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Chapter- 18

Assessing the Uncertainties of Inland Shrimp Farming in Purba Medinipur: A Comprehensive Study

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Keywords: Shrimp culture, Water parameter, Hardness, Inland shrimp farming, Juvenile mortality

Abstract:

Inland shrimp farming is a highly profitable business and growing industry in Purba Medinipur, West Bengal, India, presenting various opportunities and challenges. The study evaluates environmental, economic, and social uncertainties impacting shrimp farming practices. Key ecological factors include water quality, disease outbreaks, and climate change, which pose significant risks to shrimp health and productivity. The usage of groundwater for inland shrimp farming is responsible for changing water parameters in different inland areas of Purba Medinipur. The hardness level in water is one of the important parameters responsible for the juvenile mortality of shrimp in inland shrimp cultures. Economic uncertainties involve market price fluctuations, high initial investment costs, and access to credit and subsidies. Social factors encompass labor availability, community acceptance, and potential conflicts over land and water use. Findings highlight the critical need for adaptive management strategies, improved disease control measures, and robust financial support systems to mitigate risks. Policy recommendations emphasize sustainable practices, enhanced infrastructure, and community engagement to ensure the long-term viability and resilience of inland shrimp farming in Purba Medinipur.

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Introduction:

Purba Medinipur is traditionally famous for its rich agricultural productivity for many decades. The major agricultural activity includes paddy cultivation as a primary occupation for local people. However, a shift in land use pattern has been evident during the last few decades due to the rapid extension of vannamei shrimp farming into the adjacent areas of the Bay of Bengal as well as various inland areas of Purba Medinipur that are distant from the coastal belt. Vannamei shrimp is commonly known as white shrimp which is so economically important in the aquaculture field (Junda, 2018). Vannamei shrimp cultivation is performed under brackish water conditions (Boyd et al., 2021). The coastal belt of the Bay of Bengal, including Purba Medinipur, offers an ideal condition for vannamei shrimp farming due to its proximity towards the shore and easy availability of brackish water. So many vannamei shrimp farms have been established along the coast supporting the livelihood of local people. However, the intensification of vannamei shrimp culture is increasing in various inland areas of the Purba Medinipur district. The multifaceted impact of inlandification on agricultural and socio-economical status has been evident during past few years. The paddy cultivation is severely affected by an increased level of salinity in soil and water. The yield of crop production has been declining due to increased salinity resulting economic instability among local people (Kumaran et al., 2017). Water quality parameters can be one the major responsible factors for the failure of shrimp farming in these inland areas of Purba Medinipur, West Bengal. Some common consequences of the failure of vannamei shrimp farming in this region are loss of investment, reduced income and disrupted livelihood of local people (Maiti et al., 2021).

Materials and method:

This research work aims to study and compare the frequency of inland vannamei shrimp culture in three different areas of Purba Medinipur district. The study was performed based on extensive field surveys and primary data that were collected from Vannamei shrimp farms. Some statistical methods were used to analyze the collected data sets.

Study area:

We took three study areas for our research work. Three areas are significantly distinct and distant from each other. Three geographical areas are near coastal areas, far from coastal areas and too far from coastal areas. These three distinct locations will help to examine the impact of water quality parameters and other constrains that are related to vannamei shrimp culture.

Site 1: This study site (Fig.1) is situated far from coastal area. It will help to study the alternative source of water for inland vannamei shrimp culture. Additionally extensive study in this area helped us to know the maintenance of optimum water quality parameters in shrimp culture ponds. This study area comes under Contai I block of Purba Medinipur district of West Bengal in India. Primary information was collected from many shrimp farms of Uttarkhasda village (latitude 21°48´52.5´´ N; longitude 87°40´52.5´´E).

