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Short communication

Impacts of Shrimp Farming on The Relative Abundance and The Biodiversity of Wild Shrimp Along the Coastal Areas of Batticaloa District in Sri Lanka

N. Janane and M.N.M. Fouzi*

Department of Farm Animal Production and Health, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Peradeniya, Sri Lanka

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Fouzi, M.N.M.
https://orcid.org/0000-0002-6993-7163

ABSTRACT

Impairment of wild shrimp biodiversity is one of the key ecological concerns linked to shrimp aquaculture. This study assessed the abundance and biodiversity of wild shrimp along the coastal region of Batticaloa District, Sri Lanka, considering shrimp farming and non-shrimp farming areas. Sampling was conducted at six locations, consisting three non-shrimp farming sites in Batticaloa Lagoon (Arayampathy, Kallady, and Muhathuwaram) and three (shrimp farming sites in the Vaharai Lagoon (Vattawan, Panichankeni, and Vaharai), during the period from July 2022 to August 2023. Wild shrimp species were identified using the taxonomic keys, and biodiversity was analysed using Simpson's and Shannon's indices via PAST3 software. Results revealed that Simpson's diversity index (1–D) was significantly highest at Arayampathy (0.6653) and lowest at Vattawan (0.4804), indicating reduced diversity near intensive shrimp farming zones. Shannon's diversity index also followed a similar pattern, showing high diversity in non-farming areas. Muhathuwaram recorded the highest average shrimp abundance of 85 individuals per catch, whereas Vattawan had the lowest (42 individuals). The observed patterns suggest a significant ecological separation between the sites, with non-farming areas showing greater richness and evenness. The decline in wild shrimp biodiversity and abundance in farming areas is likely driven by effluent discharge from shrimp farms, but may also be influenced by habitat degradation, agricultural runoff, overfishing, and broader environmental changes. These findings highlight the need for strict regulation of farm discharges and introduction of broad ecosystem-based approach in shrimp farming management.

*Corresponding author- mnmf@vet.pdn.ac.lk or naleeem.fouzi@gmail.com

INTRODUCTION

Shrimp aquaculture has grown into a multibillion-dollar industry, over the past three decades, generating substantial foreign exchange earnings and employment, particularly in developing Asian countries (FAO, 2020). Asia accounts for nearly 80% of global farmed shrimp production at present, with *Penaeus monodon* and *Litopenaeus vannamei* being the most commercially important species (Pazmiño et al., 2025; Harris & Vinobaba, 2013; Sohel & Ullah, 2012). This expansion has been largely fuelled by rising international demand, especially from key markets in the United States, Japan, and the European Union.

Shrimp farming is a well-established aquaculture practice in Sri Lanka, concentrated mainly in the North-Western and Eastern coastal belts. As of 2018, wild-caught shrimp still contributed more than two-thirds (16,970 MT) of national shrimp production which amounted to 25,150 MT (NAQDA, 2021). While the North-West remains the primary hub for commercial production, the Eastern Province, particularly Batticaloa District, has shown a steady rise in shrimp farming since the end of the civil conflict in 2009. From the 1980s through the early 2010s, the black tiger prawn (*P. monodon*) dominated Sri Lankan shrimp aquaculture (Galappaththi & Nayak, 2017), with smaller-scale farming of the giant freshwater prawn (*Macrobrachium rosenbergii*) was also taking place.

Periodic disease outbreaks in *P. monodon*, especially white spot syndrome virus (NAQDA, 2022), prompted the National Aquaculture Development Authority to authorise the commercial farming of the Pacific white shrimp (*L. vannamei*) in 2018. This intervention led to wide approvals and rapid industry expansion during 2019–2020 (WOAH, 2021). Production of *L. vannamei* increased sharply from 543 metric tons in 2019 to approximately 10,535 metric tons by 2021, surpassing *P. monodon* production (3,880 metric tons) in the same year (Kono et al., 2024).

