Geographic distribution of shrimp hatcheries in coastal India: Implications for sustainable aquaculture planning

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Received: July 2026 Accepted: September 2026

Abstract

Shrimp farming has become one of the salient sources to the blue economy of India, with high export earnings and creating jobs in the rural areas. The spread of the shrimp's hatcheries, however, is very imbalanced in the country, with state of Andhra Pradesh having more than 76 percent of the national data. This focus brings ecological, economic and sustainability concerns to the fore, including raised ecological risks of locally concentrated disease outbreaks and water resources stress and vulnerability to climate change. This study has identified 474 hatcheries across the country in six coastal States, information provided by Coastal Aquaculture Authority and interviews conducted during field visits, and found significant regional variations. Results of such work help to create a sense of urgency for the concept of a spatially balanced and comprehensive aquaculture that also takes into account ecological carrying capacity, bio security and climate resilience. The demand for policy measures including establishing tighter regulation, diversifying hatchery projects, use of modern technologies like probiotics, specific pathogen-free brood-stock, and phage therapy. India has a well-established shrimp industry that will obtain a better support with a more decentralised and sustainable shrimp hatchery network that will make the industry more competitive and sustainable in a long-time future.

Keywords: Shrimp Farming, Blue Economy, Hatcheries, Sustainability, Climate Resilience

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[DOI: 10.22034/injbir.5.1.117]

Introduction

Shrimp farming has become one of the most vibrant and economically important industries in India that plays a major role in export earnings and the livelihoods of villages. However, the distribution of the shrimp hatcheries is highly uneven with Andhra Pradesh alone contributing about 60 of the country spread (Prasad *et al.,* 2019). This unfair concentration, although economically profitable in the short term, leads to severe sustainability issues, which are not only localized overuse of water resources but also increased exposure to disease outbreaks in the densely populated farms all due to the introduction of poor-quality seed into them (Patil *et al.,* 2021; Benala *et al.,* 2023). The lack of planned spatial planning indicates a wider governance hole rooted in the fact that growth usually increases due to market demand instead of the ecological or environmental limit (Brugère *et al.,* 2021). The unregulated expansion can also affect the state of the environment and long-term sectoral stability since climate change predisposes to salinity intrusion, sea-level increase, and extreme crises in the coastal territories (Radhakrishnan *et al.,* 2022). Sustainable development of aquaculture pressing calls the fusion of spatial planning with the traditions and more environmentally friendly intensive culture, the implementation of Best Management Practices (BMPs) that bring about better bio security and limit diseases (Boyd and Jescovitch, 2020; Wyban, 2025). Managing the distribution of shrimp hatcheries and farms in all the coastal states necessitates enhanced conformity to the state and central regulations, as well as the formulation of the aquaculture plans on the regional basis. On the one hand, such plans must include prediction of seed demand, ecological, and carrying capacity planning, and climate vulnerability planning, where there is an optimal existence at ecological levels (Weitzman and Filgueira, 2020; Fisher *et al.,* 2023). Recent innovations in hatchery methods, including those of probiotics, phage therapy, and disease-free brood-stock, have already proven their effect on the maintenance of production and the lightening of the burden of reliance on a high-density and risk-based farming (Benala *et al.,* 2023; Rai *et al.,* 2024). Aquaculture of shrimp has steadily continued to expand across Asia, South America, and Africa to serve as a source of direct food security and poverty reduction (Boyd and Jescovitch, 2020). The introduction of the *Litopenaeus vannamei* to the Indian market emphasizes the presence of India on the global arena in terms of competitiveness, but the sustainable growth will depend on the degree to which the management structure is able to balance the goals of the economy and the nature of the environment (Kumaran *et al.,* 2017; Brugère *et al.,* 2021). Therefore, the deadlines to transform the shrimp sector in the Indian background into the high order paradigm of sustainable blue economy would be to ensure proper spatial management, impose strict standards of bio security,

[DOI: 10.22034/injbir.5.1.117]

and apply the methods of an environmentally friendly culture.