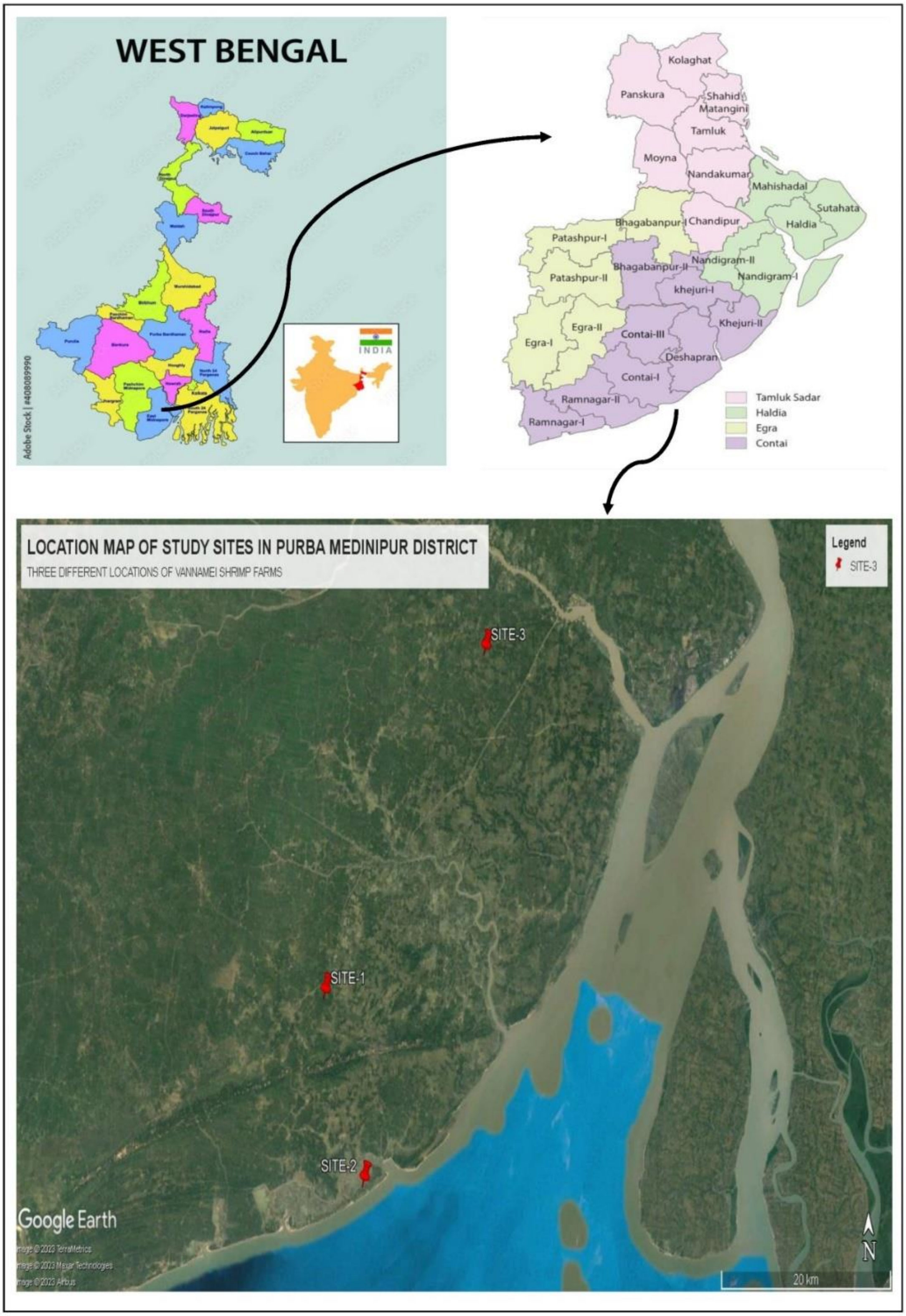


Figure 1. Three different locations of vannamei shrimp farms in Purba Medinipur of West Bengal, India (Source: Google Earth).

Site 2: The study site (Fig.1) is situated near coastal area. So, there is easy access to salt water, which is a major challenge in the case of inland shrimp cultures. This study area comes under Contai-I block of Purba Medinipur district of West Bengal in India. Several villages near Soula Sea Beach (latitude 21°40'48.00"N; longitude 87°43'38.00"E) have been extensively visited for our research work.

Site 3: This area (Fig.1) is located so far from the coast line. It will help us to compare between two inland shrimp cultures as well as to know the various challenges associated with inland shrimp culture. This area comes under Chandipur block of Purba Medinipur of West Bengal in India. Primary data were collected from several shrimp farms in Balabhadrapur village (latitude 22° 4'4.61"N; longitude 87°51'51.75"E).

Instrumentation:

Various water quality parameters were measured by applying different instrumentation and methods. Salinity was measured by following the standard Strickland and Parsons Method, dissolve ammonia was measured by Liddicoat method, nitrite was measured by Shinn method, alkalinity that includes carbonate and bicarbonate ions was measured by Anderson and Robinson method, total hardness was measured by EDTA method and pH was measured by using TOA (WQC22A, Japan).

Result and Discussion:

Inlandification and its consequences:

The practice of cultivation of white shrimp named *Litopenaeus vannamei* in inland areas of Purba Medinipur indicates the inlandification of vannamei shrimp culture in Purba Medinipur district of West Bengal, India. In recent years, this shift from brackish water shrimp farming to inland shrimp farming has been seen, and this trend is gaining so much popularity due to its high profit-to-investment ratio. The rapid expansion of vannamei shrimp farming creates conflict in land use patterns as the conversion of agricultural land or freshwater systems is essential for inland shrimp farming. It is evident that this can disrupt the existing agricultural practices (Maiti et al., 2021). The significant increase in inland shrimp farming can be easily seen by the comparison between the 2000 and 2020 heat maps (Fig. 2) of the vannamei shrimp farming areas of the Contai I block. This heat map comparison clearly indicates that the shrimp farming areas have taken over the fertile agricultural lands as well as freshwater ponds during last two decades (Maiti et al., 2021). There is a gradual increase in the vannamei shrimp culture in Study site-3, which is too far from the coastal area. In 2013 there was no trace of any shrimp culture pond. The change in land use pattern due to shrimp culture in those inland areas is clearly observed by comparing different satellite images (Fig. 3).

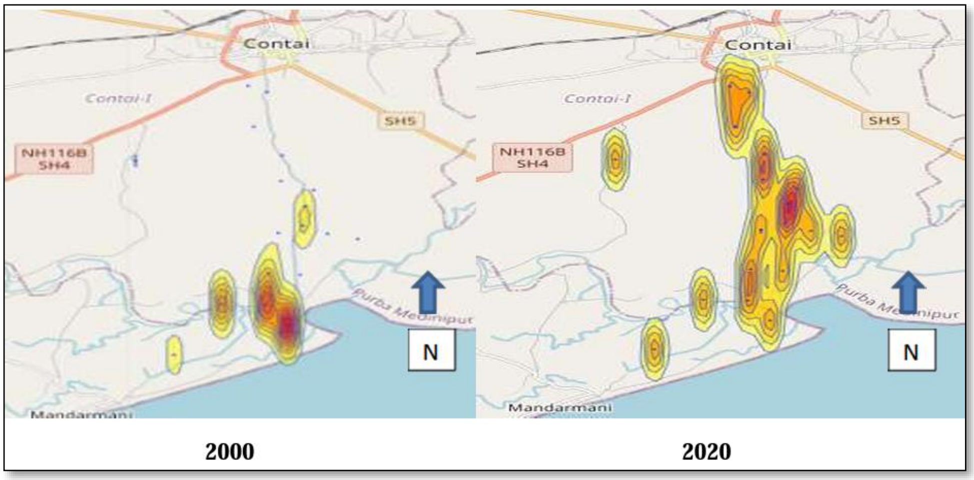


Figure 2. Comparison between 2000 and 2020 heat maps of shrimp culture areas of Contai-I block (source: Maiti et al., 2021).

