impacts of shrimp culture (Y) = 0.99 + 0.216* Manure amount + 0.347* Income + 0.557 * Farming method + 0.217* Production.

4. Discussion

Fisheries and aquaculture have long been a vital component of Bangladeshi coastal communities' lives and livelihoods. This industry is the second-largest contributor to Bangladesh's overall economy, accounting for over 3.65% of GDP, 23.81 percent of gross agricultural output, and 1.97 percent of total export profits. It accounts for almost 60% of animal protein intake in Bangladeshi diets, with a per capita fish consumption of 24.08 kg per year, which is greater than the global average (DoF, 2017). In both rural and urban parts of Bangladesh, people rely heavily on fish to meet their protein demands. Bangladesh has an estimated 1.32 million full-time fishermen, predominantly artisanal fishermen, and up to 2.00 million full-time equivalent individuals work in aquaculture (Hussain, 2016), ranging from small family-run businesses to huge shrimp and fish farms. However, the number of persons obtaining income and support from fishing and aquaculture activities on a full and part-time basis is far higher, estimated at 14.7 million people (DoF, 2017), accounting for roughly 11% of Bangladesh's total population. Hundreds of stakeholders are involved in the value chain from capture to pond/farm to plate/fork and beyond, whose lives are entirely dependent on fisheries and aquaculture, as well as associated and ancillary activity.

Shrimp farming has long posed serious threats to Bangladesh's ecological systems, including deterioration of soil and water quality, depletion of mangrove forests, reduction in local fish and shellfish variety, saline water intrusion in ground water, local water pollution, and changes in local hydrology (Kabir and Iva, 2014). Shrimp farming has resulted in a significant loss of forest cover in the Chakaria-Sundarbans, as well as a near-complete loss of mangrove forest and biodiversity of flora and wildlife (Shahid and Islam, 2002). Groundwater salinization and saline water intrusion in the surrounding areas have wreaked havoc on the coastal environment's ecology and economy. Due to widespread shrimp farming, salinity has been labeled a silent poison in coastal Bangladesh (Kabir and Iva, 2014). Particularly in Chittagong division, the area under aquaculture increased from almost zero ha in 1976 to 36,486 ha in 2000 and further, increased to 45,073 ha by 2010. In this division, the area under mangrove forest decreased annually by 4.18 percent during over the period 2000 to 2010 (Hasan et al., 2013). Over the years, fishermen built dams in the mouth of the creeks; this disrupts tidal inundation and causes water stagnation that is responsible for the reduction in the river width but increase in water surface area from 24% to 26% between 1972 and 2017 (Prince et al., 2018). In our analysis also found that there is a scarcity of safe surface water. The conductivity range of groundwater was between 560-1100 µS/cm in which the standards conductivity range of groundwater is 0-800 µS/cm. A study in the southeastern part of Bangladesh revealed that coastal conductivity value range from 500-1500 µS/cm (Benneyworth et al., 2016).

The mangrove forest was formerly an important feature of Chakaria's eastern shore. Salt panning and scattered shrimp cultivation were the main economic activities around the mangroves in 1972. Mangrove deforestation became a problem after 1972, yet a sliver of mangrove forest remained until 1990 (Iftekhar and Islam, 2004). Residents of Chakaria were drawn to aquaculture after 1972 because of its high return on investment, and it rapidly surpassed conventional rice growing as the preferred method in the area (Islam et al., 2019).

Aquaculture farming occupied 12,235 ha (12%) of land in the post-monsoon season of 2016, while traditional farmland occupied only 2,526 ha (2 percent of the area). Because evaporative salt production is not possible in Chakaria during the rainy season, land use for salt pans was not assessed. The area used for aquaculture was reduced to 6,977 h during the pre-monsoon season. During the February monsoon season, aquaculture land was reduced to 6,977 ha (7 percent of the total area), agriculture to 3,116 ha (3 percent of the total area), and salt panning to 5,856 ha (5 percent of the total area) (6 percent of the area).

Similar practices are widely used in another coastal region of Bangladesh. A research was carried out to assess the current socioeconomic situation as well as the soil and water quality of the shrimp (*Paeneus monodon*) farming in the *gher* area of Bagerhat District (Mitro et al., 2015). This research was conducted in ten villages in Bagerhat District's five Upazillas (Bagerhat Sadar, Rampal, Mangla, Chitalmari, and Fakirhat). Because the soil is not ideal for agricultural crops due to the high saline percentage, most of the population in this research region were involved in shrimp production. Shrimp culture provided an annual household income of more than 200000 taka for most farmers (45%). The pH of the soil was all neutral to slightly alkaline. They also claim that shrimp farming has no discernible effect on soil quality. However, shrimp farming has certain detrimental effects on water quality, such as an increase in the range of K and Na in water and a decrease in the range of Ca. The residents of this region get increasingly involved in shrimp farming (Mitro et al., 2015).

