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Managerial efficiency in shrimp aquaculture: An empirical study of farmer perceptions and constraints in brackish water systems

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Abstract

This paper aims to study the challenges shrimp farmers face in the managerial efficiency of farming activities and propose solutions to address these challenges. The primary data were collected from 150 study respondents in three blocks of Nagapattinam district with the help of a proportionate random sampling method. The data were analyzed using frequency and percentage methods. The study unveiled ten key constraints, with disease outbreaks receiving the highest response rate (95.33%), followed by price fluctuations, poor seed quality, high feed costs, scarcity of skilled labour, inadequate electricity supply, high tariffs, insufficient awareness about shrimp farming schemes, weather fluctuations and cyclones, lack of governmental backing, and inadequate credit and insurance provisions. The most valuable recommendation proposed by respondents, in descending order of significance for mitigating these challenges, was the establishment of a disease diagnostic center offering affordable services (72.66%). Next, recommendations were made to the state fisheries government, including initiatives to establish a stable market price regulated and disseminated via social media, create seed certifying agencies, and improve credit and insurance facilities. Therefore, our study will significantly contribute to guiding actions by generating novel research avenues in shrimp farming aimed at fostering sustainable production.

Keywords: Aquaculture, constraints, managerial efficiency, shrimp farmers, sustainable production

Introduction

Globally, aquaculture is one of the fastest-growing food production sectors, with an annual growth rate of 8%, and supplies 49 percent of the global demand for seafood (FAO, 2022) [1]. The total supply of aquaculture increased dramatically from 0.7 million tonnes in 1950 to 178 million tonnes in 2020, and that by itself represents an annual growth rate of 3.3 percent. (FAO, 2022) [1]. Aquaculture production should increase with the adoption of new technologies, and systematic implementation of existing technologies plays an important role in creating more efficient, economical, conservationist, and adaptable regulations (Anderson, 2002; Asche, 2008) [2] [3]. In 2001, shrimp aquaculture moved from a capture based into a culture-based industry sector (Csavas, 1994; Rosenberry, 1997; Primavera, 1998) [4] [5] [6]. At the time, few species are farmed; black tiger shrimp and white-legged shrimp contribute nearly 90% of the total volume. In 2022, the global supply of reared shrimp production reached around 9.4 million tonnes (FAO, 2023) [7].

In India, the shrimp aquaculture sector plays a vital role in economic development and stands as the most rapidly expanding segment in the food industry. Its impressive contribution to economic export earnings value and employment opportunities to the rural people. 50% of the farmed shrimp exports from India. In 1990, tiger shrimp (*Penaeus monodon*) was the leading species in front of the farmers. But due to the high cost of production and the vulnerability of these shrimp to disease outbreaks (White Spot Syndrome Virus) and other associated problems. Subsequently, in 2009, an alternative species, *Litopenaeus vannamei* (Pacific white legged shrimp), was introduced, offering new exotic, disease-resistant varieties that are superior to *P. monodon*. The production of *Litopenaeus vannamei* has increased steadily since 2009-10 and reached 11.00 lakh tons in 2022-23 (MPEDA, 2023) [8]. Aquaculture is presently prioritizing technological advancements to achieve sustainable, traceable, and quality-certified practices.

Nine states are the major contributors to farmed shrimp production in India, with Andhra Pradesh leading, followed by Odisha. Tamil Nadu ranks fifth and has rich brackish water resources (56,000 ha), with 18,000 ha identified as

suitable for shrimp farming. Currently, 8,199 ha are used for *Litopenaeus vannamei* culture, yielding about 39,558 MT (MPEDA, 2023) [8]. Shrimp farming is active in 12 coastal districts, especially in Tiruvarur, Nagapattinam, Cuddalore, and Mayiladuthurai, covering 4,455 ha and contributing 3,797.1 MT. It plays a vital role in the socio-economic development of Tamil Nadu's coastal communities. In recent times, shrimp farming in India, including Nagapattinam district, has faced major challenges due to disease outbreaks like Enterocytozoon hepatopenaei (EHP), White Feces Syndrome (WFS), and Acute Hepatopancreatic Necrosis Disease (AHPND), leading to reduced survival rates and economic losses (Kumar *et al*., 2022). Farmers also struggle with fluctuating prices, rising input costs, and climate-related issues such as salinity changes and extreme weather (FAO, 2023) [7]. Export pressures from global markets, especially regarding antibiotic residues and sustainability standards, have further complicated production (Singh *et al*., 2024) [9]. Many farmers have been forced to scale down operations due to limited access to quality seed, feed, credit, and labour. There is no doubt that shrimp farmers have been facing struggles in sustaining their livelihoods under these mounting pressures.