Methodology

This paper utilised composite information to describe the distribution of hatcheries on India coastline. The required data from the state fisheries department and the Coastal Aquaculture Authority (CAA) which were triangulated by field verification during the equivalent time. All 474 hatcheries had been mapped using QGIS 3.16 version, with the distribution ranging between zero and 363 in he respective states, across the six coastal states for which complete CAA-verified enumeration data were available at the time of field survey (Andhra Pradesh, Tamil Nadu, Odisha, Gujarat, Karnataka, and West Bengal). Kerala was originally included in the survey design; however, incomplete state-level enumeration at the time of data aggregation meant it could not be verified to the same standard as the other six states, and it has therefore been excluded from the quantitative analysis presented here pending a dedicated follow-up survey. District-level frequency counts were used as the primary basis for mapping; while this is adequate for describing gross state- and district-wise distribution, it does not by itself quantify the statistical intensity of clustering. To move beyond simple frequency plotting, subsequent spatial analysis of the same hatchery point layer should apply Nearest Neighbour Analysis (Clark and Evans, 1954), which yields an R-statistic testing observed hatchery spacing against a random distribution, and Kernel Density Estimation (Silverman, 1986) in QGIS to generate a continuous density surface. Applied to the Kakinada-Nellore corridor specifically, these tools would allow the degree of agglomeration to be expressed as a quantified statistic rather than only a descriptive pattern, and are recommended as a priority enhancement for the next iteration of this mapping exercise once precise hatchery-level coordinates are available for all six states (Figs. 1 to 8 and Table 1).

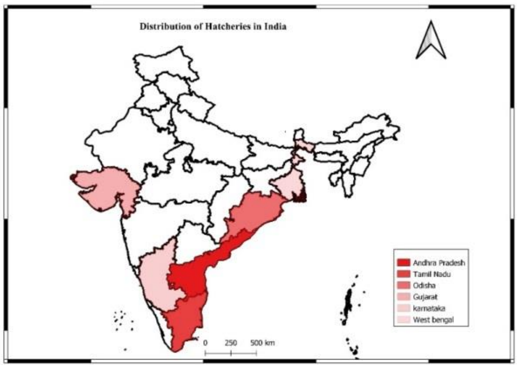

Figure 1: Distribution of hatcheries in India.

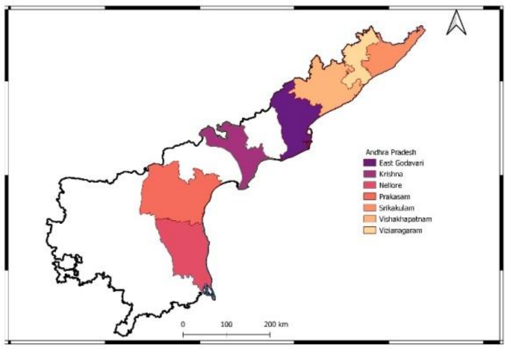

Figure 2: Distribution of hatcheries in Andhra Pradesh.

[DOI: 10.22034/injbir.5.1.117]

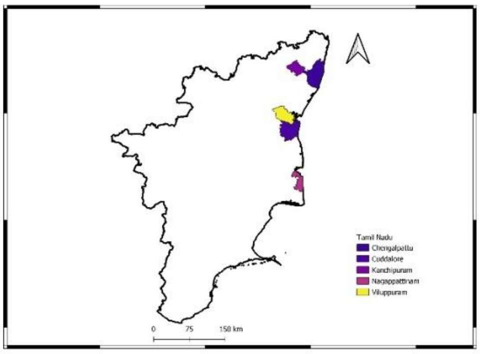

Figure 3: Distribution of hatcheries in Tamil Nadu.

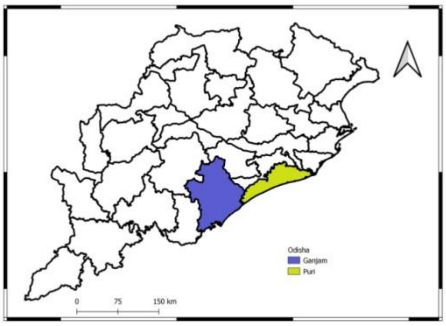

Figure 4: Distribution of hatcheries in Odisha.