Rich fishery resources in the Batticaloa district have long supported local livelihoods and food security through wild shrimp harvesting. However, the rapid intensification of shrimp farming in the region has raised environmental concerns. Pond construction often leads to the loss of ecologically important habitats such as mangroves and estuarine wetlands, which serve as nursery grounds for wild shrimp (Dahdouh-Guebas et al., 2002; Berlanga-Robles et al., 2011). In addition, effluent discharge from farms can deteriorate water quality by elevating nutrient and salinity levels, enhancing the chances for algal blooms, and introducing pathogens into surrounding natural water bodies (Sohel & Ullah, 2012; Stephen Hopkins et al., 1995). In this context, Biodiversity indices, including the Shannon–Weaver index (H′) and Simpson's diversity index (1–D), assessing the impacts of shrimp farming on wild shrimp biodiversity is vital for informing sustainable aquaculture practices and conserving coastal ecosystem functions in the Batticaloa District. The findings of this study provide essential baseline evidence to support science-based management interventions and regulatory frameworks aimed at balancing aquaculture expansion with the preservation of wild shrimp populations and their habitats. This study aimed to examine the effects of shrimp farming on the relative abundance and biodiversity of wild shrimp in the coastal lagoons of Batticaloa District. Specifically, the study compares species composition and diversity between farming and non-farming areas using standard biodiversity indices and evaluates how aquaculture-related environmental stressors may influence these patterns.

METHODOLOGY

Study area

The study was conducted in the coastal lagoons of the Batticaloa District, Eastern Sri Lanka. Among the six sampling stations selected, three were located in areas adjacent to active shrimp farming operations (Vattawan, Panichankeni, and Vaharai) and three were in non-shrimp farming areas in Vaharai Lagoon (Arayampathy, Kallady, and Muhathuwaram). These sites represent diverse lagoonal habitats with varying degrees of anthropogenic influence (Figure 1). Sampling stations were purposively chosen to represent lagoon sites with and without shrimp farming influence, and also based on proximity to aquaculture activity and accessibility. Within each zone, specific sampling points were selected among active artisanal fishing locations to ensure ecological comparability and reduce spatial bias. Sampling was consistently conducted at fixed GPS-referenced points over the 12-month period. This consistency in sampling location enhanced the reliability and comparability of biodiversity and abundance estimates across time and space.

Sample collection

Wild shrimp were sampled from each station twice monthly during the period from August 2022 to July 2023, following the lunar cycle (aligned with full moon and new moon). The lunar cycle was followed because the local fishermen correspond it with peak catch periods. At each station, five fishermen used the same size, standardized cast nets to catch shrimp, ensuring consistent effort and gear across all sites. Samples from each station were pooled, and shrimp were identified to species level using taxonomic keys developed by Lovett (1981) and Chan (1998), with additional descriptions referenced from Piratheepa et al. (2016) and New (2002). Catch data including total shrimp count, species composition, and seasonal patterns were recorded and analysed. The main species were identified based on the key characteristics (Table 1).

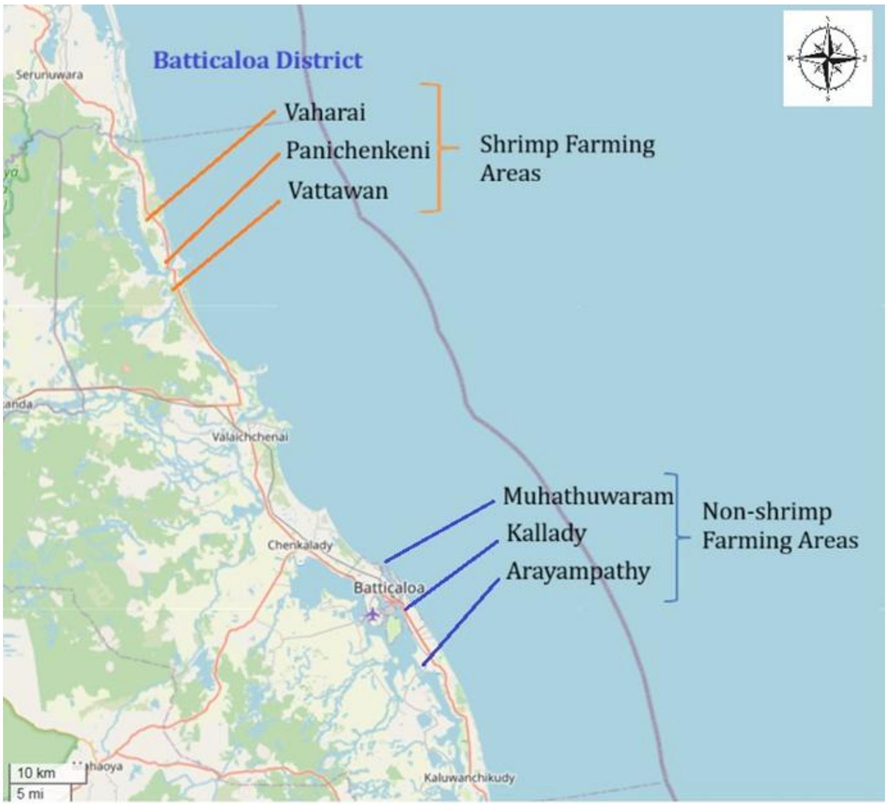

Figure 1 Map of the study area showing shrimp farming (Vahari Lagoon) and non-shrimp farming (Batticaloa Lagoon) sampling stations