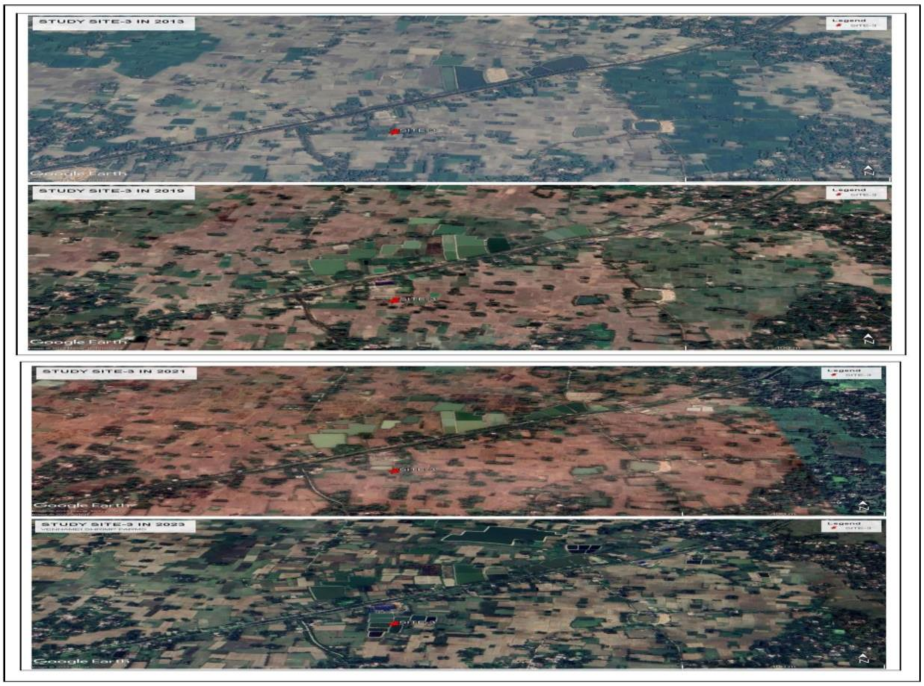


Figure 3. Comparison of study site-3 by satellite imagery at different time stamps showing inlandification of shrimp culture.

Comparison between agricultural areas and shrimp farming areas shows a negative correlation, indicating the increase of shrimp farming lands with decreasing agricultural land from 2000 to 2020. However, in between 2019 and 2020 there was almost no change of agricultural land due to vannamei shrimp farming in Contai I block. A little decrease in inland shrimp culture was evident during 2019-2020 due to low productivity of shrimp farms (Maiti et al., 2021).

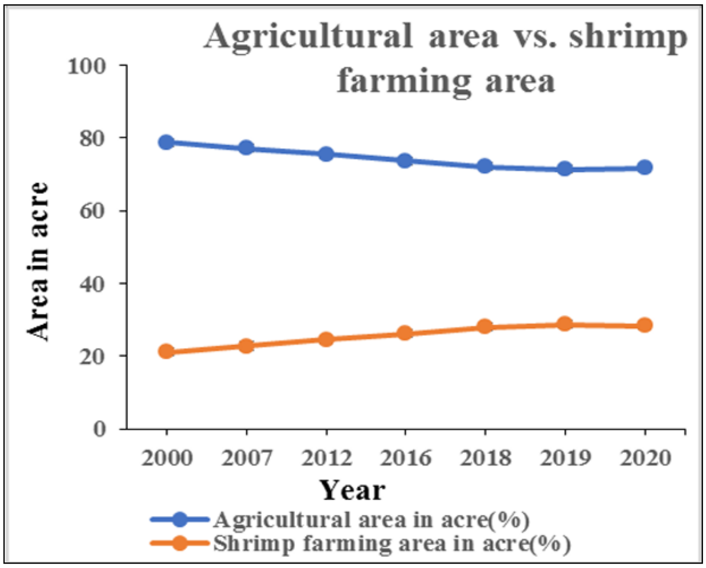


Figure 4. Negative co-relation between agricultural area and shrimp farming area of Contai I block.

A significant amount of water is required for vannamei shrimp culture. So, competition for freshwater can be seen between shrimp farmers and others agricultural farmers. As a huge amount of ground water is used for shrimp farming in inland areas, scarcity of water is already a major concern for local communities.

The comparison between annual shrimp yield per acre and shrimp farming areas during 2012-2019 is showing the rapid increase of total shrimp farming area with the gradual decrease of annual shrimp yield per acre. This indicates the increasing risk of vannamei shrimp farming in inland areas and farmers are facing financial losses with increased shrimp farming areas.

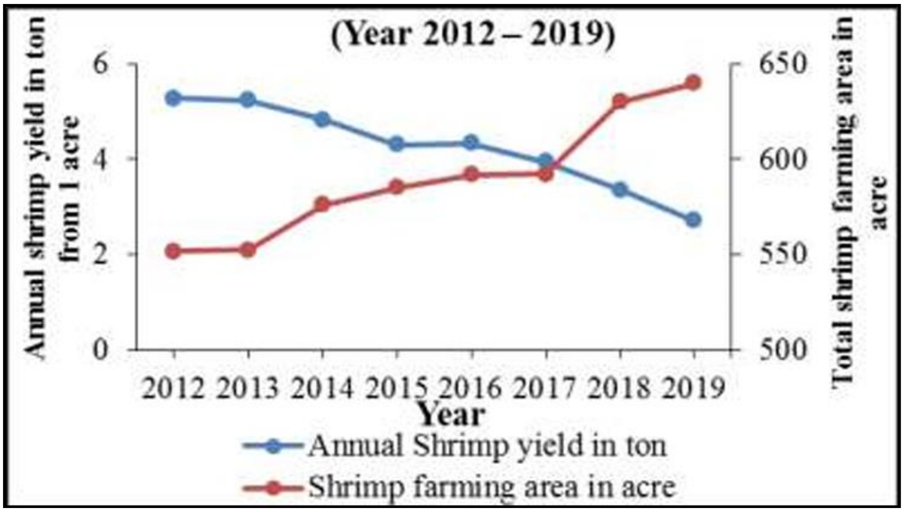


Figure 5. Comparison between shrimp farming area and annual shrimp yield in study site -1.