In another study, which is based on primary investigations (focus group discussions, field observations, household interviews), laboratory analysis for soil and water quality (heavy metal test, pH, salinity, electricity conductivity, particle size analysis), and secondary materials (remote sensing data, satellite image analysis, and so on), reveals that due to poor drainage system and continuous shrimp affect the soil and water quality. Due to an inadequate drainage system and continued shrimp farming, salinity levels in both soil and water are growing in Chandipur Village, Debhata Upazila, Satkhira District (1.6 ppt and 13.4 ppt, respectively). In addition, the pH, salinity, and electrical conductivity of the soil and water were found to be in bad condition. In the soil of ghers, heavy and hazardous metals such as Na, Fe, Cr, Zn, Ni, and Pd have been identified (Kabir and Iva, 2014).

On the other hand, Abdullah et al. (2017) investigated the impact of shrimp farming on the livelihoods of people living near Bangladesh's Sundarbans mangrove forest. They found that shrimp revenue accounts for 46 percent of total household income for higher-income households, but only 26 and 8 percent for middle- and lower-income households, respectively, based on data from 264 households in six villages in Mongla. Higher-income households earn more absolute and relative income from the shrimp sector than lower-income households, owing to the fact that they started with more land and exploited that to acquire ownership or access to the majority of the remaining land. This has compounded existing imbalances, making shrimp aquaculture more inequitable than other professions like fishing or farming which indicates the existence of conflict. They also reported that converting agricultural land into shrimp farms has been a major factor in the growth of shrimp farming. The poorest people are sometimes driven into low-wage labor or the collecting of resources from the mangrove forest, making them even more vulnerable (Abdullah et al., 2017). This discrimination is also aligned with our findings.

5. Conclusions

The study was conducted to find out the impacts of shrimp farming in Chakaria, Bangladesh. We conducted questionnaire survey and collected water samples from the different locations of Chakaria. Our analysis showed that revealed that groundwater quality is slightly saline. However, the surface water is moderately saline because of salinity intrusion in farming ponds. Organic matter content in the soil is found below the acceptable limit. A rapid expansion of shrimp farming took place at commercial shrimp farming due to higher economic returns. The monthly income of shrimp labourers, rice farmers, alternating shrimp and rice producers, depot workers remains economically satisfactory. That's why they are highly interested in conducting shrimp culture besides other aquaculture. The amount of different manure, high production rate, and traditional farming method is the main driving force of large-scale shrimp farming in Chakaria. Besides, mangrove forest, the agricultural and the available bare land are being converted into the seasonal shrimp culture at an alarming rate. Most people suffer from water-borne diseases during the flooding period. In that case, safe and purified drinking water becomes an acute problem in Chakaria. The study also revealed that some internal conflicts exist between different stakeholders in Chakararia Upazila. Encroachment, low wages, decreasing grazing land are common in that Upazila. The people didn't show interest in feeding cow and other domestic animals of decreasing grazing land. The local people, including women and children, use the traditional unscientific method and meshed mosquito nets to catch the shrimp larvae. In that case, they caught the larvae of fish and other aquatic organisms besides shrimp larvae. This may bring negative impacts on existing biodiversity.

Limitation of the study

i. Some farms located in a very distinct area. Considering security problem, those farms are neglected.

ii. There is also an internal transport problem in Chakaria, where shrimp are generally cultivated. Therefore, it was very difficult to reach every union to collect the relevant data.

iii. Relevant secondary data related to impacts of shrimp aquaculture, especially in Chakaria Upazila are not accessible.

Scope of future research

i. A cross-sectional and longitudinal analysis of the impacts of shrimp farming on other aquatic ecosystems is essential for robust decision making.

ii. Understanding of socio-ecological systems and their dynamics in relation to social conflicts are still unexplored.

iii. A comprehensive study on biodiversity loss due to shrimp farming in Chakaria is a fruit for thoughts for the future research scope.