Table 1 Key identification characteristics of the main shrimp and prawn species identified.

Species	Key identification characteristics
Penaeus indicus (Indian white shrimp)	Body generally whitish to translucent with scattered dark chromatophore dots; rostrum straight with regularly spaced dorsal teeth; tail fan whitish.
Penaeus monodon (Giant tiger prawn)	Large-sized; body greenish-grey to blackish with distinct transverse brown to black bars; pleopods with yellow or reddish tips; robust rostrum.
Penaeus semisulcatus (Green tiger prawn)	Body pale brown to greenish with oblique dorsal bands across abdomen; rostrum with a distinct median groove (partly sulcate).
Penaeus merguiensis (Banana prawn)	Body creamy to yellowish-white, sometimes pinkish; rostrum long and slender, often extending beyond antennal scale; abdominal bands absent.
Macrobrachium rosenbergii (Giant freshwater prawn)	Distinct from marine penaeids; very long, toothed rostrum; males with greatly elongated second chelipeds; telson extends beyond last abdominal spines.

Biodiversity Analysis

Species abundance and biodiversity were analyzed using Biodiversity Professional v2 and PAST3 software. Two primary diversity indices which provide quantitative measures for assessing species richness and evenness in aquatic ecosystems were calculated for each site. These indices consider both the number of species and the relative abundance of individuals, making them effective indicators for detecting ecological impacts of human activities (Lin, 2011; SilvaI et al., 2014).

- Simpson's Index of Diversity (1–D):

$$1 - \boldsymbol{D} = 1 - \frac{\sum ni(ni - \mathbf{1})}{N(N - \mathbf{1})}$$

  Where n_i is the number of individuals of species i and N is the total number of individuals across all species. A value closer to 1 indicates higher diversity.

- Shannon–Weaver Index (H′):

$$H' = \sum pi \ \log_{10} pi$$

  Where p_i is the proportion of individuals belonging to the ith species. Higher H' values indicate greater species richness and evenness.

- Pielou's Evenness Index (J′):

$$J' = \frac{H\prime}{\log_{10} S}$$

Where S is the total number of species. J' values closer to 1 indicate a more even distribution of individuals across species.

Data were statistically analysed to identify differences in biodiversity between shrimp farming and non-shrimp farming areas. One-way ANOVA was used to compare biodiversity indices between shrimp farming and non-shrimp farming areas. The seasonal trends were also examined during the period. Post-hoc comparisons were performed using Tukey's HSD test. PCA, correspondence analysis, and hierarchical clustering (Euclidean distance, single linkage) were applied to visualize species relationships and spatial trends. Analyses were carried out using PAST3 software.

RESULTS AND DISCUSSION

The diversity of wild shrimp in non-shrimp farming areas were higher than that of shrimp farming areas. A total of five wild shrimp species, namely *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *P. merguiensis*, and *Macrobrachium rosenbergii*, were identified during the study period across the six lagoon sites in Batticaloa District: These species varied in both abundance and distribution between shrimp farming and non-shrimp farming areas. The overall abundance of wild shrimp was noticeably higher in non-shrimp farming locations, where Muhathuwaram showed the highest year-round availability. Seasonal fluctuations were evident, with peak catches recorded between October and April, which coincides with the rainy season.

Shannon's diversity index (H′) values varied considerably across sites (Figure 2). Arayampathy and Muhathuwaram, which are non-shrimp farming areas, recorded the highest H′ values of 0.494 and 0.476 respectively indicating greater species richness and evenness, particularly during the rainy season (November to February). In contrast, the lowest diversity was found at Vattawan (H′ = 0.292), which is a shrimp farming area located within 1 km of intensive aquaculture operations. During the off-season months, Shannon index in non-farming areas remained relatively stable, while that in farming areas dropped significantly, highlighting a seasonal sensitivity linked to farming activity.

