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A Comprehensive Review on the Socio-Economic and Environmental Dynamics of Global Shrimp Aquaculture

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Abstract- Shrimp is a globally popular seafood, and its cultivation significantly contributes to the sustainability and socioeconomic well-being of shrimp farming communities. However, infectious diseases pose a major challenge to shrimp aquaculture worldwide. This review examines the status of shrimp aquaculture, particularly in India, where an estimated 11.91 lakh hectares across 10 states and union territories are suitable for cultivation, though only about 1.6 lakh hectares are currently utilized. Notably, Andhra Pradesh and West Bengal lead in shrimp cultivation land.

The article also delves into the socio-economic aspects of shrimp farming, including living standards, occupational status, and women's participation in fisheries. It highlights the shift from agriculture to shrimp farming, often driven by economic benefits and increasing salinity. While shrimp farming has significantly increased farmers' incomes and purchasing power, it has also led to a reduction in livestock raising and tree production. Furthermore, the review discusses the adoption of improved aquaculture practices and the critical role of water quality parameters such as salinity, temperature, pH, dissolved oxygen, alkalinity, hardness, carbon dioxide, ammonia, nitrite, and nitrate for optimal shrimp growth and health.

Keywords: Shrimp, Aquaculture, farming.

I. INTRODUCTION

Shrimp is one of the most popular types of seafood all over the world. Shrimp culture contributes significantly to the resilience, sustainability and socioeconomic status of shrimp farmer communities. However, infectious diseases in shrimp are a significant constraint in shrimp aquaculture around the world. Adopting management methods makes aquaculture-based food more consumer-friendly, organic and aids in the establishment of sustainable aquaculture.

II. STATUS OF SHRIMP AQUACULTURE

India has a long coastline, which allows for extensive marine wealth exploitation. Fishermen began concentrating on capturing shrimps in the 1970s due to the high valuable return on investment due to their export value. Shrimp culture is practised in Kerala as Pokkali, West Bengal as Bheries, Orisa as Gheries, Goa as Ghajani and Karnataka as Kharlands (Rawool, 2005). During 1991-1994, brackish water prawn farming took off in a big way, particularly in the coastal districts of Tamil Nadu and Andhra Pradesh. In India, the estimated brackish water area suitable for shrimp cultivation is around 11.91 lakh ha spread across 10 states and union territories, namely Orissa, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Goa, Maharashtra, Gujarat and Pondicherry (TNAU, 2014). About 1.6 lakhs ha are currently under shrimp farming, so there is plenty of room for entrepreneurs to enter this field

(MPEDA, 2021). The states with the highest shrimp cultivation land are Andhra Pradesh (74512 ha) and West Bengal (50844 ha). The estimated total shrimp production in these states in year 2020-21 is 639896 tons and 54582 tons (MPEDA, 2022). Nearly, 6,52,253 MT fozen shrimps of value Rs 34,152.03 Crores were exported from India in 2019-20 (Handbook on Fisheries Statistics, 2020).

Soil salinization is an environmental threat that has a negative impact on farming community and agricultural output. In North India, inland salinity is rising rapidly, and there is an abundance of non - utilized inland saline soil. Approximately 40 percent of inland saline areas (92.33 lakh ha) are located in the states of Haryana, Punjab, Rajasthan, and Uttar Pradesh and are not used for agricultural purposes (Annual report of Department of Fisheries, 2021-22). As a result, productive use of these soils through aquaculture has begun in order to convert waste land into productive land. According to annual report of Department of Fisheries (2021-22), shrimp farming had begun in saline affected areas of these four states under the Rashtriya Krishi Vikas Yojana and Blue Revolution Scheme. Shrimp farming is currently being promoted in 493 ha of Haryana, with a production of 3,120 ton and an average productivity of 6.32 ton/ha (Department of Fisheries, Govt. of India, 2022).

Socio-economic parameters in shrimp culture

Various socio economic parameters linked with shrimp farming are explained under the relevant headings below.

Living standards

The adequacy of living resources, education status and industrial production influence life quality and living standards (Ali et al., 2014). In Bangladesh, 34 percent of farmers do not have access to electricity. The Rural Electrification Board (REB) and solar energy (SE) are the primary sources of electricity for the rest of the population followed by sources such as battery and oil engine generators (Ray et al., 2021). Electricity is an unavoidable resource to maintain sustainable living standards. The regular supply of electricity and other renewable resources affect the investment pattern in shrimp farming and ultimately influence the living standards of shrimp farming community. The other most important indicators used to assess the economy of a community is housing pattern. According to Chittem and Kunda (2018), the majority (54.40 %) of L. vannamei farmers had RCC type of houses, 32.20 percent had tile roofed houses and only 13.3 percent lived in hut/shed type of houses.