Based on this background, the present study aimed to analyze the key constraints affecting shrimp aquaculture in Nagapattinam district of Tamil Nadu, and to identify site-specific remedial measures to address these challenges.

Methodology

The study was conducted in the Nagapattinam district of Tamil Nadu, which is highly engaged in shrimp farming practices. out of seven blocks only, three blocks were selected purposively from Nagapattinam district, and villages were selected by random sampling techniques from the three blocks. A total of 150 shrimp farmers were selected randomly from the respected villages in Table 1. The respondents were personally interviewed using a structured set of questions. These questions were tested beforehand to ensure they were clear and suitable for our study. The first-hand information regarding the incidence of various management factors problem and constraints in shrimp farming were collected from the respondents during the survey. Thereafter, all the constraints were classified under eight major heads *viz.*, disease outbreak, seed, marketing, feed, financial, labour, miscellaneous, and extension constraints. Statistical measures such as frequency and percentage analysis were employed to derive conclusions. The weighted average technique was employed to analyze and rank the various constraints experienced by shrimp farmers. This method is widely applied in allocation problems involving balancing-based constraints, as also noted by Bonfietti and Lombardi (2012) [10].

Table 1: Selection of shrimp farmers in Nagapattianm district (n=150)

No.	Name of the block	Total number of the respondents	Number of respondents selected in blocks under villages	
1	Nagapattinam	71	North poigainallur,	14
			Therkku poigainallur	
			Nagore	
			Karuvelankadai	
2	Keelvelur	230	Vettaikkaraniruppu	47
			*Viz*hunthamavadi	
			Karapidagai	
			Thirupoondi	
			Prathabramapuram	
3	Vedharanyam	442	Naluvedapathi	89
			Vellapalam	
			Thopudurai	
			Kovilpathu	
			Sembodai	
			Talanayar	
			Kallimedu	
			Thethakudi North	
			vedharnayam	
	Total	743		150

Source: State Fisheries Department and MPEDA, 2018 Nagapattinam

Results and Discussion

Constraints faced by shrimp farmers in Tamil Nadu were categorized into eight groups: disease outbreaks, seed issues, marketing challenges, feed shortages, financial constraints, labour limitations, miscellaneous obstacles, and extension difficulties. In Table 2, the weighted average is presented for each constraint.

Table 2: Constraints faced by shrimp farmers of Nagapattinam (n=150)

No.	Constraints	Weighted average Max score = 150	Rank
1	Disease outbreak constraints	104.3	1
2	Seed constraints	103	2
3	Marketing constraints	93	3
4	Feed constraints	85.7	4
5	Financial constraints	70.4	5
6	Labour constraints	67	6
7	Miscellaneous constraints	65.75	7
8	Extension constraints	64	8

The results (Table.2) revealed that disease outbreak constraints had the highest weighted average of 104.3, while seed constraints were ranked second, they received a weighted average score of 103. The third rank was for marketing constraints followed by feed, financial, labour, miscellaneous, and extension constraints. Additionally, it was noted that all constraints have different weighted average scores, and it is essential to focus on giving equal importance to all constraints. From this study, it can be inferred that constraints cannot be addressed as individual components and that a comprehensive approach is required. Van Ginkel (2013) [11] reported that individual component-based approaches have either failed or are having a decreasing impact. So, it is evident that interventions are required to address restrictions in all of their dimensions. Hence, there is a need to find a solution through integrated approaches to all the constraints. As following is a detailed discussion about each constraint.

Disease Outbreak Constraints

Table 3 shows the disease outbreak constraints faced by the shrimp farmers. Table 3 clearly shows that 95% of shrimp farmers in the Nagapattinam district of Tamil Nadu encountered disease outbreak constraints, specifically white feces syndrome disease. As following 63% of the respondents facing WSSV followed by running mortality syndrome gaited (50%) during poor water quality conditions in an unpredictable situation.