Simpson's diversity index (1–D) showed similar trends (Figure 3). Arayampathy yielded the highest value of 0.6648, whereas Vattawan recorded the lowest value (0.4804). Non-farming stations consistently showed high diversity during the rainy season (0.505–0.665), while farming areas presented more variability and generally lower values than non-farming areas.

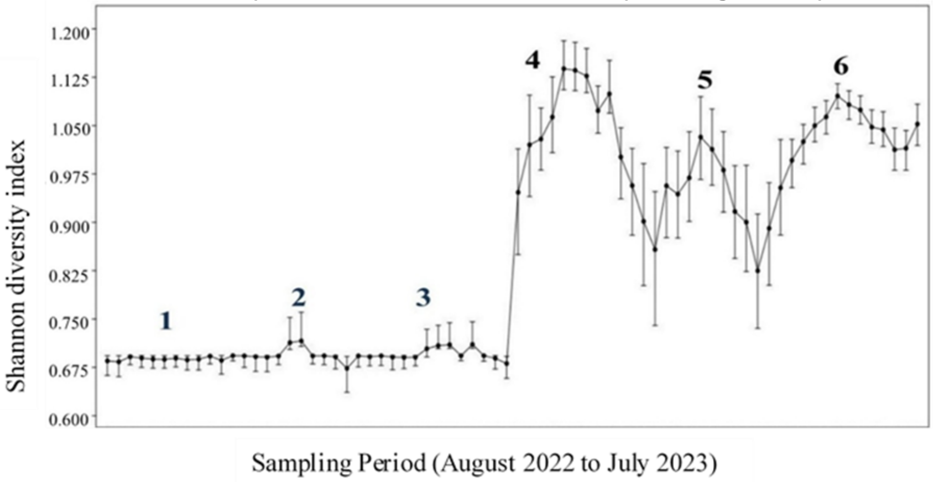

Figure 2 Comparison of Shannon's diversity index (H′) across shrimp farming (Stations 1–3) and non-shrimp farming (Stations 4–6) sites.

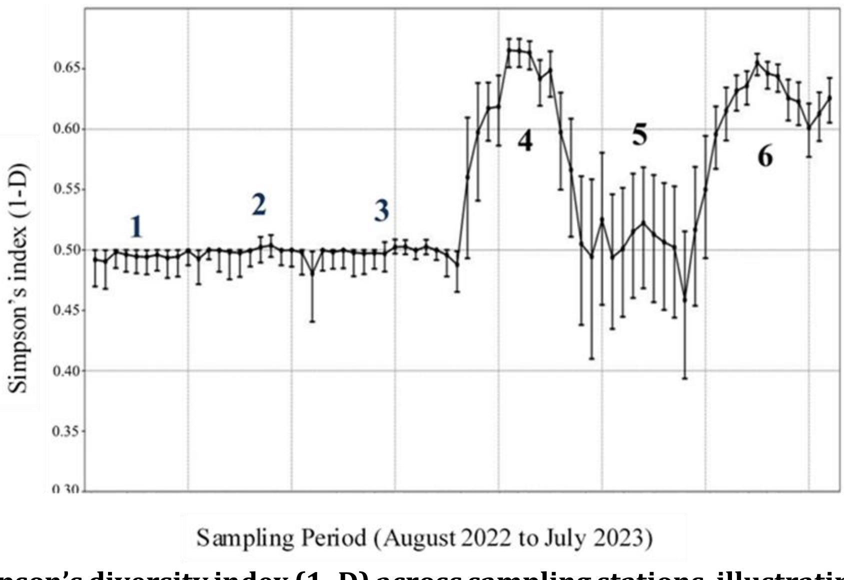

Figure 3 Simpson's diversity index (1–D) across sampling stations, illustrating biodiversity differences between shrimp farming (1-3) and non-shrimp farming (4-6) areas.

Principal Component Analysis (PCA) revealed that *P. indicus* was the dominant species across all sites, contributing the most to variation among stations (Figure 4). In shrimp farming areas, species distributions were more clustered, indicating less ecological variability, while in non-farming areas, species were more dispersed, suggesting a more balanced ecosystem structure. Principle components revealed the contributions for the total variability were 0.10928 for *M. rosenbergii* and 0.55221 for *P. indicus*. This implies *P. indicus* is dominating in wild catch of Batticaloa district. Variables of Principal component 2 in the shrimp farming areas were positively correlated (0.26065-0.44372). In non-shrimp farming areas, stronger correlations were observed among environmental variables and shrimp species distributions, reflecting more intact ecological interactions compared to the shrimp farming areas. Thus, there were high correlation between species distributions and stations in non-shrimp farming areas.