Water quality parameters:

The health, growth and overall success of shrimp farming directly depend on the water quality parameters of shrimp culture ponds (Carbajal-Hernández et al., 2013). There are several factors, such as pH, salinity, dissolved oxygen, Total Ammonia Nitrogen (TAN), hardness, alkalinity and others, play a crucial role in shrimp farming. Water temperature is one the major important factors responsible for better growth of white shrimp. Comparatively warmer water enhances the metabolic activity of shrimp, improving digestion and nutrient absorption. However the temperature below or above optimal range leads to cessation of growth and mortality. The white shrimp can tolerate wide range of salinity as they are euryhaline in nature. They can tolerate 5 to 25 ppt of salinity range. The optimum salinity range (10-25 ppt) in culture ponds maintains the osmotic balance and proper physiological functions in the shrimp. Extreme fluctuation of salinity can disrupt the osmoregulation and increase the susceptibility towards disease (VVenkateswarlu, 2019). The optimal pH (7.5 to 8.5) range ensures the proper enzymatic activity of shrimp. The pH values outside the optimum range cause reduces growth and nutrient absorption (VVenkateswarlu, 2019). The sufficient dissolved oxygen is maintained by proper aeration in shrimp culture ponds. The proper dissolved oxygen level (3.5 to 4 ppm) helps the white shrimp to grow faster and maintain their health. Low dissolved oxygen can cause mass mortality of shrimp in culture ponds due to hindrance in respiration (Maiti, 2018). High levels of ammonia are toxic to shrimp health. So, the level of ammonia needs to be less than 0.1 ppm. Proper management of wastewater and regular exchange of water help to maintain low concentrations of ammonia in water. As hardness of water is one of the major water quality parameters responsible for the growth of shrimp, it needs to be maintained carefully. The optimum range of hardness in water is 1000-3000 ppm. However, the extremely high level of hardness in culture ponds causes huge juvenile mortality at early stage of shrimp culture (VVenkateswarlu, 2019). Several other water parameters like BOD, COD, total nitrite nitrogen, and sulphide also play crucial roles in vannamei aquaculture in inland as well as coastal areas.

Table 1. Optimum water quality parameters for shrimp growth.

Water parameter	Optimum range
Salinity	10-25 ppt
pH	7.5-8.5
Dissolved Oxygen (DO)	3.5-4 ppm
Total nitrite nitrogen	1.0 ppm
Total ammonia	< 1.0 ppm
Temperature	26-32 (°C)
Alkalinity	100-300 ppm
Total hardness	1000-3000 ppm
CO_3	0-40 ppm
HCO_3	100-300 ppm

Vannamei shrimp culture in inland areas needs mixture of saline water and freshwater for better growth of shrimp. Water quality parameters change with the composition of freshwater and saline water. There is change in certain water parameters that can be measured while using only freshwater or only saline water, or a mixture of both. To ensure the optimal growth of shrimp it is very important to control these parameters. The salinity level of mix water varies depending upon the mixture of freshwater and saline water. The white shrimp, *Litopenaeus vannamei* can tolerate wide range of salinity and can grow with freshwater treatment. But culture in freshwater shows a significant hike of total hardness above optimum range. The normal range of harness is about 1000-3000 ppm. During June to August in 2022, a culture using only freshwater has showed the average hardness level of 6732 ppm. This abnormal level of hardness in water was responsible for mass mortality of juveniles I shrimp culture ponds. The pH of the water in culture pond depends upon the source of freshwater and saline water. However, throughout field measurement of water parameters no abnormalities have been found related to pH level of water in shrimp culture ponds. Several other parameters like alkalinity, ammonia and nitrate have found within normal range in culture ponds.

The shrimp culture ponds in study site-1, which are far from coastline, have shown extraordinarily high levels of total hardness in water. The water parameters of four consecutive shrimp cultures were measured at different months. The measurement of water parameters was taken several times during June to August in 2022. In this culture, only freshwater or ground water was used to cultivate shrimp. All the measured parameters were normal except the level of hardness in water. The second culture took place from October to December 2022, and this time also, water parameters were also measured several times. In this culture, freshwater and saltwater were mixed at 6:4 ratios to prepare culture ponds. Here hardness level was significantly lower than previous culture but still it was far more than optimum range. In the third and fourth cultures, which took place from January to March and April to May in 2023, freshwater and saltwater were mixed at a 7:3 ratio. This time hardness is still higher than optimum range. Figure 6 and Figure 7 show the change in water quality parameters of the shrimp culture pond in study site-1 at different ratios of freshwater and saltwater mix. Interestingly though last two cultures (shown in Fig.6) had same ratio of mixed water, the hardness level was not same.

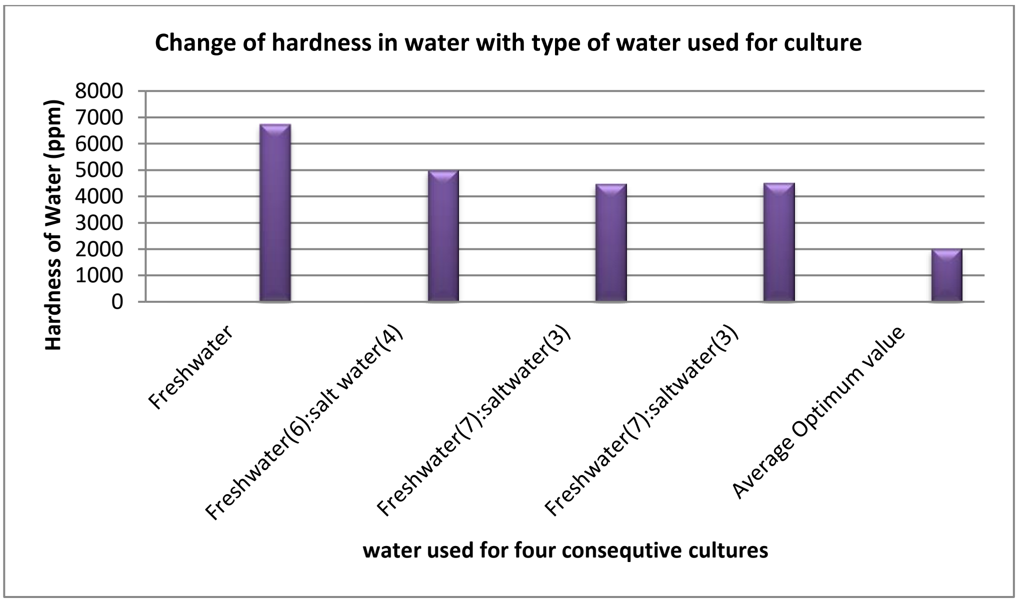


Figure 6. Change of hardness in water during 2022-23 with different mixed water and freshwater in study site-1.