Table 3: Disease outbreak constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	White Feces Syndrome	95 (143)	I
2	WSSV	63 (95)	II
3	RMS	50 (75)	III

It is clear that disease outbreak in shrimp culture has recently received significant attention and resulting in crop failures. Other than viral diseases, the reasons for their prevalence may be attributed to poor water quality management, high stocking densities, and inadequate Best Management Practices (BMP) maintenance at shrimp farming facilities. Similar results are agreeing with the studies of Nayak *et al.* (2001) [12], Swasthi Lakshmi *et al.* (2008) [13], Pandey and Ritu Dewan (2006) [14], Rahaman *et al.* (2013) [15], Baruwa *et al.* (2012) [16], Koteshwari *et al.* (2014) [17], Tejavath Jagadeesh (2015) [18], Umamaheswari *et al.* (2016) [19], Kumaran *et al.* (2017) [20], and Chittem and Kunda (2018) [21] also reported that disease is the most serious limiting factor for shrimp farmers, presenting a pressing and dangerous issue for shrimp farming communities. According to Srinivas and Venkatraylu (2016) [22], viral and bacterial disease outbreaks were identified as a major constraint by 66.7% of the farmers. The most common diseases observed in their study included Black Gill Disease, Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), White Muscle Disease, White Gut Disease, Running Mortality Syndrome, and White Spot Syndrome Virus (WSSV). State government and fisheries institutes were taken efforts to address the constraints by establishing aquatic animal disease surveillance, remedial methods to disease (White gut disease), and diagnostic centers for the farmers at affordable cost. Shrimp farmers' skills, knowledge, and attitude toward adopting the best farm management and disease management practices should be prioritized over short-term remedial measures because the implementation of (BMP) has proven beneficial for farmers, the environment, and society. BMP implementation enables farmers to use resources more efficiently and sustainably. Patil and Sharma (2018) [23] highlighted the importance of training for shrimp farmers in achieving these goals.

Seed Constraints

Table 4 presents the seed constraints encountered by shrimp farmers. The findings regarding seed constraints indicate that 91% of the respondents experienced poor quality seed, followed by 64% facing high seed costs, and an additional 77% reporting low seed availability within the required timeframe from the hatchery. As a result, good quality seed is playing successful culture in shrimp farming inputs. The quality seed would help improve growth and survival rates while lowering shrimp production costs. A sufficient number of good seed hatchery units must be established near shrimp farming surrounding areas.

Similar results were underscored by Rajarajan (2017) [24] in Tamil Nadu, Jagadeesh (2015) [25] in Andhra Pradesh, and Koteswari *et al.* (2014) [17] also in Andhra Pradesh. According to Srinivas and Venkatrayalu (2016) [22], shrimp farming is flourishing in the West Godavari district of Andhra Pradesh. The inadequate availability of high-quality seeds poses a significant challenge to the sustainability of shrimp farming, potentially diminishing the interest of farm entrepreneurs in engaging in farming activities.

Table 4: Seed constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	Poor quality of seed	91 (137)	I
2	High cost of seed	64 (96)	II
3	Low availability of seed in the required time	51 (77)	III

The major constraints from the shrimp farmer's perspective were poor quality of seed from the hatchery and a similar result was reported by Das *et al.* (2014) [26]. Most of the respondents reported low availability of seed in the required time was felt as a controlling factor by half of the respondents. The current findings are consistent with previous researchers' findings (Alam, 1997 and Talkudar, 2000) [27] [28]. High-quality seed is crucial for successful aquaculture, and ensuring a timely supply of fingerlings or shrimp seeds to farmers is a key aspect of the process.

Marketing Constraints

Table 5 outlines the different marketing constraints encountered by shrimp farmers.