Correspondence analysis further confirmed the divergence between farming and non-farming sites (Figure 5 and 6). Shrimp species in non-farming areas showed greater spread and lower similarity indices, reflecting higher biodiversity. In contrast, farming areas showed tighter clustering and higher similarity, indicating ecological homogenization. Similarity between shrimp species and stations in shrimp farming areas ranged between -1.06909 and -1.28999, whereas it ranged within 0.265508- 1.70328 in non-shrimp farming areas These results suggest that the lower similarity observed among species in non-farming areas is indicative of higher biodiversity and greater ecological variability. Conversely, the higher similarity detected in farming areas reflects reduced biodiversity, likely driven by habitat modification and anthropogenic pressures associated with shrimp aquaculture.

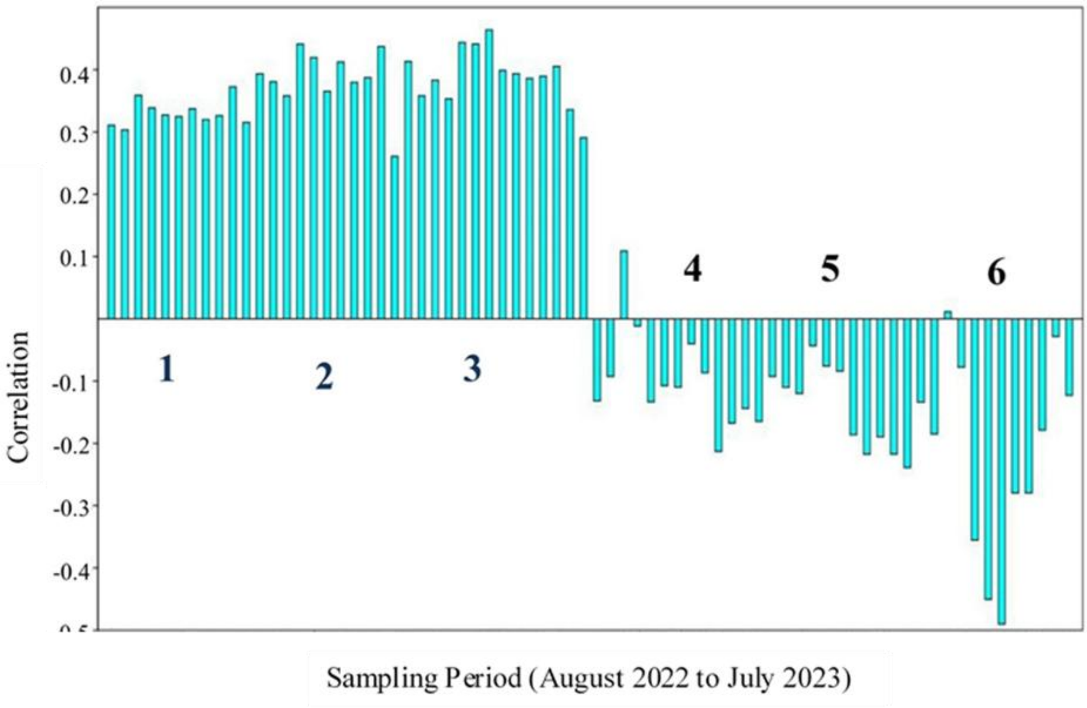

Figure 4 Principal Component Analysis (PCA) showing species distribution patterns across all sampling sites.