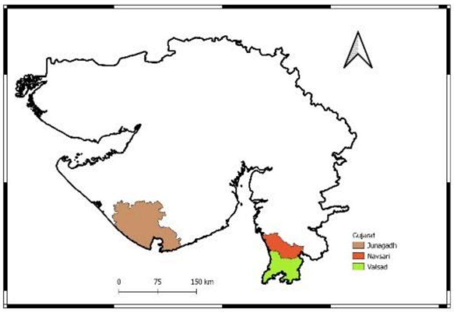

Figure 5: Distribution of hatcheries in Gujarat.

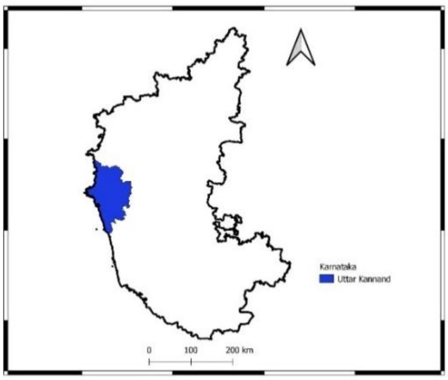

Figure 6: Distribution of hatcheries in Karnataka.

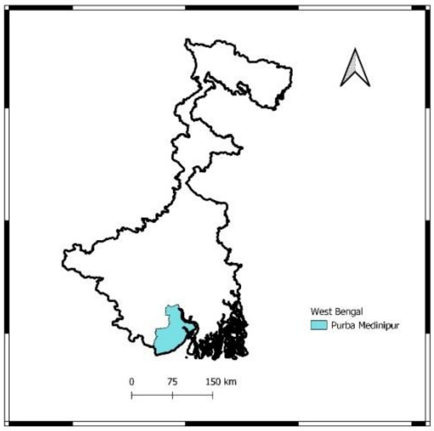

Figure 7: Distribution of hatcheries in West Bengal.

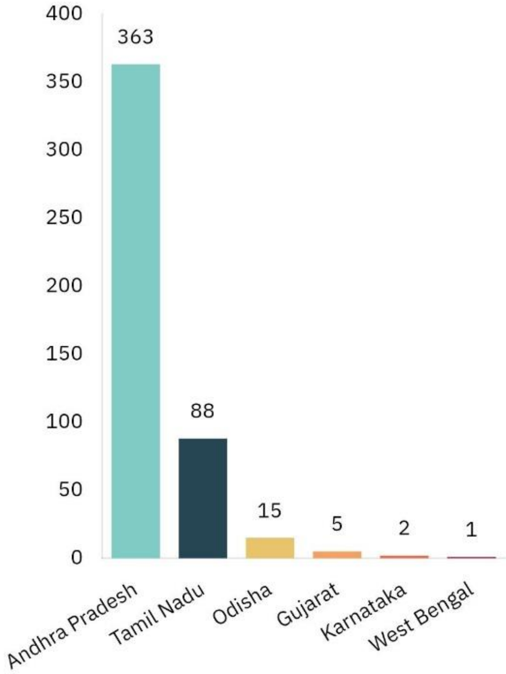

Figure 8: Distribution of hatcheries across India.

Results

There are 474 shrimp hatcheries identified in the study, and definitely an uneven geographical distribution of the shrimp hatcheries along the south-east coast. The highest number of facilities (363; 76.6 % of the national level) is observed in Andhra Pradesh. Kakinada district showed the highest number of hatcheries (155) whereas 57 and 98

[DOI: 10.22034/injbir.5.1.117]

production units were reported in Kakinada and Kundinagaram districts respectively (Kumaran *et al.,* 2017; Prasad *et al.,* 2019). This imbalance is more likely to be due to the restructuring of the districts and not due to under-enumeration. The above-mentioned districts (Kakinada, Konaseema and East Godavari in present times) have been carved out from the erstwhile East Godavari district on 4th April 2022.

Table 1: District-Wise Distribution of Shrimp Hatcheries in Key Coastal States of India.