In recent times, during covid 19 pandemic situation shrimp farming industry faced several obstacles due to fluctuation in market price, low shrimp demand, exports restriction, etc., even though a good market price is available in the domestic market for farmed shrimp. The majority of respondents (92%) said that price fluctuation of shrimp and a lack of information on market price (64%) were the biggest marketing challenges, whereas less demand in the domestic market (59%), lack of minimum support price

system (53%) and lack of storage facilities (42%) were the major marketing constraints in shrimp culture at Nagapattinam. State fisheries department should take an initiative to regulate the shrimp price fluctuation and share the information with shrimp farmers at regular intervals time by a corporate company. it is mainly contributed to the farmers to control the crop losses. The price fluctuation, minimum support price, and cold storage facilities were avoided through the batch culture system in the pond. It helps to create year around shrimp culture, efficient use of land, and water resource, and also obtain constant income from shrimp culture.

Table 5: Marketing constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	Shrimp price fluctuation	92 (138)	I
2	Lack of information o market price	64 (96)	II
3	Less demand in domestic market	59 (88)	III
4	Lack of minimum support price system	53 (80)	IV
5	Lack of storage facilities	42 (63)	V

Koteswari *et al*. (2014) [17] reported that shrimp farmers were producing optimal yields, but market price fluctuations were impacting shrimp cultivators' income. In the past, the fishing and aquaculture industries' market prices were volatile. shrimp farmers should be aware of market prices during harvesting time, and it is preferable to get daily updates on market prices to benefit from shrimp farming. It was observed that 64% of shrimp farmers reported a lack of information on market prices. Similar results were observed by Rathord. *et al*. (2011) [29]. Baruwa *et al.* (2012) [16], Sanusi *et al.* (2016) [30].

About 59% of straggled that less demand in domestic markets, is due to less awareness and low consumption behaviour about seafood in the non-coastal area and reported as major constraints. Chittem and Kunda (2017) [21] reported similar results.

The Marine Product Export Development Authority (MPEDA) recently introduced the 'Fish Exchange Portal,' aimed at facilitating seafood exports from the nation. This one-stop shop portal caters to the entire spectrum of trade needs, allowing buyers from around the globe to interact and source seafood directly from MPEDA-registered exporters. The portal provides state-wise average farm gate prices for *L. vannamei* shrimp, offering valuable market insights to shrimp farmers. Additionally, farmers can now access market prices for both Vannamei and Black Tiger shrimp via telephone. Formerly determined solely by exporters, shrimp prices are now accessible to farmers internationally, including in Japan, the USA, and the EU, through a simple missed call SMS service. But shrimp farmers revealed that they are not aware of such facilitation in marketing strategies.

Feed Constraints

Another significant constraint for shrimp growers in the current study area was feed constraints presented in Table 6. The majority of shrimp farmers face high feed costs (77%), with 51% citing a lack of feed mill availability, and 43% report low-quality feed. It is well known, that the feed cost of the production unit contributed nearly 60-80% to shrimp farming (FAO, 2007) [31]. Importance to supply of affordable cost of feed with high quality in long self-life of feed, which is necessary to improve storage facilities in culture pond and to provide fewer credits to farmers. The findings align with the research conducted by Koteswari *et al*. (2014) [17], Tejavath Jagadeesh (2015) [25] and Sanusi *et al*. (2016) [30].

Table 6: Feed constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	High cost of feed	77 (116)	I
2	Lack of feed mill availability	51 (76)	II
3	Low quality of feed	43 (65)	III

Nearly 77% of respondents pointed high cost of feed as a significant constraint in their production units. Feeding and application of manure and fertilizer demand more investment. According to Rajarajan (2017) [24] said the high cost of supplementary feed was a major constraint followed by Umamaheswari *et al*. (2016) [19], Rahaman *et al*. (2013) [15], Ponnusamy *et al*. (2001) [32], and Krishnamurthy (1997) [33]. Supplementary feeds serve as a primary energy source in the commercial practices of shrimp culture. It was observed that farmers reported 60-70% of the cost spent on shrimp feed. The average rate of shrimp production costs around Rs.140/ for one kg of feed. The recent, annual rate of feed contribution in shrimp culture one-third of production cost. Avanti, Growel, C.P. aquaculture, Water base, BMR, Sonac, and Godrej are some of the companies that supply shrimp feed. The average rate of feed is Rs. 80/kg. Feed cost is a major constraint because it raises production costs. The cost of shrimp feed has risen from Rs. 50/kg to Rs. 80/kg in the last ten years, raising concerns. In recent years from 2017 to19 increased feed costs from around Rs.78 to Rs. 90 kg. Similar results were observed by Patil and Sharma, (2020) [34]. To address this problem, many organizations and institutes were researching low-cost feed, indigenous feed, and green feed with rich nutrient composition. Still, commercial feeds are practiced by shrimp farmers. There have been suggestions for ways to cut operation costs by Naegel (2010) [35] changed feeding practices and composition levels, and purchasing a bulk quantity of commercial feed. Then reduce capital and maximize profit with the help of build an auto-feeder and biofloc or nursery technology in shrimp farm followed by knowledge about carrying capacities in shrimp culture. Lack of feed mill availability was one of the severe constraints (51%) responded by shrimp farmers. Devaki and Senthil Kumar (2011) [36] ranked the high cost of feed and marketability as the 3rd and 4th constraints, respectively. However, Das *et al*. (2014) [26] ranked the high cost of feed as the 5th most important constraint.

