Journal of Agroforestry and Environment

Volume 17, Issue 2, 2024

Journal DOI: https://doi.org/10.55706/jae

Journal homepage: www.jagroforenviron.com

Environmental Impact of Shrimp Farming: A Case Study of Coastal Community

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Received: 19/09/2024

Accepted: 30/12/2024

Available online: 31/12/2024

Abstract: Shrimp farming in the coastal area has impacts on the soil, water, air, fish habitats, agricultural farmland, grazing land, indigenous fish, household vegetation, land fertility, and mangroves. The objectives of the study were to assess the socio-economic status of the shrimp farmers and understand the environmental impact of shrimp farming in coastal areas. A structured questionnaire survey was conducted among 100 randomly selected respondents from Satkhira Sadar and Debhata Upazila. Data were analyzed using descriptive statistics to evaluate the socio-economic conditions and perceived environmental impacts. Thirty-eight percent of respondents were professional farmers. The maximum respondents reported that their monthly income is limited to 6000- 9000tk, and they are not highly educated. Ninety-six percent of respondents have no idea about air quality. Because they are not highly educated. The average water salinity is found to be 6.6 ppt, and the soil pH is relatively acidic. Most of the respondents (64%) reported that shrimp farming led to a decrease in indigenous fish, while two percent reported an increase. About twenty-six percent of the respondents indicated that shrimp farming has led to people migrating to other places for work. Despite these negative impacts, shrimp farming can be sustainable and environmentally friendly if proper practices are implemented, such as the use of organic feed instead of industrial feed, periodic monitoring of water salinity, and training farmers on environmentally sound waste disposal methods. These suggestions are based on the issues identified in the field data, including high water salinity, poor awareness of air quality, and declining indigenous fish populations. This study could help to promote more sustainable and responsible shrimp farming practices that reduce the impacts on the environment, agriculture, and human health.

Keywords: Shrimp farming; Environmental impact; Coastal community.

INTRODUCTION

Due to rise in global demand, shrimp has recently become one of the most significant export goods. Rural residents in Bangladesh's southwestern region, which is regarded as the primary region for shrimp farming, rely heavily on the income provided by shrimp farming. Knowing the current culture methods and safety measures used by shrimp farmers is crucial if the trend of exporting shrimp around the world is to continue (Al-Mamun et al., 2020). Since the 1970s, the culture of shrimp (Penaeus monodon) has been widespread in Bangladesh (Rahman and Hossain, 2013). Shrimp are well adapted to the "Gher" farming system (Paul and Vogl 2011, Rahman et al. 2011), and salinity has been related to shrimp and is thought to be a significant concern in coastal parts of Bangladesh (Uddin and Haque, 2010; Hossain et al. 2012). With annual exports exceeding 40,000 metric tons and generating approximately USD 500 million in revenue, shrimp farming stands as Bangladesh’s second-largest source of foreign exchange, following the apparel industry. Around 40% of the total shrimp production is consumed domestically (DoF, 2017). This industry plays a significant role in the national economy, fostering collaboration between the government, international financial institutions, and multinational companies (Shamsuzzaman et al., 2020; Bashar et al., 2021).

When shrimp agriculture takes place in a closed or semi-closed environment, there is a risk of waterlogging and higher saline levels, which could change drainage patterns and the soil's quality (Battacharya, 2005). Bangladesh's Khulna, Satkhira, Bagerhat, and Cox's Bazar regions are primarily known for their shrimp culture. Shrimp farming plays a vital role in enhancing the socioeconomic status, sustainability, and resilience of coastal communities in Bangladesh, particularly in the southern regions (Ray et al., 2021). While it contributes significantly to foreign exchange earnings, some research also notes its complex relationship with national economic indicators (Bhattacharya, 1999). In many areas of Southern Bangladesh, farmers have transformed their unproductive rice fields into ghers—a local term for traditional shrimp enclosures—as a more profitable alternative (Feroz et al., 2009). The farming of Penaeus monodon typically takes place in river-adjacent ponds (Islam and Asaduzzaman, 2015).

A gher is formed by modifying rice fields, involving the construction of elevated dikes and internal canals deep enough to retain water during the dry season, thus enabling effective shrimp cultivation (Ahmed et al., 2008). However, the expansion of shrimp aquaculture in the southwestern region has led to several environmental and social challenges due to poor planning and regulatory oversight. These include deforestation of mangroves, intrusion of saline water, disease outbreaks, pollution, land conflicts, and a decline in agricultural land, all of which have contributed to broader economic and social disruptions (Hein, 2002; Paez-Osuna et al., 2003; Chowdhury et al., 2006; Azad et al., 2009).

Many species, including those that are endangered, have lost their habitat as a result of the clearing of mangrove forests for shrimp farming. The overuse of chemicals like pesticides and fertilizers, as well as the dumping of shrimp waste into the soil, led to soil degradation (Kamal and Mustafa, 2016). Due to the large-scale untreated wastewater discharge from shrimp aquaculture into neighboring water bodies, which contaminated the water with high levels of organic debris, minerals, and hazardous compounds like antibiotics and heavy metals (Mohapatra and Choudhury, 2016). The inappropriate disposal of shrimp farm trash can cause environmental degradation and have a detrimental effect on the health of local residents (Heal et al., 2021).

The coastal regions of Bangladesh have experienced considerable ecological and economic degradation due to increased salinization of groundwater and the intrusion of saline water into surrounding areas (Wahab and Karim, 2003). Soil greenhouse gas (GHG) emissions in mangrove ecosystems are closely linked to microbial processes, including microbial activity, organic carbon availability, nutrient levels, and redox conditions (Chen et al., 2010; Nóbrega et al., 2016). For instance, methane (CH_4) production requires highly reducing environments (Eh around 200 mV) (Kreuzwieser et al., 2003; Nóbrega et al., 2016), whereas carbon dioxide (CO_2) emissions are often stimulated by increased availability of organic carbon in the soil (Alongi et al., 1999; Kristensen et al., 1995; Lewis et al., 2014). Although bagda (Penaeus monodon) shrimp farming has boosted export earnings, it has simultaneously triggered notable environmental and socioeconomic challenges in the southwestern coastal belt. The practice has disrupted local ecosystems by degrading soil and water quality, harming agricultural land, depleting fish resources, and contributing to the loss of mangroves. These impacts have disproportionately affected smallholders, marginal farmers, and landless communities by threatening their livelihoods and food security (Saha, 2017).

Additionally, shrimp exports from Bangladesh declined during the first quarter of the current fiscal year, largely due to reduced demand from major markets such as the EU and the US, both of which are facing economic uncertainty linked to the Russia-Ukraine conflict (The Daily Star, 2022). A wide range of studies has investigated the diverse impacts of shrimp aquaculture on environmental and socio-economic systems (Chen et al., 2010; Nóbrega et al., 2016; Saha, 2017; Queirozet et al., 2019; Hossain et al.; Prodhan et al., 2019; Al-Mamun et al., 2020; Bull et al., 2021). But their different environmental impact were not available in those studies. This study will provide more clarity about it. The objectives of the study are 3) to assess the socio-economic status of the shrimp farmers in the coastal areas and 3) to understand the environmental impact of shrimp farming in coastal areas.