State	Top districts (with hatcheries)	Total hatcheries	% of total hatcheries	Hatchery presence
Andhra Pradesh	Kakinada (155), Nellore (63), Prakasam (40), Anakapalli (35), Bapatla (16), Visakhapatnam (17), Tirupathi (14), Konaseema (4), Dr. B.R. Ambedkar Konaseema (4), Krishna (8), Srikakulam (5), Vizianagaram (2)	363	76.60%	Very High (363)
Tamil Nadu	Villupuram (49), Chengalpattu (30), Mayiladuthurai (7), Kanchipuram (1), Cuddalore (1)	88	18.60%	Moderate (88)
Odisha	Ganjam District (13), Puri District (2)	15	3.20%	Very Low (15)
Gujarat	Gir-Somnath District (2), Valsad District (1), Navsari District (1), GU Junagadh District (1)	5	1.10%	Very Low (5)
Karnataka	Uttara Kannada (2)	2	0.40%	Extremely Low (2)
West Bengal	Purba Medinipur (1)	1	0.20%	Extremely Low (1)
Total		**474**	**100.00%**	

The unit data in this reorganisation indicates a lower overall figure than the previous survey of the existing, undivided district, which found 57 and 98 units. When compared with the previous sources earlier than 2022, the number 155 mentioned here must be viewed as current and district boundary of Kakinada was re-structured. The others who are leading districts are Nellore (63), Prakasam (40), Anakapalli (35), Vizakhapatnam (17), Bapatla (16), Tirupathi (14), Krishna (8), Konaseema (4), Dr B R Ambedkar Konaseema (4), Vizianagaram (2). This distribution indicates that the fish factories are concentrated in the areas, which already have the best coastal topography, brackish water reservoirs and/or well-developed fish farm structures (Prasad *et al.,* 2019; Brugère *et al.,* 2021). The second was Tamil Nadu with 88 hatcheries (18.60 of total) and mostly located in Villupuram (49) and Chengalpattu (30). Other smaller clusters were found in Mayiladuthurai (7), Kanchipuram (1), and Cuddalore (1) (Weitzman and Filgueira, 2020). The

[DOI: 10.22034/injbir.5.1.117]

geographic trend implies a regionalized growth into movement on the environmentally positive coast zones, with the accompanying inter-connected aquaculture concentration; however, great potential is not fully exploited elsewhere. While the geographical tendency indicates regionalised growth that has taken the form of movement along environmentally positive coastal zones, and the interconnected aquaculture concentration, many opportunities for growth are not being fulfilled in other parts of the world (Radhakrishnan *et al.,* 2022). 4.85 per cent of all national hatcheries (23 out of 474 hatcheries) were located in all four coastal States, overall. There were 15 hatcheries in Odisha of which 13 were in Ganjam and 2 were in Puri. There were five in Gujarat, spread across Gir-Somnath (2), Valsad (1) and Navsari (1) and Junagadh (1). Karnataka already possessed two hatcheries in Uttara Kannada while one operation was existing in West Bengal in Purba Medinipur (Prasad *et al.,* 2019). The total area of hatcheries in these small areas, especially in the presence of ample coastal space in these states, implies that there is much potential for developing aquaculture infrastructure in under-represented areas (Boyd and Jescovitch, 2020; Fisher *et al.,* 2023).

Implications for sustainable aquaculture planning

The shrimp hatcheries in Andhra Pradesh is basically a major threat to sustainability of the Indian shrimp-farming industry in the long-run. This concentration of a single geographical location makes it more vulnerable to ecological stress, epidemic diseases and financial fluctuations (Brugère *et al.,* 2021; Patil *et al.,* 2021). The key solution to these risks is to shift aquaculture planning to an even-distributed scientifically based model of growth, including ecological carrying-capacity analysis and climate-resilience factors (Radhakrishnan *et al.,* 2022). The principal regulatory oversight is the Coastal Aquaculture Authority through the Coastal Aquaculture Authority Act, 2005, and its following Rules and Guidelines (2024). Such frameworks impose that all hatcheries should be registered, adherence to approved site-selection norms, and bio security measures (CAA, 2024). Recent CAA guidelines on the culture of Specific Pathogen-Free (SPF) -*Litopenaeus vannamei* and -*Penaeus monodon* focus on the development of strong quarantine facilities, disease monitoring, and brood-stock testing before the hatchery is approved (Benala *et al.,* 2023; CAA, 2024). However, field level assessments have shown that, although some practices, like footbath and brood-stock virus screening are widely followed, important practices like quarantine isolation and live-feed pathogen screening are adopted unevenly with gaps of more than 80% for many hatcheries (Raja *et al.,* 2013). In conjunction with these actions, the Department of Fisheries (DOF) released a 2025 notification to govern hatcheries and farms that grow native species of shrimp. According to these revised