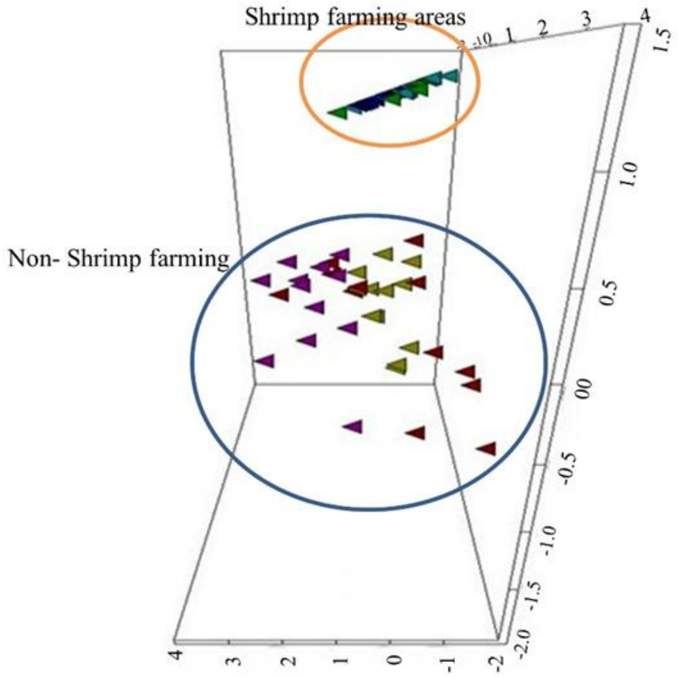

Figure 5 Correspondence analysis depicting species-station associations in shrimp farming and non-shrimp farming areas. (n=72)

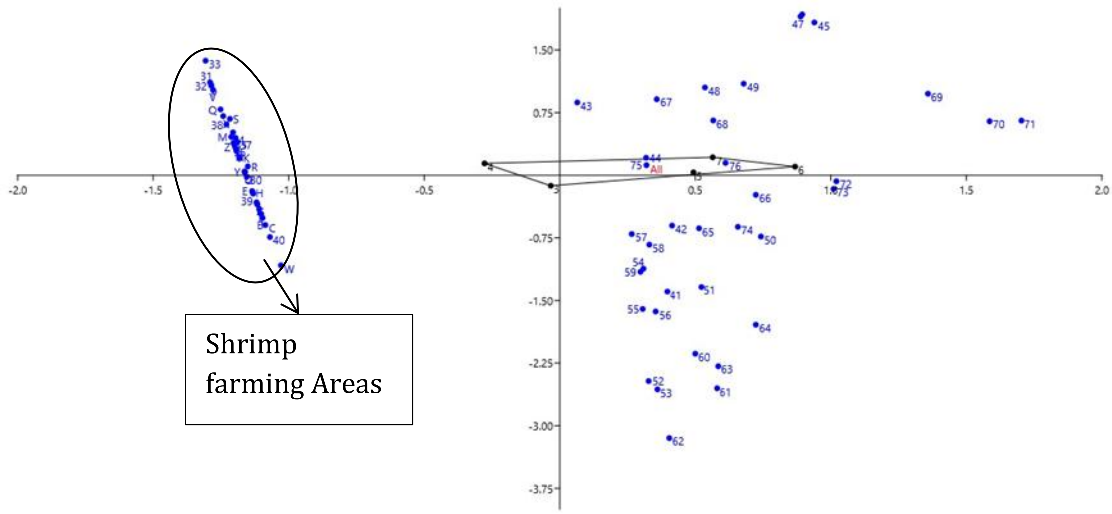

Figure 6 Scatter plot of correspondence analysis for shrimp species across study locations. (n=72)

Hierarchical clustering (Euclidean single-linkage) demonstrated the strongest similarity between *M. rosenbergii* and *P. monodon*, while *P. indicus* stood out with the largest distance to other species, confirming its dominant presence across the region (Figure 7). Even in off season the catch of *P. indicus* is present in low amount. Low distance value of 0.0132 is present between *M. rosenbergii* and *P. monodon.*

High abundance of wild shrimps throughout the year was recorded in *Muhathuvaram* (Non-shrimp farming area) which is the mouth of the *Batticaloa* lagoon. Summary of shrimp abundance in all stations throughout the study period is shown in Figure 8. Though the numbers are lesser than shrimp season, shrimps are present in *Muhathuwaram* during the off season. According to the records, major proportion of wild caught shrimps is supplied by *Muhathuwaram* to *Batticaloa* district. High abundance could be seen during the rainy season in all stations.