MATERIALS AND METHODS

Study area

Satkhira Sadar Upazila, situated in the southwestern region of Bangladesh within the Satkhira District of the Khulna Division, covers an area of 264.79 square kilometers. It comprises 14 unions and 185 villages, with a population of 316,577 and a population density of approximately 1,200 people per square kilometer, based on the 2011 census data (BBS, 2022). Among its unions, Fingri is located at a geographical coordinate of 22.43°N latitude and 89.05°E longitude (BBS, 2022).

Debhata Upazila, also part of the Satkhira District in Khulna Division, spans 258.37 square kilometers and includes 14 unions and 205 villages. The literacy rate in this area is 56.5%, with male literacy at 61.2% and female literacy at 51.5% (BBS, 2022). Located in the northwestern part of Debhata, Kulia Union lies at 22.64°N and 88.98°E. It is bordered by Alipore Union to the north, Parulia Union to the south, and Fingri Union and Bhomra to the east. Bhomra shares a boundary with the Indian state of West Bengal (SDA, 2022).

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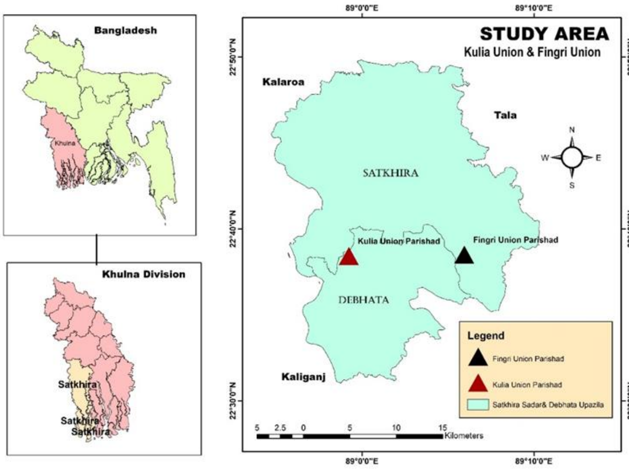

Figure 2.1. Location of the study area in the map.

Methodological framework

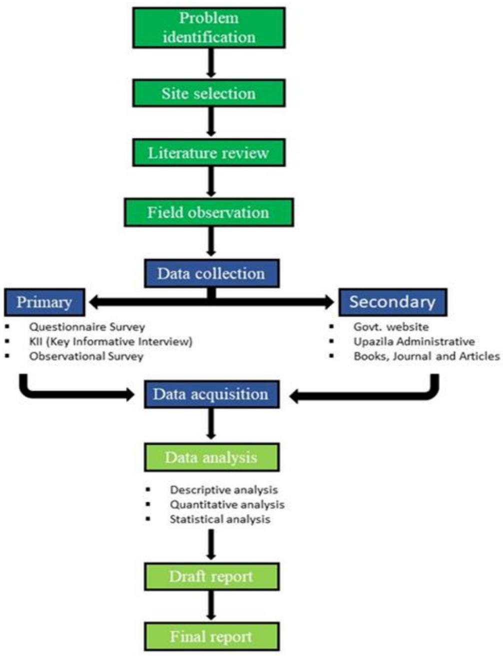

Figure 2.2. Conceptual Framework for the Study

Sample size

Determining the right sample size is a vital component of research design, as it helps ensure that the study can meet its objectives with sufficient accuracy and statistical power. The appropriate sample size is influenced by various factors, including the specific research question, the desired level of significance, the anticipated effect size, and the variability within the data. In this case, it is stated that the sample size of 100 respondents was selected randomly from the study area. Further, the 100 respondents were divided equally between two areas, with 50 respondents from Satkhira Sadar and 50 respondents from Debhata Upazila.

2.4 Collection of data

A sample size of 100 respondents from Satkhira and Debhata Upazila has been selected using random sampling. This sample size is relatively small, but it may be appropriate depending on the research objectives and level of desired significance. The use of random sampling is a good approach as it helps to ensure that the sample is representative of the population of interest and reduces the potential for bias in the sample selection process. The areas of livelihood measured in this study included income sources, employment stability, access to agricultural land, and household expenditure. The theoretical framework followed the Sustainable Livelihoods Framework (SLF), which includes five key components: human, natural, financial, physical, and social capital.

Overall, the design of the questionnaire and the use of random sampling for the sample selection process are good steps towards ensuring that the study is able to provide meaningful insights into the impacts of shrimp farming. However, the quality of the study's findings will depend on the quality of the questions and the accuracy and completeness of the responses provided by the participants.

KII is a research technique used to gather information from knowledgeable individuals who have relevant and valuable insights on a particular topic or issue. The key informants are typically individuals who have specialized knowledge or experience in the field being studied, such as experts, community leaders, or stakeholders. It is widely used in qualitative research to gather in-depth information on specific topics from knowledgeable individuals who have relevant insights and experiences. In this study, one KII was conducted with a Scientific Officer from the Shrimp Culture Demonstration Farm and Training Center. Various important insights were gathered from him.

Data analysis

After collecting the data, the responses were recorded and entered into a spreadsheet. The data were analyzed using statistical software such as SPSS or Excel 2013. The data analysis focused on identifying the patterns and trends in the responses. Various graphs, charts, and tables were also generated with SPSS or Excel. Map prepared by ArcGIS 10.8. Also uses MSWord- 2013.

RESULTS AND DISCUSSION

Demographic information of the respondents

Both male and female respondents are involved in shrimp farming across different age groups. It is notable that there are significantly more males than females in the sample, with 93% males and only 7% females. This could suggest that the shrimp farming community in Satkhira and Debhata is predominantly male. The majority of individuals in the sample fall into the 20-45 age group. This could suggest that the shrimp farming community in Satkhira and Debhata is relatively young. Previous research indicates that individuals aged 16 to 30 accounted for the highest participation rate (45%) in this occupation (Das et al., 2015). It is interesting to note that there are no females under the age of 20 represented in the sample. This could

DOI: https://doi.org/10.55706/jae1739

suggest that young females are not typically involved in shrimp farming in this community.

Table 1. Demographic information of respondents

Variables		Respondent	Percentage
Sex	Male	93	93%
	Female	07	07%
Age	Under 20	03	03%
	20-45	57	57%
	46 and above	40	40%
Education	Illiterate	18	18%
	<SSC	42	42%
	SSC-HSC	32	32%
	Hon's / higher educated	08	08%
Family member	<4	22	22%
	4 to 7	62	62%
	>7	16	16%
Monthly income	<6000	18	18%
	6000-9000	44	44%
	9000-15000	22	22%
	>15000	16	16%
Occupation	Day labour	22	22%
	Part-time farming	34	34%
	Professional farmer	38	38%
	Others	06	06%
Farming experience	<5 years	4	4%
	5-10 years	50	50%
	11-20 years	30	30%
	>20 years	16	16%
Total land	<1 acre	12	12%
	1-5 acre	40	40%
	5-10 acre	30	30%
	>10 acre	18	18%
Fish farming land	<1 acre	15	15%
	1-5 acre	42	42%
	5-10 acre	29	29%
	>10 acre	14	14%
Ownership	Owner farmer	36	36%
	Lease	40	40%
	Lease & Owner	24	24%

The distribution of individuals in the shrimp farming community is based on their educational level. The table categorizes individuals into four groups: illiterate, individuals with education below SSC (Secondary School Certificate), individuals with SSC-HSC (Higher Secondary School Certificate) education, and individuals with Hons (Honors) or higher education. There are 18 individuals in the sample who are illiterate, which represents the smallest group. The largest group consists of individuals with SSC-HSC education, which is the educational level obtained after completing secondary and higher secondary education. This group comprises 32 individuals. The second largest group consists of individuals with an education level below SSC, which is represented by 42 individuals. The smallest group consists of individuals with Hons or higher education, which represents only 8 individuals. There is a lack of highly educated farmers. Higher levels of knowledge increased the likelihood that shrimp farmers would employ environmentally friendly diets and good pond management (Hoque and Hossain, 2016). Rahman (1994) noted that fishermen face social, economic, and educational disadvantages, and they often do not have the financial means to support educational investments. Here, most shrimp farmers are not highly educated, which is the main obstacle to environmentally friendly farming practice.