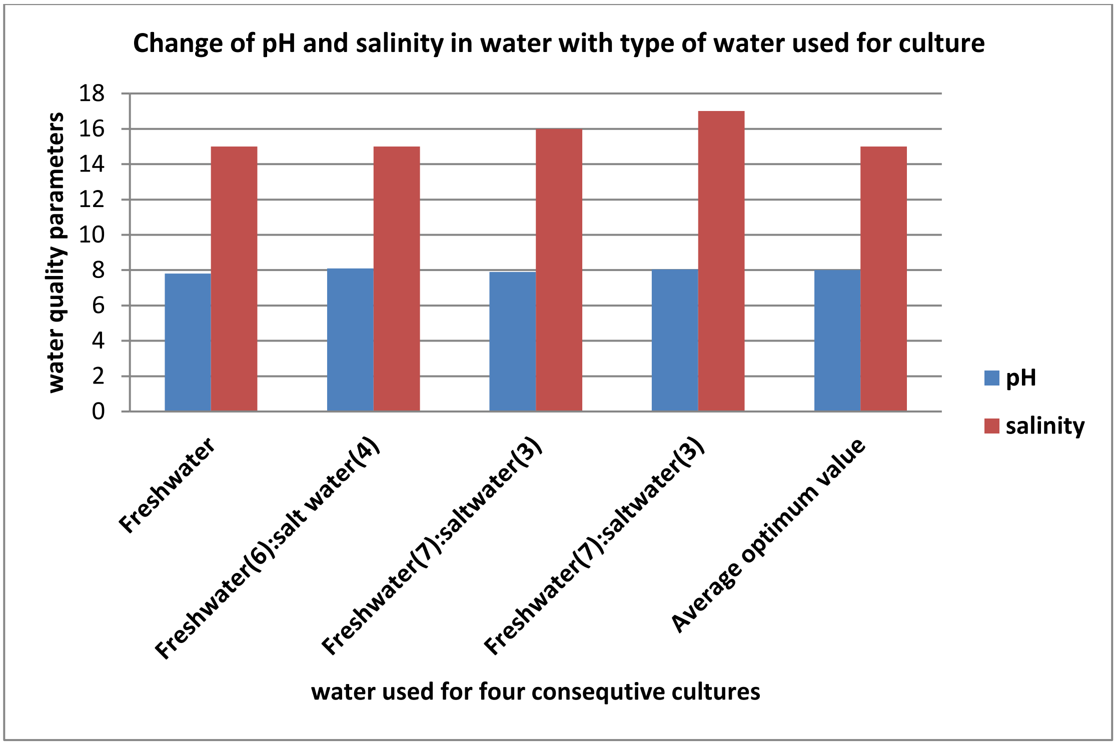
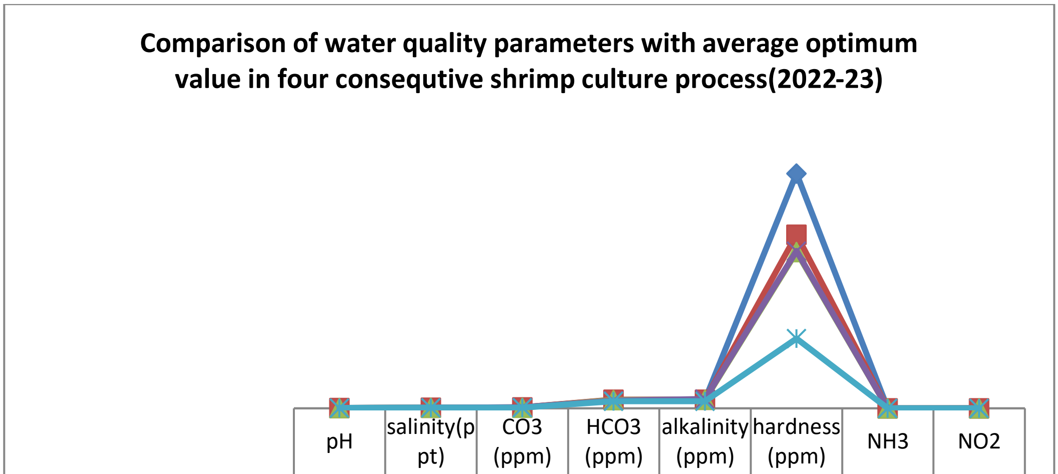


Figure 7. Change of pH and salinity in water during 2022-2023 with different mixed water and freshwater in study site-1.

During 2022-23 all four consecutive cultures had shown an average hardness level which was higher than optimum level. But the average of all other parameters in those cultures remained the same within optimal range. Figure 8 has shown that among all the water quality parameters hardness is the key parameter that is responsible for reduces growth and mortality of shrimp in inlands.