[DOI: 10.22034/injbir.5.1.117]

provisions, in-house quarantine facilities, close water-quality check-ups, regular testing of pathogens and full record-keeping are all conditions that must be satisfied before a hatchery can be registered (DoF, 2025). It is believed that these actions will lead to the diversification of the hatchery development to under-exploited but ecologically feasible coastal states to lessen over-reliance on Andhra Pradesh (Boyd and Jescovitch, 2020). Nonetheless, there is evidence that financial and operator knowledge limitations have been a significant barrier to consistent application of bio security standards and highlights the need for newly constructed hatcheries to have stringent and enforceable measures in place at the start of production (Raja *et al.,* 2013). The policy interface has also shown the importance of the private-sector investment in cold-chain facilities, digital observation systems, and capacity development as facilitators of sustainable aquaculture development (Fisher *et al.,* 2023). An example is the recent emphasis of the Andhra Pradesh Fisheries Department on the need to embrace modern technologies, to train farmers, and to build value chains to deal with hatchery distribution disparities at the regional level (Times of India, 2025). The CAA governs registration and site-selection compliance, but it is only part of the regulatory picture. The Marine Products Export Development Authority (MPEDA) is the topmost organization for promotion and quality assurance of Indian seafood exports and its extension arm, the National Centre for Sustainable Aquaculture (NaCSA) is equally significant. In response to the export shrimp farming crisis which occurred in the late 1990s due to White Spot Syndrome Virus (WSSV) attacks, MPEDA formed NaCSA in 2007, and currently groups together over 90% of Indian shrimp farmers who operate small or marginal farms, training them in Better Management Practices (BMP) and by implementing a cluster-based approach that synchronises stocking, water exchange and harvesting schedules, it's able to minimise production costs and the potential spread of disease between neighbouring farms (MPEDA, 2026). Hatcheries are the first node of a supply chain that ultimately feeds MPEDA-registered export processors, so NaCSA's cluster societies and its eSanta direct-marketing platform effectively shape which hatcheries' seed reaches export-grade farms, and NaCSA societies routinely assist member farmers in obtaining CAA licenses. Any account of hatchery governance in India should therefore treat the CAA's registration mandate and MPEDA/NaCSA's developmental and market-linkage role as two parts of the same system rather than as separate tracks.

Discussion

The location of shrimp hatcheries in India is highly skewed in favour of the south-eastern seaboard of India with a share of 76.6 % of the total units in operation estimated to be in Andhra Pradesh. Such intense focus is explained by an ideal combination of both abiotic