According to Srinivas and Venkatrayalu (2016), 54.8 percent of shrimp farmers had less than a 10th-grade education, 42.6 percent had a 12th-grade diploma, 2.2 percent were graduates and 0.4 percent were post graduate. Chittem and Kunda (2018) reported that majority of shrimp farmers (27.7 %) had education beyond the primary level (6th -10th grade), 20 percent had 1-5th grade education, 13.8 percent had intermediate education, 17.2 percent had graduate education and 12.2 percent had education beyond the graduate level. It is worth noting that 8.8 percent were uneducated who were involved in L. vannamei farming and employing best management practices.

Occupational status

Shrimp farmers relied on alternative occupations to meet their financial demands either due to increased financial stress or to make investment of earned income. Chittem and Kunda (2018) revealed that the majority (26.60%) of the L. vannamei farmers were engaged in agriculture as a secondary occupation, while 23.80 percent relied on dairy, 19.40 percent on fish culture, 9 percent on fishing and fish marketing, 7.70 percent worked as agriculture labour, 5.50 percent on petty business, 3.30 percent on rural enterprises, and 1 percent were involved in sericulture as a subsidiary occupation.

Ray et al. (2021) described alternative employment for shrimp farmers. Mong the ishing (48%) agriculture (25%) and private businesses (12%) stayed most preferred sources of income among shrimp farmers, whilst personal business (30%) was also the favoured secondary income source.

Participation of Women in Fisheries

Women's role are widely acknowledged and their economic contribution is growing significantly

(Gurumayum et al., 2004). Meetei et al. (2016) discovered that 65 percent women actively participated in fish culture only followed by capture and culture fisheries (35%). Accourding to them, women operate only those activities that do not demand immense strength, such as the use of the push net, Chinese dip net and traps in the capture fisheries sector. Women's role and involvement in aquaculture value chains (shrimp, fish, crab fattening and seaweed farming) appear to be even more prevalent than in fisheries. Women's participation in Tonle Sap Lake in Cambodia ranged from 50 percent in fish culture to 85 percent in sale and purchase (ADB, 2006). In Nigeria, women work as aquaculture labourers and managers of production process (Olufayo, 2012).In Southeast Asia female participation ranges from 42 to 80 percent in Vietnam and Indonesia (Williams, 2016).

Shift from agriculture to shrimp culture

The major reasons for the shift from agriculture to shrimp farming are the significant economic benefits and the lack of appropriate prices, dependence on weather including water and soil parameters (Hossain et al., 2009; Saha, 2017). According to Ray et al. (2021), southwest coastal Bangladesh, formerly a hub of rice agriculture, has undergone a significant shift from rice cultivation to shrimp farming. More than half (56%) of the farmers mentioned salinity as the primary reason for their shift from agriculture to farming of shrimps. Apart from that, the reasons for this shift are poor rice production (10%), salinity and higher income (14%) were also important factors for the shift.

Impact of shrimp farming on agriculture and livestock

The massive shift in livestock raising practises vaguely alluded to the possibility of economic solvency (Akber et al., 2017). With decreasing land for fodder cultivation and grazing, shrimp farming has reduced small or personal livestock raising (Ray et al., 2021). Following shrimp farming, the proportion of people who did not own cows increased from 14 to 68 percent and that of goats increased from10 to 40 percent, respectively. Commercial level farming (< 6 cattle unit) of cows (42 %) and goats (32%) increased prior to shrimp farming times.

Shrimp farming has been reported to reduce tree production (Islam et al., 2005), particularly for expansion of shrimp farms (Deb, 1998; Islam et al., 2002). Following shrimp farming, the tree production in coastal regions decreased significantly. Deteriorating water quality levels might also be the reason for unsuitability of soil for growing seedlings and trees (Ray et al., 2021).