The distribution of individuals in a certain population based on their number of family members and monthly income. Categorizes individuals into three groups based on the number of family members, which are: less than 4, 4 to 7, and more than 7. Individuals are also categorized into four groups based on their monthly income, which are: less than 6000, 6000-9000, 9000-15000, and more than 15000 (Table 1). In terms of monthly income, the largest group consists of individuals with a monthly income in the range of 6000-9000, with 44 individuals falling into this category. The second largest group consists of individuals with a monthly income of less than 6000, with 18 individuals falling into this category. The other two groups, 9000-15000 and more than 15000, are equally represented in the sample, with 22 individuals in each group. The distribution of individuals in a certain population based on their occupation categorizes individuals into four groups: day laborers, part-time farmers, professional farmers, and others. The largest group of individuals in the sample is engaged in farming, with 38 individuals falling into this category. The second largest group consists of part-time farming, with 34 individuals falling into this category. Day laborers are the third-largest group, with 22 individuals in this category. The smallest group is "other", which includes individuals who are engaged in an occupation that does not fall into any of the other three categories, with only 6 individuals in this category (Table 1). Because of their subsistence-level livelihoods, many seasonal and professional fishers take on various part-time income-generating activities, particularly during periods when fishing yields are low (Paul et al., 2018). A significant number of fishers also participate in agricultural work (Goswami et al., 2002; Rahman et al., 2016; Hossain and Hasan, 2017; Islam et al., 2017).

The farming experience of individuals is present across four categories: <5 years, 5-10 years, 11-20 years, and more than 20 years. In terms of the farming experience of individuals, the data shows that more males have over 20 years of experience (62 individuals) compared to females (6 individuals). The adoption of sustainable shrimp farming techniques, such as the use of organic fertilizers and eco-friendly feeds, was more likely to occur among farmers with more years of farming experience (Tung et al., 2018).

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From the data, we can observe that the experience of the farmers can make shrimp farming more sustainable.

The fish farming lands are further sub-classified into owner-farmer, lease, and lease & owner. The percentage data shows that 24% of farmers have lease & owner land, 36% of farmers have leased land, and 40% of farmers have their own land. This information is shown in the above table-1). Shrimp farming leases are primarily offered by landowners to leaseholders for a fixed period of time, usually 3-5 years, with a rental fee paid in advance. The leaseholders are responsible for managing the shrimp farms and selling the produce. The study also found that many leaseholders are not adequately trained in shrimp farming practices, which can lead to poor quality and low productivity (Islam and Hossain, 2018). Landowners often have greater bargaining power than leaseholders and are able to charge high rental fees, leading to unequal distribution of benefits from shrimp farming. Furthermore, the study revealed that many landowners are not interested in investing in infrastructure or improving the environmental sustainability of shrimp farming (Islam et. al., 2017). So the owner farmer has to concentrate on investing in shrimp farming.

Livelihood

Shrimp farming has a significant impact on livelihoods, according to the respondents. It has been able to create job opportunities for the local community, with 74% of the respondents indicating that shrimp farming has provided employment for people who may have been previously unemployed or underemployed (Fig: 4.2). This suggests that the industry has been successful in addressing the issue of job scarcity in the region. Additionally, none of the respondents indicated that shrimp farming has led to unemployment, indicating that it has not had a negative impact on job opportunities in the local community. Shrimp farming has been found to provide significant income opportunities, particularly for women and other marginalized groups (Islam and summon, 2018). Additionally, the growth of the shrimp farming industry has led to the development of new infrastructure and services that can benefit local communities, such as roads, electricity, and health clinics (Haque and Bell, 2008). However, 26% of the respondents indicated that shrimp farming has led to people migrating to other places for work.

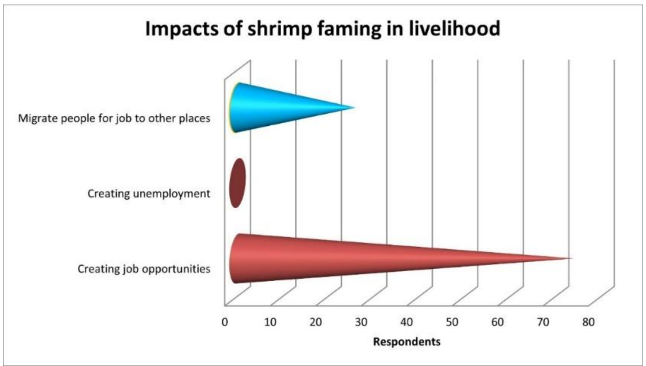

Figure 3.2. Impact of shrimp farming on livelihood

Shrimp farming generally supports local livelihoods by generating employment opportunities within the community and does not appear to contribute to unemployment. Nevertheless, some individuals may still need to relocate to other areas to secure work in the industry. These insights are essential when assessing shrimp farming's contribution to local economic growth and in forming strategies to tackle regional job shortages.

Application of chemicals

During germination and the culture period, various chemicals, fertilizers, and feeding are used. According to the respondent, lime (CaCO3) and bleaching powder are used for chemical applications. The average amount of lime used ranges from 128.5 kg during gher preparation and 175 kg during the culture period (Fig. 4.3). Also, a small amount of bleaching powder is used during gher preparation and the culture period. TSP, MOP, Urea, Potash, etc. However, the majority of farmers apply lime during the pond-drying process after harvesting and prior to refilling it with fresh water. Additionally, large amounts of inorganic fertilizers such as urea and TSP are commonly used (Ali et al., 2016).

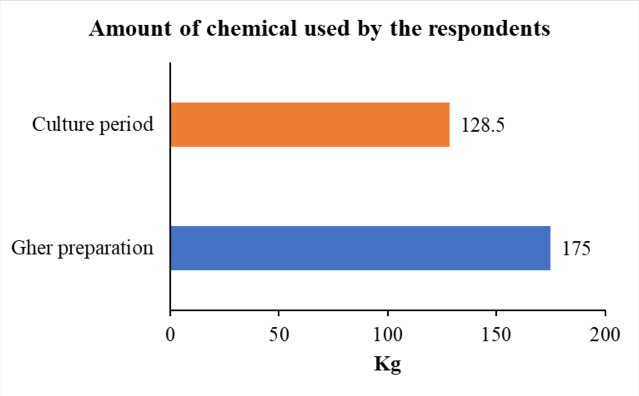

Figure 3.3. Amount of chemical used by the respondents.