As mentioned earlier, the usage of fresh water in culture ponds leads to an abnormal hike in the hardness level of water. Other water parameters had shown variation with different times of the year during different cultures. Figure 8 is explaining the change of water parameters during different times of 2022-23. Among all culture seasons the first culture during June to August in 2022 was conducted using only freshwater for shrimp culture and rest of the cultures were conducted using mixed water with different compositions of freshwater and salt water (Figure 6 and Figure 7). All the shown parameters in Fig.8 were measured multiple times for each culture events and the average of all the measured parameters were finally included in every culture seasons to interpret the measured parameters. The usage of different types of water as mentioned previously (Figure 6 and Figure 7) and different seasons of the year determine the values of water parameters. However, these parameters are not the same for every inland vannamei shrimp farm. Study site-3, which is too far from the coastline, showed a normal level of hardness in the water of the shrimp culture pond. All the other water parameters of study site-3 remained same as optimal range of water parameters in vannamei shrimp culture ponds.



	pH	salinity(ppt)	CO3 (ppm)	HCO3 (ppm)	alkalinity (ppm)	hardness (ppm)	NH3	NO2
Jun to Aug(2022)	7.8	15	31	243	248	6732	0	0.04
Oct to Dec(2022)	8.1	15	33	248	246	4974	0	0.02
Jan to Mar(2023)	7.9	16	21	237	248	4483	0	0.04
Apr to May(2023)	8.04	17	28	224	272	4512	0.02	0.1
optimum value	8	15	20	200	200	2000	0.05	0.01

Figure 8. Water quality parameters in four consecutive shrimp cultures of study site-1 during 2022-23.

During these four consecutive cultures in study site-1 the growth of shrimp varied with each culture season. The total number of ponds we have studied is 15 in Study site 1. The average size of each pond is approximately 1500 sq. ft. In each pond on an average 170000 white shrimp seeds (*Litopenaeus vannamei)* were cultured at early stage. However, at the end of every culture season very less number of mature shrimps were left in the pond. During June to August in 2022 on an average 15000 shrimps were collected from each pond. So, there was mass mortality happened at early stage of shrimp culture. In second culture season and third culture season (October-December, 2022 and January to March, 2023) almost same amount of shrimp was collected from each pond. In these two consecutive cultures the average number of shrimps collected from each pond was between 50000 to 70000 out of 170000. However, in the last culture season, from April to May 2023, a very small number of shrimp were found alive at the end of the culture. As compared to previous two cultures fewer amounts of shrimps were collected from each pond. The average number of shrimps collected from the last culture was between 20000 and 30000 in each pond. Fig.9 is showing the mortality of shrimp seed in inland shrimp farms due to various reasons such as water parameters and disease. The highest mortality was seen in the first culture due to the exceptionally high level of hardness in the water.

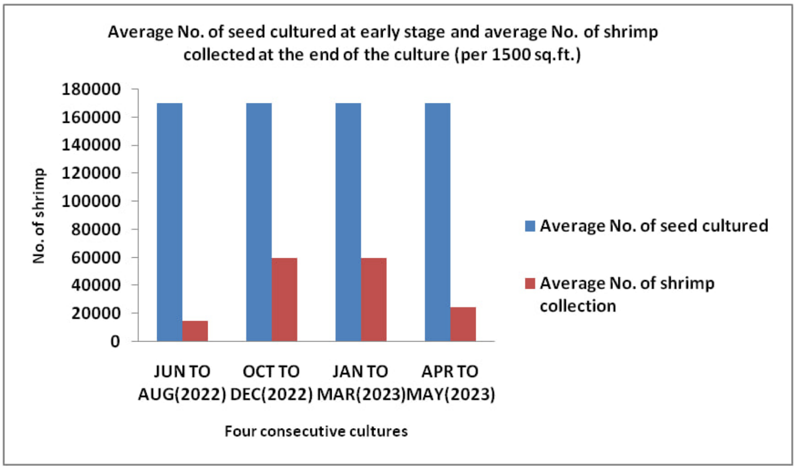


Figure 9. Average mortality of shrimp seeds during each culture season in study site-1.

There is a correlation between hardness in water and growth of the shrimp. Total 15 ponds were studied in study site-1. In each shrimp culture season, the growth of the shrimp varied with changing water parameters especially hardness of water. During April to May in 2023 the water quality parameters and shrimp growth were measured several times. In this culture a significant amount of shrimp growth had been seen in 7 out of 15 ponds. The average weight of each shrimp in Pond No. 9, 10, 11, 12, 13, 14, 15 was in between 35 to 38 gm. However, rest of the ponds showed poor growth. In Pond No. 1, 2, 3, 4, 5, 6, 7, 8 the average weight of each shrimp was 7 to 15 gm. There is a correlation that can be seen by observing Fig.10. The ponds having well-grown shrimps are showing a low levels of hardness in water. In contrast, the ponds that show poor growth of shrimp have high levels of hardness in water. The highest level of hardness was measured at about 5031 ppm in Pond No. 2. The ponds having well-grown shrimps faced huge juvenile mortality at an early stage of shrimp culture due to the high level of hardness in the water. The juvenile mortality provided more space for remaining shrimps in those ponds and that helped those shrimps to grow more.

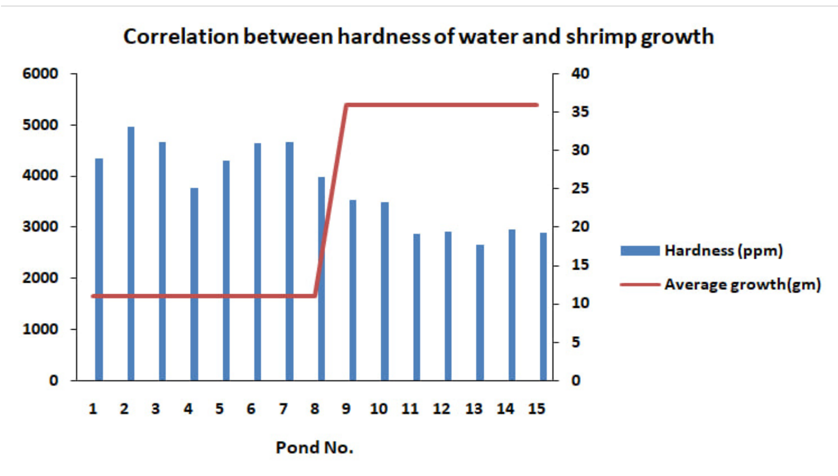


Figure 10. Correlation between hardness of water and shrimp growth during April to May in 2023.