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and biotic factors: a physiographical favourable coastline, relatively stable salinity regimes in estuarine and brackish water areas and a subtropical-tropical climatic gradient enabling year-round maturation of brood-stock and rearing of larvae. Also, the vertical integration of the state is high, and it includes brood-stock supplies, exploitation of nauplii, larvae rearing (up to post-larval animals), and delivery services. The policy interventions including the concessional power tariffs as a hatchery activity, simplified licensing system, and investment on aqua related infrastructure, have only rapidized production capacity further making Andhra Pradesh the key hatchery abode in the national mariculture value chain. The Andhra Pradesh State Aquaculture Development Authority (APSADA) Act, 2020 (Act No. 29 of 2020) which introduced a single state authority for regulating, endorsing and granting licenses for aquaculture farms and aquaculture business operations such as hatcheries, provides for the ease of licensing and vertical integration. The APSADA system streamlined the existing approvals which were dispersed across various authorities, thereby reducing the transaction costs involved in setting up and expansion of hatchery capacity in the state and strengthening the Agglomeration effects described earlier (Government of Andhra Pradesh, 2020). About 19 % of the national hatchery capacity is concentrated in Tamil Nadu, and they are at the coastal districts of Villupuram and Chengalpattu. They also possess good hydrographic conditions for high survival of larvae, sandy bottoms and low seasonality of freshwater intrusion which leads to a stable salinity adequate for the larval stage of *Penaeus vannamei* and *Penaeus monodon*. Andhra Pradesh is a small state in terms of volume of the hatchery industry but it has great possibilities to grow. Such strategic enhancement measures as the production of specific brood-stock acclimatisation facilities, implementation of recirculating aquaculture systems (RAS) to guarantee bio security, and mastering skill development programs with the help of hatchery technicians may ensure significant improvements in production efficiency and bio secure production, which in turn will allow raising the level of competitiveness of Tamil Nadu in comparison with other entities in India in the field of shrimp aquaculture. In sharp contrast, Odisha, Gujarat, Karnataka, and West Bengal put together have a figure of 4.85 percent of the total national number of hatcheries and hence the question that lingers is why the huge coastlines of their states underutilised are. There are several limitations to shrimp mariculture growth in West Bengal, Gujarat, Karnataka and Odisha: lack of cold chain facilities, specialized hatchery feed production facilities, access to specific pathogen-free (SPF) brood-stock and outbreaks of diseases occasionally, and particularly that of White Spot Syndrome Virus (WSSV). However, these areas have a high latent potential due to well-developed geomorphology and climatic conditions

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of the coastal lands. However, the risks of disease can't be ignored. National surveys have estimated losses in shrimp production at 48,717 metric tonnes annually at Rs. 1022.1 crores and disease burden have been estimated to account for 21.5 lakh man-days of loss of employment. Introduction of integrated coastal aquaculture development strategies, including genetic improvement schemes, disease surveillance systems and hatchery bio security measures, would help spawn the development of new hatchery clusters. Decentralization of production capacity is not only likely to be a boon to overcome regional imbalances, but would also enable the Indian mariculture sector of shrimp farmers to be more resilient and sustainable to climatic and market fluctuations. The dominance of White Spot Syndrome Virus (WSSV) and Loose Shell Syndrome (LSS) as the most harmful diseases in the country highlights the need for spatial diversification of hatcheries using a resilience-based approach (Kalaimani *et al.,* 2013).

Evidences from bio-security and disease-impact research

Shrimp culture in India is distinctly limited by two major issues - the improper implementation of bio-security measures, and severe disease-induced economic losses. Recent empirical studies have supplied quantitative and field level evidence that highlights the need for a more hardened and spatially diversified hatchery system. First, Raja *et al*. (2013), showed that although some bio security measures, such as foot baths and hand disinfection were adopted across Indian hatcheries, key measures (e.g., pathogen screening of brood-stock, quarantine isolation, disinfected clothing) showed gaps in adoption of more than 80%. Such mismatches make hatcheries very vulnerable to pathogen spread and focal epidemics. Also, the same study showed that although a small proportion of hatchery owners were willing to implement stricter bio security practices, lack of financial means and training have hindered consistent implementation across the sector (Raja *et al.,* 2013). Accordingly, these findings highlight how even in areas that enjoy good ecological and infrastructural conditions, such systemic bio security shortfalls undermine sustainable development outcomes. In addition, Kalaimani *et al*. (2013) measured the national economic cost of diseases of shrimp by surveying over 1100 farms in nine coastal states. The study estimated annual production loss of 48,717 metric tonnes of shrimp, valued at Rs 1022.1 crores, and loss of man-days of 21.5 lakh. White Spot Syndrome Virus (WSSV) and Loose Shell Syndrome (LSS) were found to be the most severe epidemics, then followed by mixed viral/bacterial infections. These estimates highlight that disease outbreaks are not only ecological threats, but also high-impact economic shocks destabilizing rural livelihoods and national export revenues (Kalaimani *et al.,* 2013). In summary, the evidence points to the need for India's shrimp hatchery network to urgently move beyond geographical concentration and market-driven growth. Improving bio security compliance, consistency in implementation of standard operating procedures, and diversification of hatchery distribution among underused coastal states are necessary measures. Without these interventions, the threats of disease-induced production collapse and economic instability will keep rearing their ugly heads thus eroding the resilience of India's blue economy.