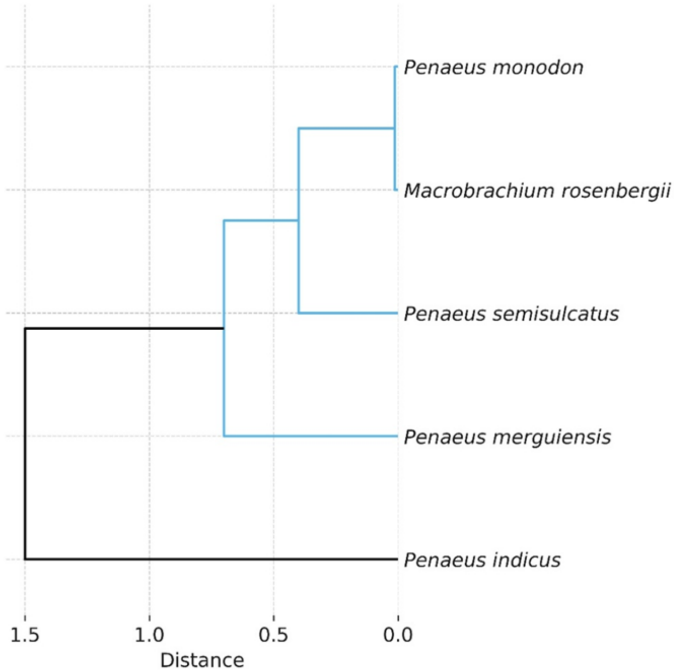

Figure 7 Hierarchical cluster analysis (Euclidean single-linkage) showing similarity among shrimp species based on distribution patterns. (n=72)

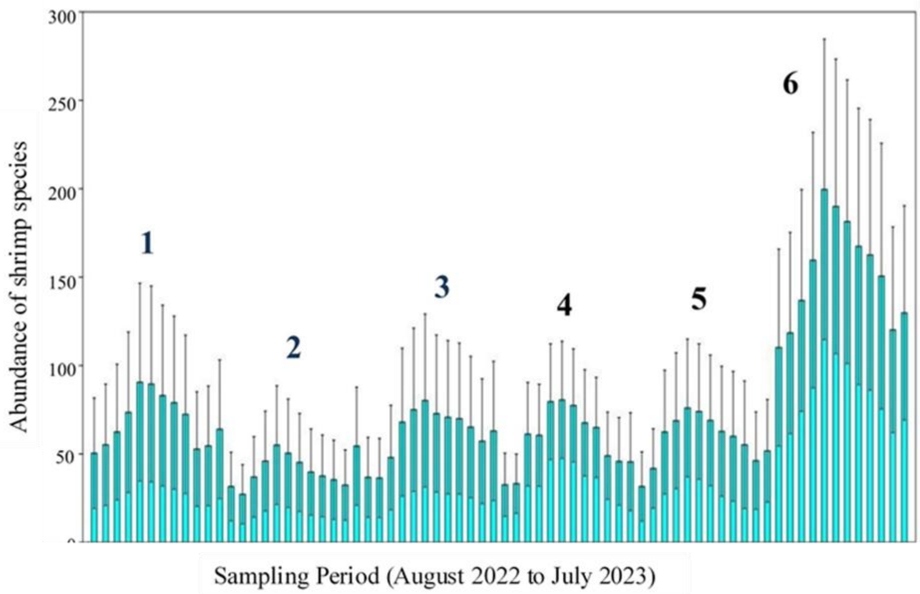

Figure 8 Annual variation in wild shrimp abundance across sampling stations. 1-3 shows the shrimp farming stations. (1 –*Vaharai*, 2- *Vattawan*, 3- *Pannichenkeni*) and 4-6 shows non-shrimp farming stations (4-*Arayampathy*, 5-*Kallady*, 6- *Muhathuvaram*).

This study aimed to compare the diversity and abundance of wild-caught shrimp between shrimp farming and non-shrimp farming areas in Batticaloa District, Sri Lanka. Our results showed a clear and consistent pattern revealing that the wild shrimp diversity and abundance were significantly higher in non-shrimp farming areas.

In contrast to the findings of Samarayanke (2003), who reported over 27 species of shrimp including six *Penaeus* spp., 11 *Metapenaeus* spp., and 10 *Parapenaeopsis* spp. across various estuarine and marine ecosystems in Sri Lanka, our study identified only five species. However, the inferences made by Samarayanke (2003) spanned a broad geographic range, including multiple coastal districts, whereas the present study focused solely on Batticaloa district. In addition, the reduced number of species in the present could be attributed gradual decline in wild shrimp biodiversity in the region, owing to a combination of activities including habitat degradation, anthropogenic pressures, and environmental change.