In shrimp farming, various chemicals are used to control water quality, prevent disease outbreaks, and enhance shrimp growth. Lime (CaCO3) is commonly used to adjust the pH of water and reduce acidity. Bleaching powder ($CaOCl_2$) is used as a disinfectant to control bacterial and fungal infections in the shrimp pond (Tacon and Metian, 2013). However, excessive use of chemicals can have negative impacts on the environment and the health of the shrimp (Tacon and Metian, 2013). Fertilizers are also used in shrimp farming to provide essential nutrients to the shrimp and promote the growth of phytoplankton, which is the primary food source for shrimp. TSP (triple superphosphate), MOP (muriate of potash), urea, and potash are commonly used fertilizers. However, the amount and type of fertilizer used should be carefully monitored to avoid excessive nutrient enrichment, which can lead to harmful algal blooms and oxygen depletion in the water. (Ahmed et al., 2015).

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Water Supply and Exchange

In the context of shrimp farming in Satkhira, the majority of farmer use a combination of tide and rainwater as their primary source of water supply. This is likely due to the fact that the areas are located near the Bay of Bengal, and the combination of tide and rainwater can provide a reliable and consistent source of water for shrimp farming (Hasan, 2015). The respondents also reported different patterns of water exchange, with the most common being yearly water exchange (76%) Interestingly, only 4% of respondents reported using weekly water exchange (Fig: 4.4). The use of new moon/full moon water exchange was also reported by a small percentage of respondents (20%), which suggests that traditional practices may still play a role in shrimp farming in the region. it was found that 60% of respondents used canal water as their primary water source, while 36% used pond water. The same study found that 67% of farmers practiced yearly water exchange, while 20% practiced monthly exchange (Hasan, 2020). Overall, the findings suggest that the combination of tide and rainwater is a popular source of water supply in the region, and that yearly water exchange is the most commonly used pattern of water exchange.

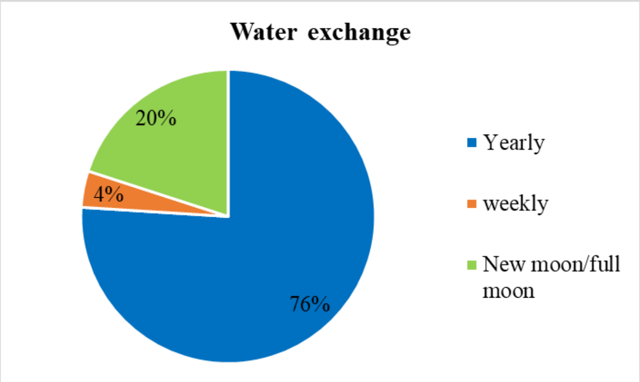

Figure 3.4. Water exchange

Water quality

Water Color

Based on the data (Figure 3.5.1), the majority of the respondents (50%) reported a brownish-green color of water in their shrimp farms. This may be attributed to the accumulation of organic matter, sediments, and other pollutants in the water, a condition frequently observed in shrimp farming. A significant percentage of respondents (32%) reported "others" as the color of water, which is not specified in the given data. This could indicate the presence of various factors affecting water quality, such as the use of chemicals or the presence of algae blooms. Additionally, 15% of the respondents reported a dark green color of water, which could indicate an excess of algae in the water. Algae blooms can harm shrimp and other aquatic organisms and negatively impact water quality. Finally, only 3% of the respondents reported transparent green water, which is the least common watercolor reported. This could indicate a relatively cleaner water source, or a recently flushed and cleaned water tank or pond. The majority of shrimp farmers reported greenish-brown water color in their ponds according to Akter et al. (2014).

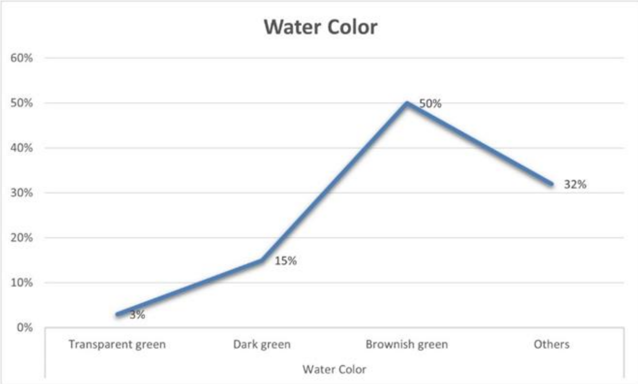

Figure 3.5.1. Water color is due to shrimp farming.

Salinity, DO, and pH

Table 2 presents the water quality parameters used in shrimp farming, including salinity, dissolved oxygen (DO), and pH levels. The salinity values range from 5 ppt to 7 ppt, which is within the acceptable range for shrimp farming. The DO values range from 4.2 ppm to 6 ppm, which is also within the acceptable range for shrimp growth. The pH values range from 6.5 to 8, which is also within the acceptable range for shrimp farming.

The table presents the mean, median, mode, and standard deviation of three water quality parameters (salinity, dissolved oxygen, and pH) measured in two upazilas in Bangladesh (Debhata and Satkhira Sadar). The mean salinity values were found to be 6.666 ppt and 6.572 ppt in Debhata and Satkhira Sadar, respectively. The median and mode values were both 7 ppt in both upazilas, indicating a relatively symmetrical distribution. The standard deviation values were 0.47 ppt and 0.55 ppt, respectively, indicating a moderate level of variation in salinity levels. The mean dissolved oxygen levels were 5.268 ppm and 5.264 ppm in Debhata and Satkhira Sadar, respectively. The median and mode values were both 5 ppm in both upazilas, indicating a symmetrical distribution. The standard deviation values were 0.65 ppm in both upazilas, indicating a moderate level of variation in dissolved oxygen levels. The mean pH values were found to be 7.566 and 7.528 in Debhata and Satkhira Sadar, respectively. The median value was 7.6 in both upazilas, while the mode values were 8, 7.3, 7.8, and 7.4 in Debhata and 7.5 and 7.6 in Satkhira Sadar, indicating a skewed distribution. The standard deviation values were 0.35 and 0.37 in Debhata and Satkhira Sadar, respectively, indicating a relatively low level of variation in pH levels. Overall, the results suggest that there is some variation in water quality parameters between the two upazilas, with slightly lower salinity levels and higher pH levels found in Debhata compared to Satkhira Sadar. Although there are slight variations, the differences in water quality between the two upazilas are not statistically significant, indicating that both areas share similar conditions suitable for shrimp farming. It is important to recognize that the data reflects a single point in time, and water quality indicators such as salinity, dissolved oxygen (DO), and pH can vary by season and location. Salinity plays a crucial role in the growth and health of shrimp and other aquatic species. While black

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tiger shrimp are capable of surviving in a wide salinity range due to their euryhaline nature, the optimal range for their growth is between 10 and 25 parts per thousand (ppt), though they can tolerate levels from 5 to 38 ppt (Rahman et al., 2015). Typically, salinity increases during the dry summer months and decreases during the rainy season. While shrimp can gradually adapt to changing salinity as they mature, maintaining conditions within the optimal range is vital for their growth and survival. For dissolved oxygen, the ideal concentration to support aquatic life ranges between 4.5 mg/L and 8 mg/L (Meybeck, 1989). As for pH, which measures the acidity or alkalinity of water, the scale ranges from 0 (highly acidic) to 14 (highly alkaline), with a neutral value at 7. In the present study, pH ranged from 8 to 8.5 ppm during the dry season and 6.5 to 8.5 ppm during the wet season in prawn, shrimp & prawn and shrimp farms, which was similar to the recommended level of pH for shrimp and prawn farms (Mazid, 2009).