Labour Constraints

Table 7 presents the labour constraints faced by shrimp farmers. The shrimp farmers struggled with major constraints of lack of skilled labour availability (59%) and lack of family members' support (30%) during the pond preparation, stocking, and harvest time. The current study confirmed previous research on the demand for higher wages and the scarcity of skilled labour. This problem could be solved by fixing standard wages for skilled/certified workers which is the responsibility of the shrimp farmers

association. Similar results were suggested by Megahed *et al.* (2013) [37], Koteswari *et al.* (2014) [17] and Tejavath Jagadeesh (2015) [18].

Table 7: Labour constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	Lack of skilled labour availability	59 (89)	I
2	Lack of family members support	30 (45)	II

Financial Constraints

Table 8 presents the various financial constraints faced by shrimp farmers. The shrimp farmers reported that high cost of electricity tariff (59%) and 47% of the respondents said the high cost of fuel is in financial constraints. These results are consistent with the studies by Koteswari *et al.* (2014) [17] and Tejavath Jagadeesh (2015) [18]. Chittem and Kunda (2017) [21] also reported that a lack of power (86.66%) was a major constraint faced by shrimp farmers in Andhra Pradesh. The problem should be encountered by the government should facilitate the provision of free electricity to shrimp farms as like agriculture.

Table 8: Financial constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	High cost of electricity tariff	59 (88)	I
2	Poor credit sources and insurance facilities	51 (77)	II
3	High cost of fuel	47 (70)	III
4	Non availability of crop insurance scheme	41 (61)	IV
5	Lack of financial support	37 (56)	V

51% of them said poor credit sources and insurance facilities are under financial constraint. Rajarajan (2017) [24] identified inadequate credit from banks as a major constraint, a finding similarly reported by Srinivas and Venkatrayalu (2016) [22]. Shrimp farming is required high capital investment in intensive farming activity and farmers are unable to meet the financial demand of the farming sector. Shrimp farming is done by small-scale practices through a contract base with help of middlemen or suppliers of seed and feeds for the credit. They purchase seeds and feeds on credit, often agreeing to sell their produce exclusively through the same vendors.

An additional 41% of respondents identified the non-availability of a crop insurance scheme as a significant financial constraint. Chittem and Kunda (2017) [21] reported that 63.33% of respondents in Pakasam district, Andhra Pradesh, cited the lack of crop insurance as the primary constraint for shrimp farmers. Similarly, Srinivas and Venkatrayalu (2016) [22] observed similar results, noting that the absence of an insurance scheme was a major constraint in Andhra Pradesh. Government, non-government, and banks can be provided crop insurance policies for shrimp culture. compared to agriculture and allied sectors provided to loss of crop with compensation, but in shrimp farming not available any compensate crop insurance facilities of more risky business. If some banks are provided insurance for their land area not for shrimp culture. Therefore, the current study reported the non-availability of crop insurance to shrimp farmers.

Miscellaneous Constraints

Table 9 presents the various miscellaneous constraints encountered by shrimp farmers. The present study revealed that weather changes and cyclones (54%) were the primary miscellaneous constraint. Additionally, 39% of shrimp farmers reported issues with floods and drought, 45% highlighted the absence of facilities for testing water quality, and 37% faced challenges due to the lack of an insurance policy. Similar results were found in the studies of Megahed *et al.* (2013) [37], Koteswari *et al.* (2014) [17], Vadher *et al.* (2014) [38] and Tejavath Jagadeesh (2015) [18], and while Kumaran *et al.* (2003) [39] reported successful shrimp farming in Andhra Pradesh and Gujarat despite constraints.