Policy challenges in aquaculture

Even though the expansion and advancement of shrimp zoning has been quite spectacular and has remained an important aspect in maintaining the livelihoods of individuals residing in the coastal areas, there is an increasing apprehension towards such development as a result of structural and policy related issues. India’s Goods and Services Tax (GST) framework helps clarify where this pressure actually falls. Live and fresh shrimp seed remain exempt from GST, and so does aquafeed (HSN 2309, including shrimp and prawn feed), so hatchery-linked producers are not taxed at the seed or feed stage. The pressure instead arises further down the value chain: frozen shrimp (HSN Chapter 3) attracts 5% GST, prepared or value-added shrimp products (HSN Chapter 16, covering breaded, ready-to-cook and ready-to-eat lines) attract 12%, and the processing machinery and cold-chain or refrigeration equipment that smallholders must invest in are taxed at the standard 18% slab. It is this cumulative burden on capital goods and processing inputs, more than a flat double-digit rate on the shrimp itself, that strains smallholder producers who lack the working capital to absorb such upfront costs. Policy reform through tax rationalisation, particularly on processing machinery and cold-chain equipment, along with the optimisation of cascading levies, remains a correct step towards enhanced profitability. Part of this burden is already offset by the Remission of Duties and Taxes on Exported Products (RoDTEP) scheme, under which the Government of India raised the seafood refund rate from 2.5% to 3.1% of export value, subject to a cap of Rs. 69 per kilogram (Press Information Bureau, 2024). In addition to domestic taxation, today trade barriers are also important constraint. Most significantly, the United States imposed a reciprocal duty of up to 50% on Indian goods in 2026 and added to the anti-dumping and countervailing duties of approximately 2.5% and 5.8% on duties on frozen shrimp, the effective rate for some US-bound consignments is now in excess of 58% (Deccan Herald, 2026). The impact of this tariff shock is especially severe in India, where nearly half of the ex-ports of frozen shrimp are shipped out by the US alone, and this is the very states, Andhra Pradesh, West Bengal, Gujarat, Odisha and Tamil Nadu, whose hatchery and farming clusters feed into this trade. The continued reliance on imported broodstock and specific feed ingredients further leaves the producers open to price volatility and risk of supply chain. GST rationalisation at the processing

[DOI: 10.22034/injbir.5.1.117]

and cold-chain level, further strengthening of RoDTEP support and moving away from over-reliance on any single export market are the fiscal and trade-policy levers most likely to safeguard the sector from being used as a source of affordable protein at home and a high-value export earner abroad.

Conclusion

The current pattern of geographically focused distribution of shrimp hatcheries in Andhra Pradesh represents both a reflection of a set of synergistic ecological suitability and policy advantages as well as an infra-structural advantage, yet this nesting of the industry carries with it risks. Over dependency of a single state exposes the shrimp aquaculture industry to risk of a disease outbreak, environment pressure and market variability that jeopardizes the viability of the shrimp aquaculture industry in India in the long run. The imbalance provision also suggests misuse of the coastal state that enjoys similar capabilities in the natural ecology not only as structural imbalance but also as an opportunity loss in impacting sustainable and inclusive benefits to build certain sectors. The deliberate transformation between the spatially balanced and ecologically conceived and complex development is to occur to ensure the resilience of the Indian aquaculture. Strict application of regulations within the Coastal Aquaculture Authority and adoption of bio secure growing fish behaviours in hatcheries, as well as guaranteed seed and self-regenerating culture systems will be critical to the change. Decentralized production could then be another solution that could harness the unseen potential of underrepresented geographical areas through strategic investments in cold chains, maximization of a brood-stock, and the ability to track digitalization and capacity development of the farmers. In the context of its development, shrimp aquaculture sector, as its component, can become a robust pillar of the Blue Economy supporting rural economies and the export competitiveness next to ecosystem health management.

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[DOI: 10.22034/injbir.5.1.117]