Soil quality

The following table provides a summary of statistical measures for two variables: salinity and pH.

Table 3. The mean, median, mode, and standard deviation for the salinity and pH data of the study area

Parameter	Mean	Median	Standard Deviation
Salinity (ppt)	8.725	8.5	0.825
pH	5.844	5.5	0.873

For salinity, the mean value is 8.725 ppt, which indicates that, on average, the salinity is higher. The median value is 8.5 ppt, which suggests that the data is relatively symmetrically distributed around the middle. The mode values are 8.0 ppt and 8.7 ppt, which implies that there are two distinct peaks in the distribution. The standard deviation of salinity is 0.825 ppt, indicating that the data points are spread out from the mean value.

Here Fig 3.6 shows the spatial distribution of salinity. The figure indicates that Debhata Upazila is more susceptible than Satkhira Sadar.

Table 2. The mean, median, mode, and standard deviation for water salinity, DO, and pH of the study area

Variable	Mean		Median		Standard Deviation	
	Debhata	Satkhira Sadar	Debhata	Satkhira Sadar	Debhata	Satkhira Sadar
Salinity (ppt)	6.666	6.572	7	7	0.47	0.55
DO (ppm)	5.268	5.264	5	5	0.65	0.65
pH	7.566	7.528	7.6	7.6	0.35	0.37

For pH, the mean value is 5.844, indicating that the pH is relatively acidic. The median value is 5.5, which suggests that the data is skewed towards the lower end. The mode value is 5.3, which is the most common value in the dataset. The standard deviation of pH is 0.873, which implies that the data points are spread out from the mean value. Here (Fig. 3.6.1 shows the spatial distribution of pH of Debhata and Satkhira Sadar Upazila.

The salinity values in the table range from 7.8 ppt to 10 ppt, with a mean value of approximately 8.8 ppt. It is worth noting that salinity is a crucial parameter for soil quality, as high salinity levels can limit plant growth and reduce crop yield (Munns and Tester, 2008). The pH values in the table range from 4 to 7.66, with a mean value of approximately 5.9. The pH of soil is another important parameter that can impact plant growth and nutrient availability, with acidic soils being less fertile than alkaline soils (Brady, 2008).

Impacts on the environment

Impact of flooding on shrimp farming

Ahmed and Diana (2015) reported that various climate-related factors, such as coastal flooding, cyclones, rising sea levels, increased salinity, drought, changes in rainfall patterns, and sea surface temperature, have negatively impacted shrimp farming and the socioeconomic well-being of farming communities. To reduce flooding, they suggest building infrastructure such as dams, flood walls, proper land use planning, and public awareness creation by the govt. Flooding has further impacts on shrimp, also. According to Seekao (2016), shrimp farmers commonly adapt to flooding by installing nets around their ponds and building dykes to protect the shrimp enclosures.

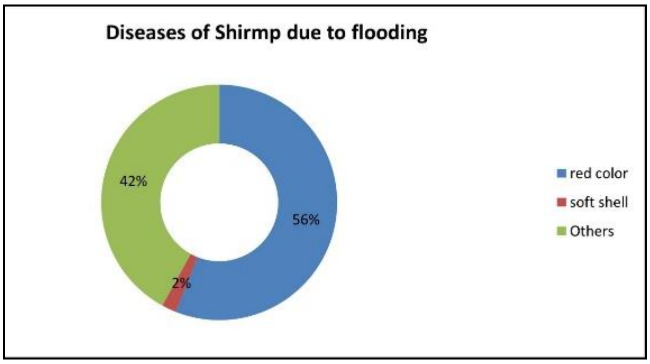

Figure 3.7.1. Impacts of flooding on shrimp farming.

As shown in Figure 3.7.1, out of 100 reported cases of shrimp diseases, 56 involved a condition that caused the shrimp to turn red, 2 cases were linked to soft shell disease, and the remaining 42 cases were due to unspecified illnesses. Flooding introduces harmful substances into the water and increases turbidity, which disrupts light penetration and inhibits photosynthesis, ultimately reducing

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shrimp productivity. Despite these risks, only 27.5% of respondents reported taking adaptive measures to minimize flood-related damage (Islam, 2018).

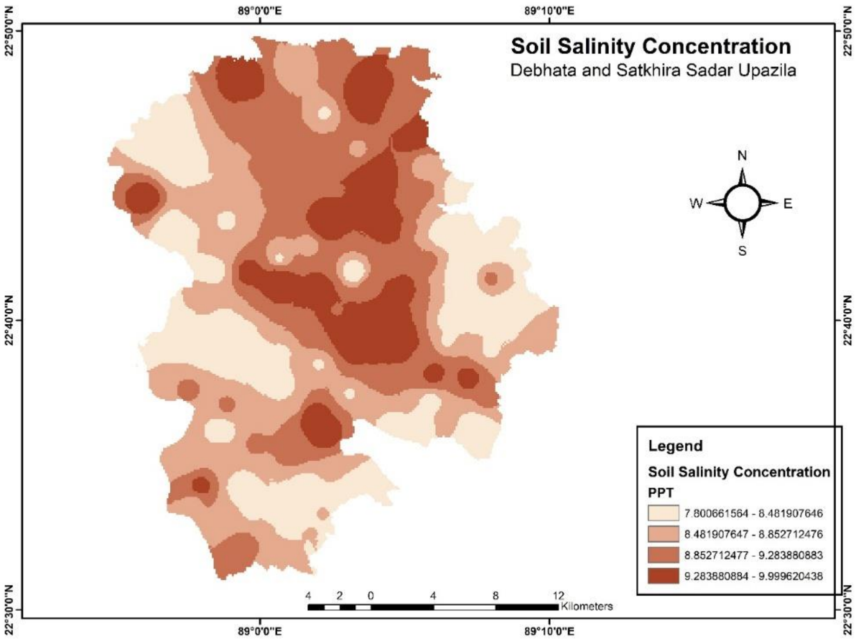

Figure 3.6. Spatial distribution of salinity concentration.