Table 9: Miscellaneous constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	Incidence of weather changes and cyclones	54 (81)	I
2	Floods and Drought	39 (59)	II
3	Lack of facilities to testing water quality	45 (67)	III
4	Lack of insurance policy	37 (56)	IV

The results indicated that sudden climate changes affected farming and cyclones (Gaja) also could sometimes damage the crop. So, Govt should alert farmers through television, and mobile applications about the weather status of the region, provide crop insurance facilities to farmers for damaged crops through any instance like cyclones (Gaja), floods, shorten mass mortality, etc. Similar results were observed by Le Xuan Sinh, (1996) [40] reported that lack of marketing facilities was perceived as a constraint faced by shrimp farmers in varying degrees. Lack of financial assistance was ranked eighth, whereas Das *et al.* (2014) [26] ranked it second. Ogunmefun and Achike (2017) [41] reported that lack of capital/finance, high cost of inputs, poor hatching techniques, pest and diseases, and lack of water supply respectively topped the list of major constraints in fish farming enterprises.

Extension Constraints

Table 10 presents the various extension constraints faced by shrimp farmers. Among the respondents, 57% of the respondents had a lack of knowledge about the scheme. 43% of them reported poor cooperation among farmers. 46% of them said lack of government support, whereas 39% of the shrimp farmers reported less extension and technical support, and 29% mentioned a lack of regular training programme. Regular training programmes and dissemination of new technology through extension personal support in timely advice and guidance will improve the farming practices. It was felt like a problem for shrimp growers. Similar findings were reported by Ponnaiah (1982) [42] and Ponnuswamy *et al.* (2001) [32].

Table 10: Extension constraints (n=150)

No	Constraints	Percentage (Frequency)	Rank
1	Lack of knowledge about scheme	57 (85)	I
2	Poor cooperation among farmers	43 (65)	II
3	Lack of Government support	46 (69)	III
4	Less extension and technical support	39 (58)	IV
5	Lack of regular training programme	29 (43)	V

Knowledge of schemes and aquaculture techniques is crucial for shrimp farmers to enhance shrimp culture. However, many shrimp farmers are not well aware of sustainable practices, available schemes, and scientific techniques in shrimp culture. In their study, Patil *et al*. (2018) [34] also stressed the necessity of assessing training needs in terms of the importance and competency of training areas while designing any capacity-building programme. Poor cooperation among shrimp farmers (43%) was faced by shrimp farmers because of the reason competition, envy, the status of farmers, credit problems, and poor cooperation among shrimp farmers. Sawant and Sawant (2003) [43] and Rajarajan (2017) [24] both indicated a lack of social networks among shrimp producers. Most shrimp farmers reported that 29% of respondents said lack of regular training programme. It is necessary to provide training to help farmers efficiently and easily access government schemes and policies, credit resources, and extension services. Mishra (1999) [44] and Talukdar (2000) [28] reported similar findings. Additionally, Chittem and Kunda (2017) [21] identified the lack of regular training programs as a primary extension limitation.

Conclusion

Shrimp farmers face significant constraints affecting their farming efficiency, including disease outbreaks, poor seed quality, high feed costs, financial limitations, labour issues, marketing problems, and lack of extension services. The availability of high-quality, virus-free shrimp seeds is crucial for productivity. Key challenges reported include lack of market price information, white feces syndrome, poor seed quality, high feed costs, lack of skilled labour, high electricity tariffs, lack of knowledge about schemes, and weather changes and cyclones.

The study concluded that shrimp farmers initially started vannamei culture with high hopes, but have faced challenges such as pond management, disease outbreaks, production costs, and marketability. To address these constraints, improving shrimp yield productivity through various schemes, training, and capacity-building programs by the government, private companies, and central institutes is essential. Programs aimed at increasing shrimp production should prioritize marginal and smallholder farmers, who are the primary contributors. Additionally, addressing the obstacles in technology dissemination is crucial to ensure successful adoption among shrimp producers.

Conflicts of interest

There are no conflicts of interest reported by the authors.

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