Monetary Impacts of shrimp farming

Shrimp farming has become a new profitable business for coastal residents. Following shrimp farming practises, the percentage of shrimp farmers earning between USD 101 and $150 increased from 16 to 36 percent. Shrimp farming has significantly increased the income of stakeholders (Matin et al., 2016). Farmers stated that shrimp farming has increased their purchasing power (Akber et al., 2017).Dona et al. (2016) reported that the annual earning of shrimp farmers in Kerala was Rs. 2 lakh per crop/ ha, whereas Naik et al. (2020) reported that the annual income of 49.15 percent of shrimp farmers in the South Konkan region of Maharashtra was more than 20 lakhs. According to Chittem and Kunda (2018), the majority of L. vannamei farmers (55%) had medium economic encouragement in terms of profit making while 31.11 percent had high and 13.88 percent had low economic motivation.

Adoption of shrimp culture practices

Although brackish water shrimp farming is gaining popularity due to its high profitability, improved aquaculture practises are required to achieve eco-friendly and sustainable aquaculture development. Pond bottom conditioning, harvesting, pond bottom sterilisation, stocking and acclimatisation of fry, feed management, pond liming and health management were all practises that shrimp farmers readily adopted. According to Naik et al. (2020), 100 percent farmers had adopted stocking of seed after checking for disease, pond preparation and using quality pelleted feed.

Effect of water quality parameters on shrimp culture

The salinity demands and tolerance to salinity fluctuations may change throughoutpenaeid shrimp life cycle. Accouding to Boyd (1990) adult shrimp reach maturity, mate and spawn in water of salinities ranging from 28 to 35 ppt. Kasnir and Harlina (2014) recorded that thesalinity in the coastal waters and river was 30.90 ± 4.01 and 17.95 ± 3.79 ppt. respectively. Others recommended that salinity of 5-35 ppt is suitable for shrimp farming and the salinity of 15-25ppt. is optimum for shrimpgrowth (Poernomo, 1992; Soewardi, 2007).Shrimp can withstand a wide range of temperatures, 15oC is the lower lethal limit and the upper limit of temperature is around 35oC - 40oC for short durations. Shrimp can survive temperatures as low as 24oC and as high as 32oC (90oF), temperatures outside of this range cause poor growth and stress (Boyd, 1990).

The pH measurement of river and coastal waters was 7.77± 0.42 and 8.06 ± 0.40, respectively whereas pH of shrimp pond water ranged between 8.06-8.17 with the highest pH obtained at 12:00 noon and lowest at 3: 30 pm (Kasnir and Harlina, 2014). The pH range suitable for shrimp farming is 6.5-8.5 with optimum pH as 8.0-8.5 (Environment Ministry, 2004). pH levels ranging from 7.0 to 9.0 can be tolerated by shrimps. Very acidic (pH <6.5) or very basic (pH >10.0) water is harmful for gills of shrimps and reduces the growth rates (Soewardi, 2007).

If oxygen is scarce, the shrimp's ability to metabolize feed is hampered, resulting in lower feed conversion and growth rates. The best growth and feed conversion ratios (FCRs) are obtained when dissolved oxygen (DO) levels are kept at or above 80 percent of saturation (Boyd, 1990). All aquatic organisms (including shrimp) will not be stressed if dissolved oxygen (DO) levels remain above 5 ppm. According to Poernomo (1992) andWidigdo and and Kadarwan (2002) the dissolved oxygen (DO) level tolerable for shrimp culture is 3 -10 mg/l with 4-7 mg/l as the optimum level. According to Cheng et al. (2003), DO values greater than 5 mg/l are usually suggested for intensive culture practises. At a shrimp farm Kasnir and Harlina (2014) recorded highest DO level (6.02 mg/l) at 12:00 noon and the lowest (5.89 mg/l) at 8 pm. They also revealed that on average DO in costal and river water was 5.88 ±1.42 and 6.02 ± 0.86 mg/l respectively.

The alkalinity value for shrimp culture ponds is recommended between 50–150 mg/l by Wurts and Durborow (1992). Similarly, Boyd (2002) and Ferreira et al. (2011) found that alkalinity concentrations should not go beyond 140 mg/l. Ariadi et al. (2019) estimated that the alkalinity of shrimp ponds ranged between 124 mg/l and 192 mg/l in Pandeglang, Banten with an average value of 154 mg/l which was higher than recommended values and disturbed the pH level recommended for shrimp farming.