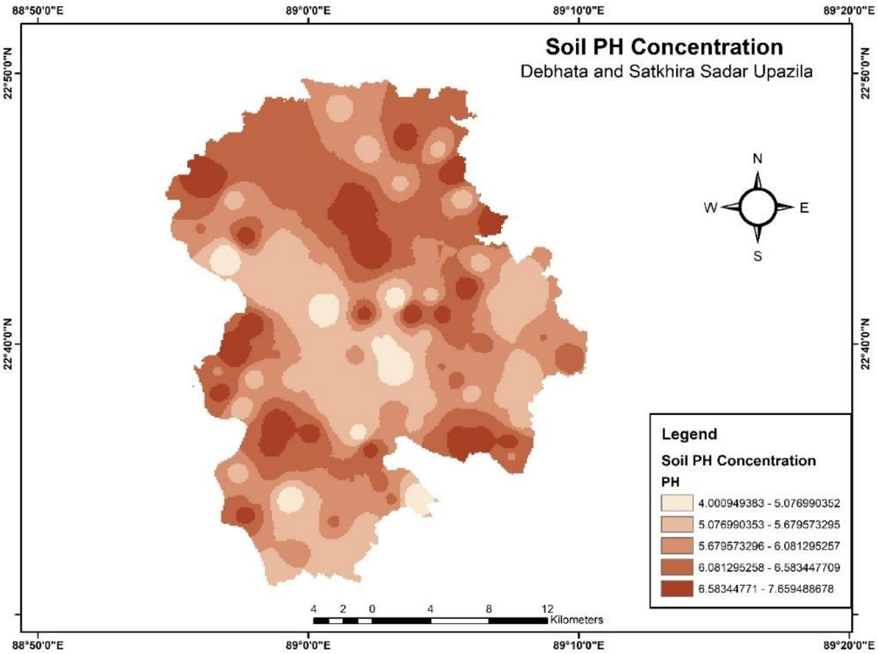

Figure 3.6.1. Spatial distribution of pH concentration

Shrimp farming impact on mangrove forests

According to 28% of respondents (Figure 3.7.2), shrimp farming has had adverse effects on mangrove forests. Reported impacts include river damming, a decline in native fish populations, and deforestation of mangrove areas. Among the most serious environmental consequences of shrimp farming is the degradation of mangrove ecosystems, which serve as essential habitats for marine species and contribute significantly to climate regulation. A case study by Ahmed et al. (2017) revealed that shrimp farming had led to the large-scale destruction of mangrove forests in a coastal region, resulting in biodiversity loss and increased carbon emissions. These negative effects can be reduced through the adoption of

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sustainable aquaculture practices and the enforcement of policies aimed at conserving and restoring mangrove habitats (Abdullah et al., 2017).

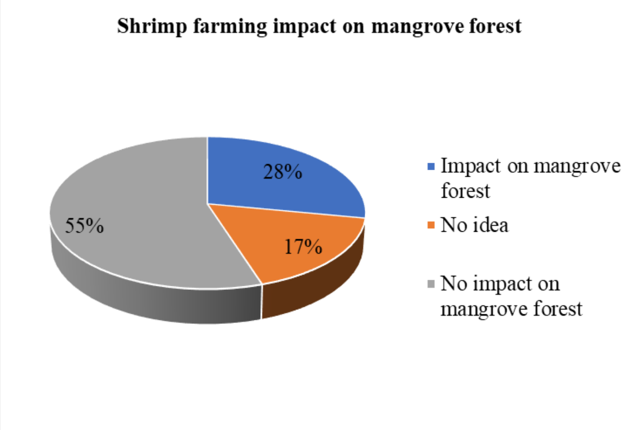

Figure 3.7.2. Shrimp farming impact on mangrove forests.

Shrimp farming impact on livestock production

Islam and Tabeta (2016) reported a significant decline in traditional cropping patterns and major crop production. Their findings also indicate that shrimp farming may negatively affect livestock production, particularly in regions where agricultural and livestock activities are closely linked. One of the key concerns is the loss of grazing land and the resulting shortage of fodder crops, which has contributed to a gradual decrease in livestock numbers.

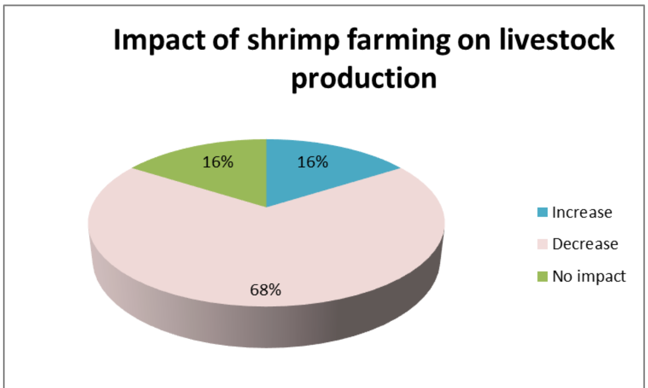

Figure 3.7.3. Impact of Shrimp farming on livestock production.

According to survey data illustrated in Figure 3.7.3, only 16 out of 100 respondents felt that shrimp farming had a positive influence on livestock production. In contrast, 68 believed it had a negative effect, while the remaining 16 respondents perceived no impact at all. These responses suggest a prevailing belief that shrimp farming adversely affects livestock rearing in the area. Shrimp farming has negatively affected the quality of available grazing lands by reducing soil fertility and increasing soil salinity, which can lead to a decline in livestock productivity. Moreover, the discharge of effluent from shrimp farms can contaminate nearby grazing lands and water sources, further reducing the productivity of livestock (Hossain et al., 2018).

Impact of shrimp farming on indigenous fish

Shrimp farming has also impacted the local environment. Based on the information (Figure 3.7.4), the respondents, out of the total responses, 64% of respondents reported that shrimp farming led to a decrease in the population of indigenous fish, while only 2% reported an increase. Additionally, 34% of respondents reported no impact of shrimp farming on indigenous fish. While this may seem like a significant proportion, the fact that the majority of responses indicate a negative impact suggests that there is a cause for concern when it comes to the impact of shrimp farming on indigenous fish populations. Shrimp farming has been found to contribute to the depletion of wild fish stocks due to the high demand for fishmeal and fish oil used in shrimp feed (Islam et al., 2019). The introduction of non-native shrimp species has resulted in the displacement of indigenous fish populations and the loss of important ecological functions performed by these species, such as seed dispersal and nutrient cycling (Alam et al., 2017).

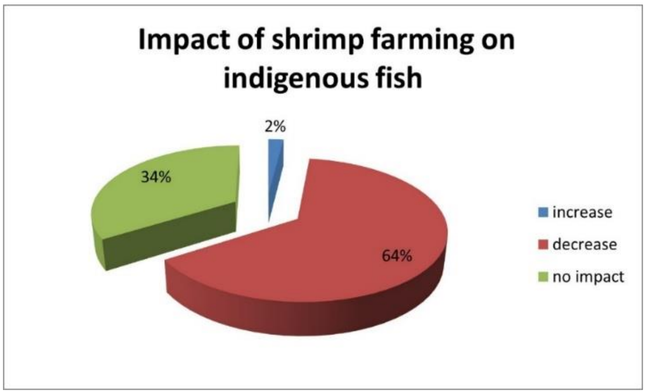

Figure 3.7.4. Impact of shrimp farming on indigenous fish.

Water pollution due to shrimp farming

There are several causes of water pollution due to shrimp farming (Figure 3.8), narrated by the respondents. The maximum amnestied chemical fertilizer (46%), antibiotic drugs (16%), pesticides (22%), and others (16%).

To reduce the impact of water pollution, the data suggest that reducing the use of chemical fertilizers and agrichemicals and implementing water treatment and filtration systems can be effective strategies (Khan et al., 2021). Moreover, the discharge of wastewater from shrimp farms can pollute nearby water bodies, causing harm to aquatic life and potentially to human health as well (Nguyen et al., 2020).