6. Recommendations

The land lessors, depot owners and other influential persons getting benefited from the shrimp farming should come into a friendly co-operation with the local underprivileged and marginalized local communities. We recommend developing a new ecohydrological approach which provides a sustainable framework for aquatic ecosystem management based on the interplay between different biota and hydrology. This ecohydrology based approach sustains the health of coastal ecosystem services provisions. It, therefore, should be adopted for the sustainable management of shrimp farming in where it is cultivated. The immediate measures for the betterment of shrimp farming and minimizes environmental impacts are:

i. Creation of ecotone zone for controlling salinity intrusion: The vegetative buffer zones with halophytes between shrimp farms and crop cultivated field have proved to be effective filters for trapping saline water.

ii. Implementation of "Denitrification wall" to protect groundwater: "Denitrification wall" is a widely used ecohydrological and ecological biotechnology to provide safe groundwater. This is a simple, low-cost and effective approach for removing nitrate from groundwater or surface discharges.

iii. Installation of sequential ponds: Sequential ponds, a nature-based management system that would trap saline water in only shrimp cultivated area. This system doesn't allow saline water to the nearby crops cultivated area at the tidal period in the river.

iv. Implementation of constructed wetlands: Constructed wetlands are man-made engineered system that use natural functions, vegetation, soil, and organisms to treat the saline water. The use of sand and gravel in a constructed wetland can trap contaminants.

References

A.R. Hossain, M., & R. Hasan, M. 2017. An assessment of impacts from shrimp aquaculture in Bangladesh and prospects for improvement. 2017, 96.

Abdullah, A.N., Myers, B., Stacey, N. et al. 2017. The impact of the expansion of shrimp aquaculture on livelihoods in coastal Bangladesh. Environ Dev Sustain 19, 2093–2114. https://doi.org/10.1007/s10668-016-9824-5

Ahmed, N. 2001. Socioeconomic aspects of freshwater prawn culture development in Bangladesh.

Ahmed, N. 2003. Environmental impacts of freshwater prawn farming in Bangladesh. Shellfish News, 15, 25–28.

Akand, A. M., & Hasan, M. R. 1992. Status of freshwater prawn (Macrobrachium spp.) culture in Bangladesh. Freshwater Prawns (Ed. by EG Silas), 33–41.

Alam, S., Hossain, M. L., Foysal, M. A., & Misbahuzzaman, K. 2014. Growth performance of mangrove species in Chakaria Sundarban. International Journal of Ecosystem, 4(5), 233–238.

Alauddin, M., & Hamid, M. A. 1999. Shrimp culture in Bangladesh with emphasis on social and economic aspects. Aciar Proceedings, 53–62. ACIAR; 1998.

Benneyworth, L., Gilligan, J., Ayers, J. C., Goodbred, S., George, G., Carrico, A., Piya, B. 2016. Drinking water insecurity: water quality and access in coastal southwestern Bangladesh. International Journal of Environmental Health Research, 26(5–6), 508–524. https://doi.org/10.1080/09603123.2016.1194383.

DoF 2014. Annual report 2013. Department of Fisheries (DoF), MInistry of Fisheries and Livestock, Dhaka, Bangladesh. 150 pp.

DoF, 2017. National Fish Week 2017 Compendium (in Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 160 pp.

FAO. 2012. The State of World Fisheries and Aquaculture 2012. Rome. 209 pp.

FAO. 2014. The State of World Fisheries and Aquaculture 2014. Rome. 225 pp.

Hagler, M., Gianni, M., & Cardenal, L. 1997. Shrimp, the Devastating Delicacy: the explosion of shrimp farming and the negative impacts on people and the environment.

Hanifi, M. A., Mamun, A. A., Paul, A., Hasan, S. A., Hoque, S., Sharmin, S., … Rasheed, S. 2012. Profile: The Chakaria health and demographic surveillance system. International Journal of Epidemiology, 41(3), 667–675.

Haque, S. A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. Pakistan Journal of Botany, 38(5), 1359–1365.

Hoq, E. 1999. Environmental and socio-economic impacts of shrimp culture in southwestern Bangladesh. Tropical Agricultural Research and Extension, 2(2), 111–117.

Horneck, D. A., Sullivan, D. M., Owen, J. S., & Hart, J. M. 2011. Soil test interpretation guide.

Hussain, M. 2016. Fisheries statistics in Bangladesh: Issues, challenges and plan.

Islam, S. D.-U., & Bhuiyan, M. A. H. 2016. Impact scenarios of shrimp farming in coastal region of Bangladesh: an approach of an ecological model for sustainable management. Aquaculture International, 24(4), 1163–1190.

Kabir, M. H., & Iva, I. J. 2014. Ecological consequences of shrimp farming in Southwestern Satkhira District of Bangladesh. Austin J Earth Sci, 1(1), 7.

Karim, M. R. 2002. Present status and strategies for future development of shrimp culture in Bangladesh. Environmental and Socioeconomic Impacts of Shrimp Farming in Bangladesh. Technical Proc. BAU–NORAD Workshop, 5, 1–8.