Hardness is a measurement of all divalent cations in water, the most common of which are magnesium and calcium. The acceptable range for $CaCO_3$ is greater than 150 ppm (Boyd, 1990). However, according to Wurts and Durborow (1992), calcium is essential in the moulting process of shrimp and it can influence the hardening of the newly formed shell. A preferable range of calcium tolerance by shrimps is 75 to 200 mg/l $CaCO_3$ (Wurts and Durborow, 1992). The appropriate dissolved carbon dioxide range is <20 ppm and the optimal range is <5 ppm (Wurts and Durborow, 1992). The main nitrogenous waste product excreted by shrimp and other aquatic organisms is ammonia. The recommended range of unionised ammonia form is < 0.03 ppm, and lethality occurs at levels greater than 0.1 ppm. According to Environment Ministry (2004), the recommended level of ammonia in water is <1.0 mg/l.

The acceptable nitrite and nitrate range is 1 and 60 ppm, respectively (Chen et al., 1990). However, Wurts and Durborow (1992) reported that shrimp can tolerate nitrite and nitrate levels up to 13.6 and 200 ppm, respectively. Kasnir and Harlina (2014) recorded that nitrite content in shrimp culture farms was 0.0556 ± 0.096 mg/l and in rivers and coastal waters was 0.0250 ± 0.0074 and 0.2483 ± 0.5690 mg/l, respectively. The recommended value of nitrite in shrimp ponds is <0.25 mg/l and for nitrate – nitrogen is 0.01± 0.01 mg/l (Boyd, 1998; Soewardi, 2007; Marine; Fisheries Service of Takalar Regency, 2008).

III. CONCLUSION

Shrimp aquaculture is a globally significant industry that supports the livelihoods of many communities, but it faces considerable challenges from infectious diseases. To ensure its sustainability and make it more consumer-friendly and organic, adopting effective management methods is crucial. India, with its extensive coastline and vast brackish water areas, has significant potential for shrimp cultivation. Despite a large suitable area of approximately 11.91 lakh hectares, only about 1.6 lakh hectares are currently utilized, indicating ample room for expansion. Notably, Andhra Pradesh and West Bengal are leading states in shrimp cultivation, with substantial production volumes. The high export value of shrimp has driven its cultivation since the 1970s, making it a lucrative venture.

A major development in India's shrimp farming sector is the productive use of inland saline soils, particularly in states like Haryana, Punjab, Rajasthan, and Uttar Pradesh, where approximately 40% of such lands are currently unutilized for agriculture. This initiative, supported by schemes like the Rashtriya Krishi Vikas Yojana and Blue Revolution Scheme, transforms wasteland into productive land for aquaculture. For instance, Haryana has already seen significant shrimp production from these saline-affected areas.

Shrimp farming profoundly impacts the socio-economic status of farming communities, influencing living standards, occupational patterns, and monetary income. Access to reliable electricity and adequate housing are key indicators of improved living standards among shrimp farmers. Education levels among shrimp farmers vary, with a significant portion having primary or intermediate education. Many shrimp farmers engage in secondary occupations like agriculture, dairy, or fish culture to supplement their income and manage financial stress. Women play an increasingly vital role in various aspects of fisheries and aquaculture value chains, including fish culture, processing, and sales.
The shift from traditional agriculture to shrimp farming is largely driven by the significant economic benefits, poor returns from rice cultivation, and increasing soil salinity, especially in coastal regions. However, this shift has also led to changes in livestock raising practices and a reduction in tree production due to decreased land for fodder and farm expansion. Despite these environmental trade-offs, shrimp farming has substantially increased the income and purchasing power of stakeholders, making it a profitable business for coastal residents. The adoption of improved aquaculture practices, such as proper pond preparation, disease checking, and using quality feed, is critical for achieving sustainable and eco-friendly shrimp farming.

Maintaining optimal water quality parameters is paramount for successful shrimp culture, as these factors directly influence shrimp growth, health, and survival. Key parameters include salinity, temperature, pH, dissolved oxygen (DO), alkalinity, hardness, and concentrations of carbon dioxide, ammonia, nitrite, and nitrate. For instance, a salinity range of 15-25 ppt is considered optimum for shrimp growth, while temperatures between 24^{\circ}C and 32^{\circ}C are ideal. A pH range of 6.5-8.5, with an optimum between 8.0-8.5, is suitable, and dissolved oxygen levels should ideally be maintained above 5 ppm for minimal stress. Alkalinity and hardness also need to be within recommended ranges to support shrimp health and molting. Proper management of nitrogenous waste products like ammonia, nitrite, and nitrate is crucial to prevent toxicity and ensure healthy growth rates. Adhering to these water quality guidelines is essential for maximizing productivity and minimizing environmental impact in shrimp aquaculture.

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