Water turbidity due to Shrimp farming

Shrimp farming can cause water turbidity, which is a measure of the cloudiness of water caused by suspended particles. Soil erosion, uneaten feed, fecal matter, chemicals, and antibiotics can all contribute to water turbidity (Rakib et al., 2022). The number of responses is shown in (Fig. 3 .8.1). About fifty percent of respondents mentioned soil erosion, thirty-two percent uneaten feed and fecal matter for water turbidity. Shrimp farming has a significant impact on water turbidity, with turbidity levels being higher in the shrimp farming areas compared to non-shrimp farming areas. High levels of water turbidity can have negative impacts on aquatic ecosystems, including a reduction in the growth and survival of aquatic organisms, and an increase in the risk of disease outbreaks (Islam et. al., 2021).

To reduce the impact of water turbidity, the data suggests implementing measures such as reducing chemical fertilizer use, improving pump and aeration systems, and addressing uneaten feed and fecal matter (Binish et al., 2022).

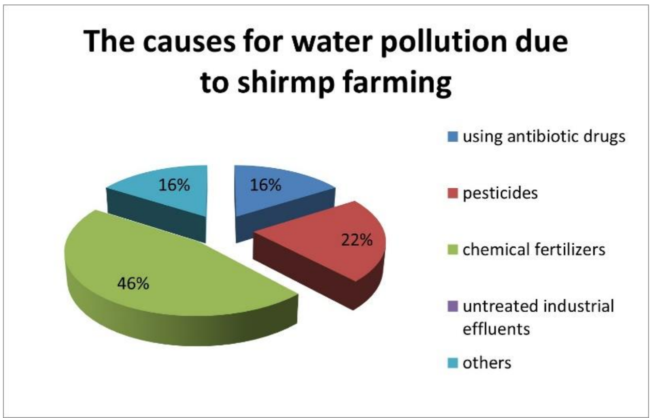

Figure 3.8. The causes for water pollution due to shrimp farming.

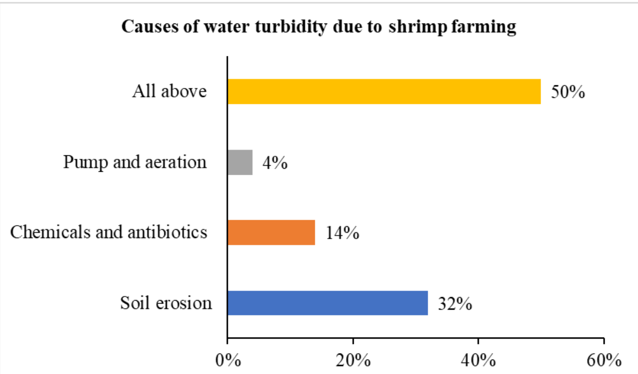

Figure 3.8.1. Causes of water turbidity due to Shrimp farming.

Agrichemicals used in shrimp farming can also have negative effects on water quality, including changes in water gases and odor. To reduce the impact of agrichemicals on water, the data suggests reducing the use of chemical fertilizers and agrichemicals and implementing proper management practices.

Impacts of shrimp farming on grazing land

As shown in Figure 3.9, 32 out of 100 respondents reported that shrimp farming had led to a reduction in available grazing land. The transformation of grazing areas into shrimp ponds has resulted in the loss of essential pasture resources, contributing to a decline in livestock production and negatively affecting the livelihoods of local communities (Hossain et al., 2013). Additionally, waste generated from shrimp farms—such as uneaten feed and feces—contains high concentrations of nutrients and organic matter, which can cause soil and water contamination, further degrading the quality of grazing land (Islam et al., 2019). Implementing sustainable shrimp farming techniques, including repurposing abandoned shrimp ponds for grazing and encouraging integrated farming approaches, can help lessen these negative effects and support the preservation of natural resources.

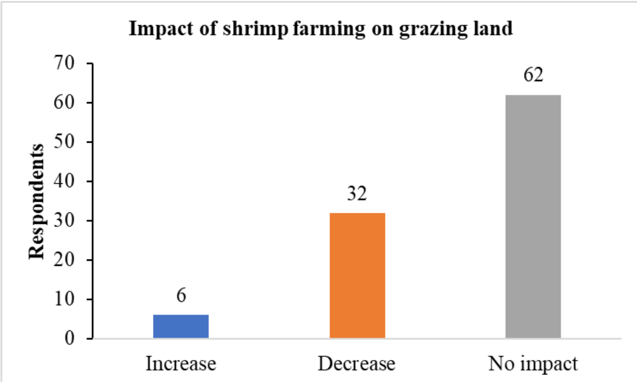

Figure 3.9. Impact of shrimp farming on grazing land.

Impacts on the air

Shrimp farming can significantly affect air quality by introducing various pollutants. However, 96% of respondents were unaware of the direct impacts on air quality. Nevertheless, they were familiar with the most common pollutants associated with shrimp farming, including odors, dust, and greenhouse gases such as methane and nitrous oxide. As shown in Figure 3.10, 34% of respondents identified greenhouse gases as a major pollutant. These emissions largely result from the use of fossil fuels in shrimp farm operations and the destruction of mangrove forests, which are vital carbon sinks (Ahmed and Glaser, 2016).

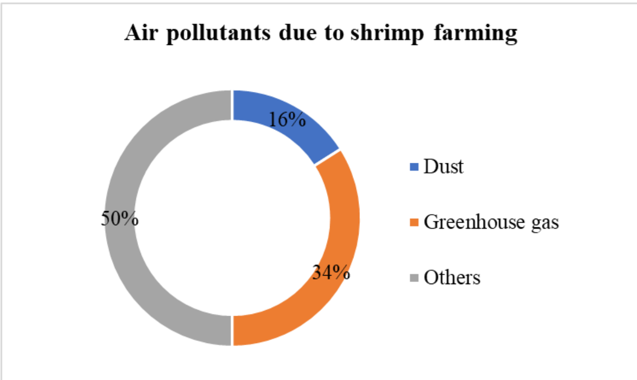

Figure 3.10. Air pollution due to shrimp farming.

The sources of greenhouse gas emissions in shrimp farming can vary, but some of the main contributors include the decomposition of organic matter, energy-intensive

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equipment, transportation, and shrimp feed production (Fig. 3.10.1). The maximum respondents mentioned shrimp feed production.

To reduce emissions from shrimp farming, there are several strategies that can be employed. One approach is to use more environmentally friendly machinery and equipment that consumes less energy and produces fewer emissions. Another option is to improve transportation methods to reduce fuel consumption and emissions. Several sources of greenhouse gas emissions are associated with shrimp farming, including the use of fossil fuels for pumping water and aeration, the decomposition of organic matter in ponds, and the discharge of effluent from shrimp farms (Islam et al., 2019).

In addition to these strategies, there are also several practices that can be implemented on shrimp farms to reduce emissions. For example, using more efficient feed production methods and reducing the amount of organic matter on the farm can help reduce methane emissions. By implementing these strategies, it is possible to reduce the impact of shrimp farming on air quality and the environment as a whole.