All the water quality parameters that are essential for shrimp culture have been measured in three different study sites in locations different from the coastal areas of the Bay of Bengal. In all three sites, on average, the water quality parameters are the same except for the hardness level in the water. Unlike study site-2 and study site-3, study site-1, which is located far from coastal areas, shows abnormal levels of hardness in shrimp culture ponds. The other two study sites (site-2 and site-3) show the normal levels of hardness in shrimp culture ponds. Study sites 1 and 3 both belong to the inland areas of Purba Medinipur and use groundwater for inland shrimp culture. However, the hardness level is not the same for the shrimp culture ponds of these two areas due to the usage of groundwater from different layers of soil. However, many other parameters, such as dissolved ammonia (Fig.12) and salinity fluctuation, can be observed in some shrimp culture ponds of study site 3. Fig.11 is showing the comparison of water quality parameters other than hardness among three study sites. Several parameters in Fig.10 remain approximately the same in the three study sites due to the usage of average values of all measured water parameters. Although some water parameters were observed to be abnormal in some shrimp culture ponds.

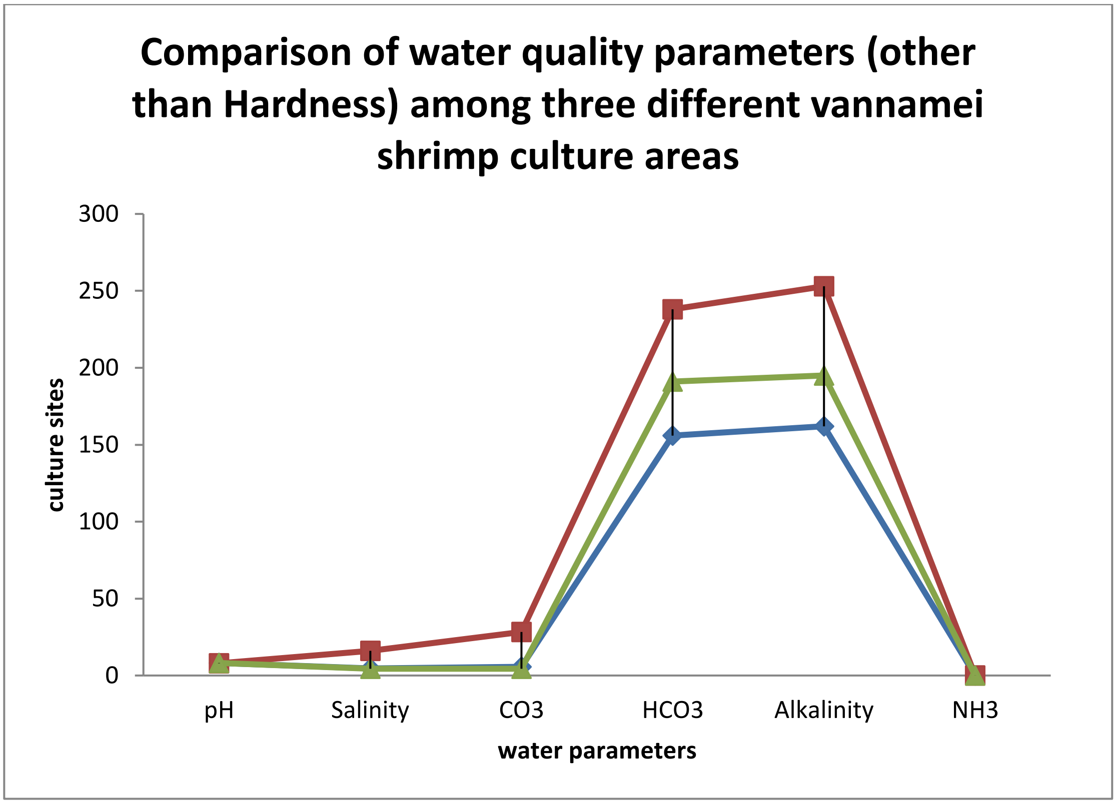


Figure 11. Comparison of water quality parameters among three study sites.

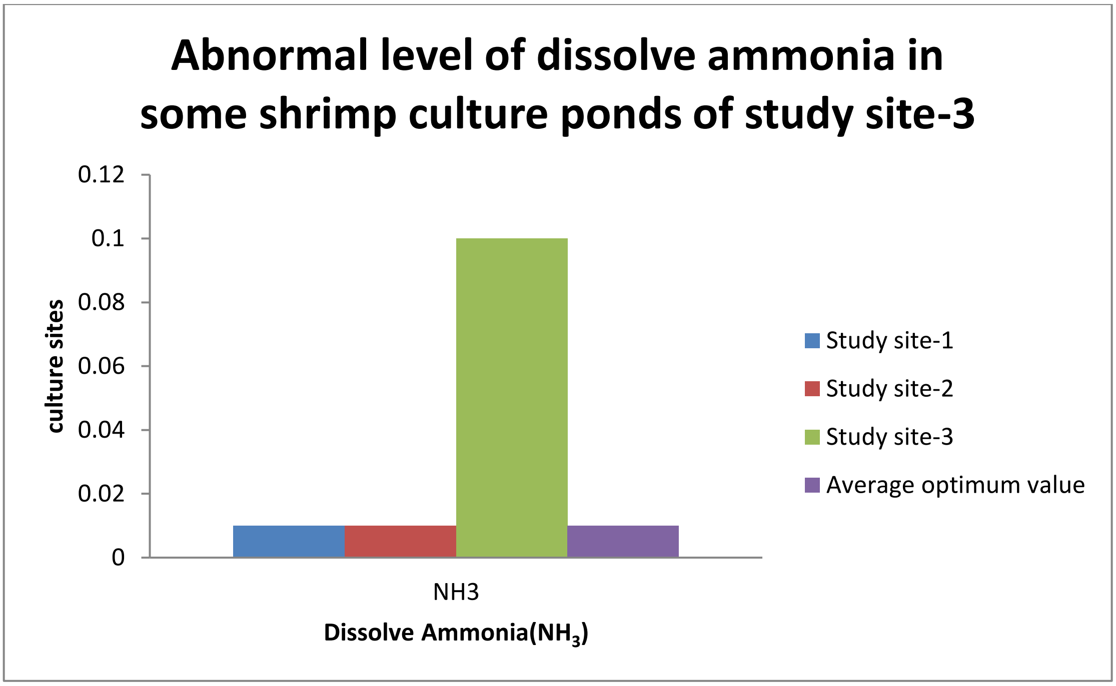


Figure 12. Comparison of dissolved ammonia in shrimp culture ponds among three study sites.