M.M., K., & M.A., A. 2014. The nexus between local politics and salinity intrusion in coastal area of Bangladesh: Unveiling the development myth. Retrieved February 12, 2019, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Khan%2C+M.M.+%26+Azad%2C+M.A.+2014.+The+nexus+between+local+politics+and+salinity+intrusion+in+coastal+area+of+Bangladesh%3A+Unveiling+the+development+myth.+Global+Journal+of+Sociology%2C+4%282%29%2C+29%E2%80%9340.&btnG=#d=gs_cit&u=%2Fscholar%3Fq%3Dinfo%3A41goDP6cvk8J%3Ascholar.google.com%2F%26output%3Dcite%26scirp%3D0%26hl%3Den

Macintosh, D. 1982. Fisheries and aquaculture significance of mangrove swamps, with special reference to the Indo-West Pacific region. Recent Advances in Aquaculture., 4–85.

Mazid, M. A. 1994. Environmental issues and aquaculture development in Bangladesh. Country Paper, Presented at the Final Workshop, FAO (Food and Agriculture Organization of the United Nations) Regional Office for Asia and the Pacific.

McCauley, A., Jones, C., & Jacobsen, J. 2009. Soil pH and organic matter. Nutrient Management Module, 8, 1–12.

Mitro, S., Khatun, R., & Baten, M. 2015. Socio-Economic and Environmental Impacts of Shrimp Culture in Some Selected Areas of Bagerhat District. Journal of Environmental Science and Natural Resources, 7(1), 265–269. https://doi.org/10.3329/jesnr.v7i1.22181

Mostafa, M. G. 1989. Methods of statistics. Karim Press and Publications, Dhaka.

Paul, B. G., & Vogl, C. R. 2011. Impacts of shrimp farming in Bangladesh: Challenges and alternatives. Ocean & Coastal Management, 54(3), 201–211. https://doi.org/10.1016/j.ocecoaman.2010.12.001

Pokrant, B., & Reeves, P. 2003. Work and labour in the Bangladesh brackish-water shrimp export sector. South Asia: Journal of South Asian Studies, 26(3), 359–389.

Potapov, P., Siddiqui, B. N., Iqbal, Z., Aziz, T., Zzaman, B., Islam, A., … Turubanova, S. 2017. Comprehensive monitoring of Bangladesh tree cover inside and outside of forests, 2000–2014. Environmental Research Letters, 12(10), 104015.

Prince, H. M., Idrees, M. O., Shafri, H. Z. M., Iqbal, M., Iqbal, M. Z., & Aziz, M. T. 2018. Effect of competing landuse practices on Chakaria Sundarbans mangrove in Bangladesh using Landsat imagery. IOP Conference Series: Earth and Environmental Science, 169, 012038. IOP Publishing.

Rosenberry, B. 1997. World shrimp farming 1999. Shrimp News International, San Diego, 284.

Shahid, M. A., & Islam, J. 2002. Impact of denudation of mangrove forest due to shrimp farming on the coastal environment in Bangladesh. Technical Proceedings of BAU-NURAD Workshop on Environment and Socio-Economic Impacts of Shrimp Farming in Bangladesh, 5, 67–75.

Shamsuzzaman, M. M., Islam, M. M., Tania, N. J., Al-Mamun, M. A., Barman, P. P., & Xu, X. 2017. Fisheries resources of Bangladesh: Present status and future direction. Aquaculture and Fisheries, 2(4), 145–156.

Sohel, M. S. I., & Ullah, M. H. 2012. Ecohydrology: a framework for overcoming the environmental impacts of shrimp aquaculture on the coastal zone of Bangladesh. Ocean & Coastal Management, 63, 67–78.

Sylus, K. J., & Ramesh, H. 2015. The study of sea water intrusion in coastal aquifer by electrical conductivity and total dissolved solid method in Gurpur and Netravathi river basin. Aquatic Procedia, 4, 57–64.

Weidner, D. 1992. World shrimp farming. Proceedings of the Special Session on Shrimp Farming, 1992.

Williams, D., & Khan, N. 2001. Freshwater prawn gher farming Systems: indigenous technology developed in southwest Bangladesh. CARE GOLDA Project, CARE Bangladesh, Dhaka.

Wolanski, E., Boorman, L. A., Chícharo, L., Langlois-Saliou, E., Lara, R., Plater, A. J., Zalewski, M. 2004. Ecohydrology as a new tool for sustainable management of estuaries and coastal waters. Wetlands Ecology and Management, 12(4), 235–276.

Zalewski, M. 2009. Ecohydrology: a framework for reversing the degradation of the Baltic Sea. BALTEX Newsletter October, 7106, 19.

Zalewski, Maciej. 2000. Ecohydrology-the scientific background to use ecosystem properties as management tools toward sustainability of water resources. Ecological Engineering, 16(1), 1–8.