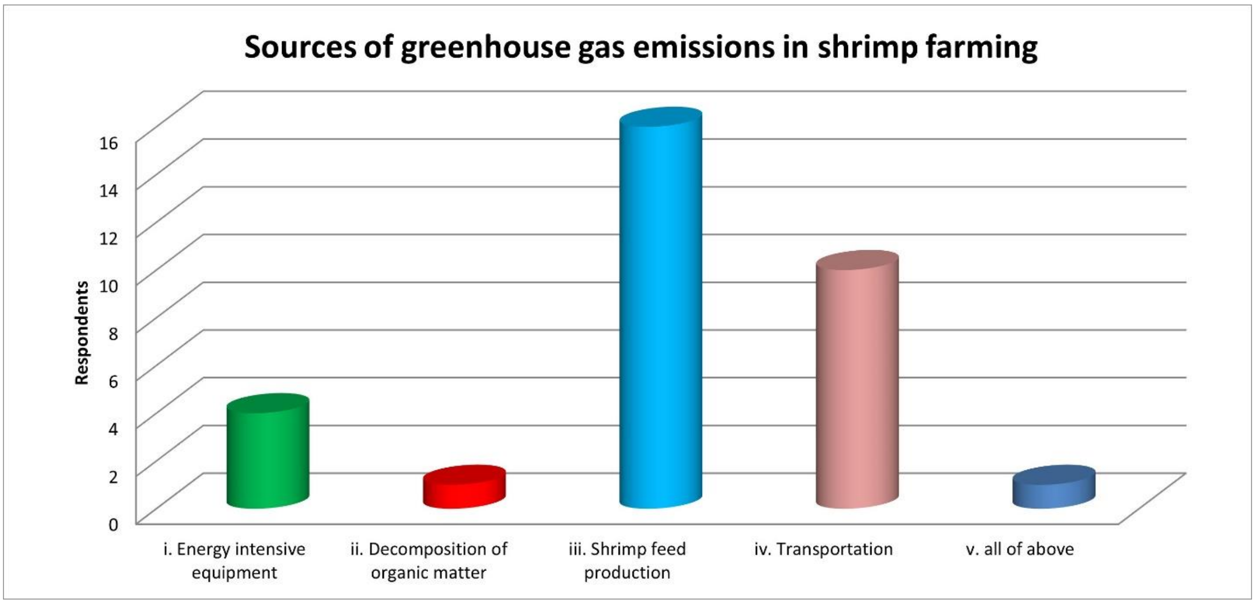

Figure 3.10.1. Sources of greenhouse gas emissions due shrimp farming.

Impacts on health

Human health

The fig. 3.11.1 summarizes the reported health effects of shrimp farming on the human body. Out of the responses received, 32 individuals reported experiencing melanosis, which is a discoloration of the shrimp meat that occurs when the shrimp are stressed. This condition is not harmful to human health, but it can affect the appearance of the shrimp. Four individuals reported experiencing skin disease, which can occur in people who come into direct contact with shrimp or shrimp waste, such as farmers or processors. Interestingly, none of the respondents reported experiencing diarrhea or abdominal pain, which are commonly associated with consuming contaminated shrimp or water that has been polluted by shrimp farming practices. Shrimp farming has the potential to cause negative effects on human health, particularly for those who are exposed to chemicals and antibiotics used in the farming process. Chemicals like pesticides and herbicides are commonly applied in shrimp ponds to manage pests and diseases, but their use can lead to contamination of nearby water and soil. This contamination poses significant health risks to local communities, including higher chances of cancer, respiratory conditions, and neurological issues (Islam et al., 2017). Furthermore, the use of antibiotics in shrimp farming has been associated with the emergence of antibiotic-resistant bacteria, which can represent a major threat to human health (Cabello et al., 2013).

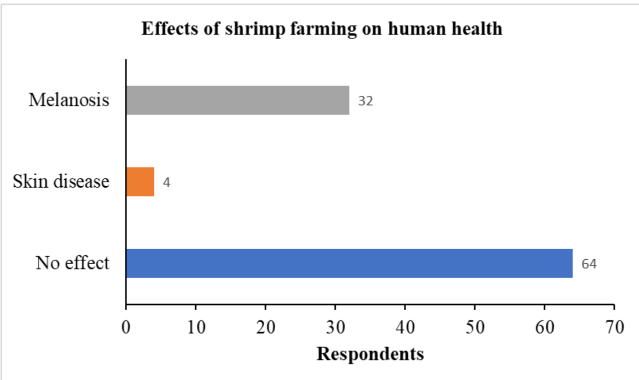

Figure 3.11.1. Effects of shrimp farming on human health.

Impact of shrimp farming on worker health

This study also includes a question about whether individuals have experienced respiratory problems while living near a shrimp farm. Out of the responses received, 70

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individuals answered "no," while 30 answered "yes. The maximum respondent reported they suffer from allergies, infectious disease (Fig. 3.11.2).

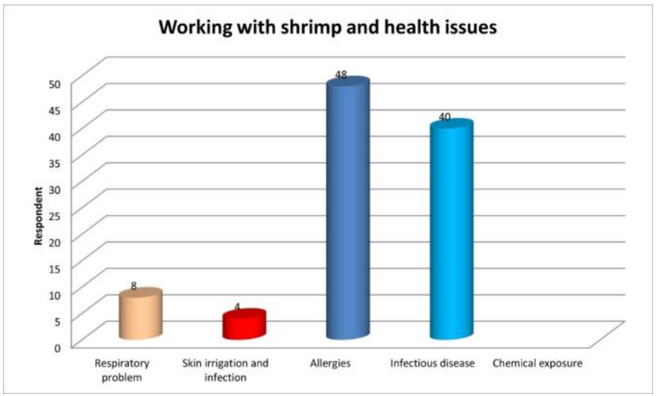

Figure 3.11.2: Impact of shrimp farming on worker health.

However, the potential health risks associated with shrimp farming should still be taken into consideration to ensure the safety and well-being of workers and nearby residents. A study conducted in Bangladesh found that the concentration of pesticides and heavy metals in farmed shrimp was higher than in wild-caught shrimp, indicating a potential health risk for those who consume farmed shrimp (Bhattacharjee et al., 2017). In addition to chemical and antibiotic use, shrimp farming can also have social and economic impacts on nearby communities. Land conversion for shrimp farming can displace local communities and disrupt traditional livelihoods, leading to social and economic instability (Sultana et al., 2019).

CONCLUSIONS

Education played an important role in reducing the use of antibiotics and other harmful chemicals in shrimp farming, which can have negative impacts on the environment and human health. Most shrimp farmers are not highly educated, which is the main obstacle to environmentally friendly farming practice. Shrimp farming is important for food, income, and employment opportunities globally, but has negative impacts on the environment, health, and livelihoods. It can cause deforestation, soil-related problems, water and air pollution, as well as health issues for workers. While shrimp farming in Satkhira and Debhata upazilas creates job opportunities, it also has negative impacts on the environment and worker health. To mitigate these impacts, sustainable alternatives should be explored. Proper management practices can make shrimp farming environmentally friendly and sustainable. These include natural feed, efficient water management, and proper waste disposal. Implementing these practices can help reduce negative impacts on the environment and human health while maximizing the industry's positive contributions to the economy and food security. To improve sustainability, the study recommends promoting the use of natural feed, better water management, and training programs to raise awareness about environmental practices. Ensuring access to clean water and supporting small-scale farmers with technical guidance could further mitigate negative impacts while maintaining the livelihood benefits of shrimp farming in the region.

Author's contributions

All authors contributed to the conception and design of the study. Material preparation, data collection, and analysis were performed by MAH, MAAK, and SK. The first draft of the manuscript was written by BR, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgments

The authors would like to thank all who helped with data collection during the survey time.

Conflict of Interest

There is no conflict of interest to declare.

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