Socio-economic constrains:

The inland shrimp culture in various regions of Purba Medinipur has potential socio-economic impact on local people. The vannamei shrimp culture demands high monetary investment to achieve the infrastructures that are required for shrimp farming. Small-scale farmers may face several challenges, such as financial problems and land acquisition problems. So, they generally take the farm lands or shrimp farming ponds on lease. Sometimes, the farmers may have to face a high investment-to-benefit ratio due to changes in water parameters, disease, and market demand. To compensate for the loss, the farmer takes risks by doing shrimp culture again and again. In inland shrimp farming there are more risk factors involved as compared to shrimp farming near the coastal area. The water quality parameters change depending upon the change of shrimp farming locations. It is very hard to control all those water parameters within optimum level.

The conversion of agricultural lands into shrimp culture ponds leads to economic instability among local people. The saline water infiltrates into nearby agricultural lands and makes those lands infertile. The conflict between shrimp farmers and other agricultural farmers is increasing with time due to the increase of inland farming. Farmers who solely depend on agriculture face economic crises due to the failure of traditional agricultural farming. However, there is no way to revert back to traditional agricultural practices or freshwater fish farming from vannamei shrimp culture in inland areas of Purba Medinipur, West Bengal in India. So, the economic uncertainties will be more prominent due to inland shrimp farming.

Uncertainties:

Several uncertainties are associated with vannamei shrimp farming, such as changes in water quality parameters, risk of high investment, disease outbreak, salinity infiltration and irreversibility of shrimp culture. The water quality parameters vary depending on the location of the shrimp farming area. The deviation from optimal range of water parameters causes reduced shrimp growth and sometimes failure of shrimp culture. The high monetary investment as well as infrastructural investment in shrimp farming makes shrimp farmers more prone to socio-economically instable. Due to several reasons shrimp farmers cannot get the desirable return as compared to the investment. So, they have to face huge economic losses. Disease is the common parameter for white shrimp culture at any location. The common diseases in shrimp culture are White spot disease, White faeces syndrome, slow growth, loose shell, Running mortality syndrome (RMS), White tail disease (WTD), Taura syndrome etc. Taura syndrome which is locally known as red viral disease is common in all three study sites. Mass mortality of shrimp is caused by the increased prevalence of red viral disease in shrimp culture ponds. Salinity infiltration into nearby agricultural fields converts agricultural area into barren land. If shrimp culture fails, then there is no way to revert back to agriculture. Freshwater aquaculture has a low margin on profit. Thus, the recovery of loss from vannnamei shrimp culture cannot be compensated by freshwater aquaculture practices. This irreversible nature of inland shrimp farming can be a matter of concern for small-scale farmers. There are many other uncertainties associated with inland shrimp farming. From the field survey, the observed uncertainties are shown in Figure 14.

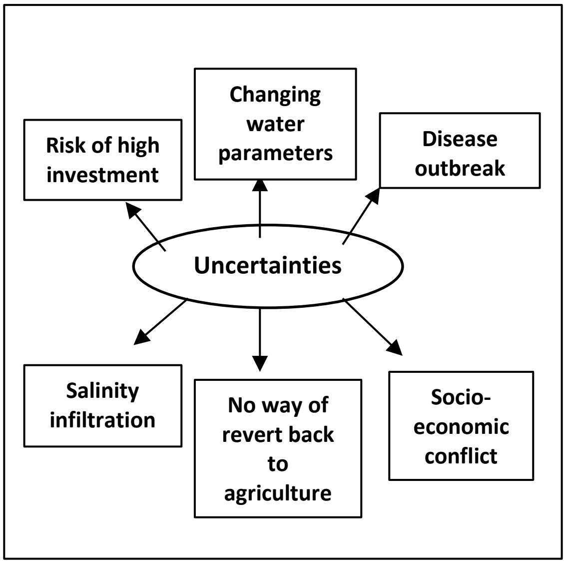


Figure 14. Uncertainties associated with inland shrimp culture.

Figure 13. Red viral disease in white shrimp.

Conclusion:

Inland shrimp farming in Purba Medinipur presents a promising avenue for economic growth and employment. However, this comprehensive study reveals several uncertainties that must be addressed to ensure sustainable development. Key uncertainties include environmental impacts, water resource management, disease control, and socio-economic challenges. The environmental implications, such as potential water contamination and habitat disruption, necessitate rigorous monitoring and regulatory frameworks. Effective water management strategies are crucial to balance agricultural needs and prevent resource depletion. Disease outbreaks pose a significant threat to shrimp yields, underscoring the need for robust biosecurity measures and ongoing research into disease-resistant shrimp varieties. Socioeconomic factors, including market fluctuations and the financial viability of small-scale farmers, further complicate the industry's stability. Supportive policies, access to credit, and market integration are essential to mitigate these risks. Additionally, community engagement and education can empower local farmers with the knowledge and tools needed to adapt to evolving challenges.

Overall, while inland shrimp farming in Purba Medinipur holds substantial potential, a multi-faceted approach that incorporates environmental sustainability, economic resilience, and social inclusivity is critical. By addressing these uncertainties through collaborative efforts among stakeholders, policymakers and researchers, the region can harness the benefits of shrimp farming while safeguarding its ecological and socio-economic fabric.

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