Several studies have documented the ecological consequences of shrimp farming, particularly the destruction of mangrove forests, which serve as critical nursery grounds for wild shrimp and other aquatic organisms. Mangrove loss has been identified as a major driver of reduced shrimp biodiversity in countries like Vietnam (Dahdouh-Guebas et al., 2002) and Bangladesh (Hossain et al., 2012). In Batticaloa, the expansion of shrimp farms often occurs at the expense of natural wetland areas, contributing to habitat fragmentation and salinity intrusion. Farmers and fishers in the area have also observed seasonal changes in shrimp availability, especially *P. monodon* is more commonly caught during full moon days, while *M. rosenbergii* becomes abundant during the rainy season when the Unnichai tank is opened. These observations align with ecological patterns and highlight the importance of integrating local knowledge into scientific studies.

The highest abundance of shrimp was recorded in Muhathuwaram, a non-shrimp farming area located near the lagoon mouth. Similarly, the highest biodiversity (as indicated by Simpson's diversity index) was observed in Arayampathy, which is another non-farming site. In contrast, Vattawan, a site adjacent to intensive shrimp farms, exhibited the lowest diversity values. This spatial pattern is consistent with previous research which suggested that effluent discharge from shrimp ponds negatively affects water quality, leading to reduced wild fishery productivity (Aeron-Thomas, 2003).

Increased salinity can negatively impact the growth and survival of freshwater and estuarine shrimp species. A study from Bangladesh reported that aquaculture practices contribute to the formation of saline buffer zones, leading to reduced agricultural productivity and the degradation of coastal habitats (Sohel & Ullah, 2012). In Sri Lanka, although shrimp farming is now concentrated in the North-Western coastal belt, the industry initially emerged in the Eastern Province, including Batticaloa, but later declined due to civil unrest. Nevertheless, aquaculture continues to be a significant sector, employing over 50,000 people and contributing substantially to national exports (Sivarajah & Harriss, 2016; Samarayanke, 2003).

As the demand for farmed shrimp continues to rise globally, particularly in markets such as the USA, Japan, and the EU, there is increased pressure on coastal ecosystems. This has often resulted in the conversion of wetlands, widespread use of low-wage labor, and the loss of more than 50–80% of mangrove areas in some major shrimp-producing countries (Macusi et al., 2022; Galappaththi & Nayak, 2017). Unfortunately, the environmental and social costs of this growth are rarely accounted for in market prices. In Sri Lanka, shrimp farms are still developed by large investors, often with limited regulation or consideration of the long-term impacts on local communities and ecosystems.

One significant ecological concern is the collection of wild shrimp fry for stocking ponds. While some farmers prefer wild fry for their robustness, the practice leads to substantial bycatch, often destroying over 60 species of juvenile fish, crabs, and other prawns (Das et al., 2016). Additionally, the construction of shrimp ponds can result in the loss of wetlands, increased nutrient loading, and the introduction of exotic species and pathogens (Berlanga-Robles et al., 2011).

Wetlands and estuarine systems in coastal Sri Lanka are rich in biodiversity and play crucial ecological roles, serving as breeding grounds, feeding areas, and migration corridors for a wide range of organisms (Samarayanke, 2003). A study in the Batticaloa lagoon indicated biodiversity loss and even the extinction of certain native fish species, with water quality deterioration posing a significant threat to commercially important species such as shrimp (Harris & Vinobaba, 2013).

The ecological functions of freshwater shrimp, such as *Macrobrachium* spp., are especially vital. These species act as detritivores and scavengers, maintaining stream health and supporting food webs by transferring energy from primary producers to higher trophic levels. Their loss can destabilize aquatic ecosystems (Soomro et al., 2016).

The PCA and correspondence analysis of the present study revealed a distinct ecological separation between shrimp farming and non-farming sites. Non-farming areas supported more diverse and resilient ecosystems, characterized by higher species richness and evenness. In contrast, farming sites exhibited reduced biodiversity and greater similarity in species composition across stations, suggesting a homogenization of the shrimp community structure (Perez et al., 2025). Notably, *P. indicus* emerged as the most dominant species across all study locations, reflecting its broad ecological tolerance and adaptability. However, this dominance may also signal a shift in community balance, where more sensitive species are being excluded from increasingly degraded or altered habitats. These reductions in biodiversity indices signal not only a loss of species but also a diminished ecological redundancy and stability, which can impair ecosystem functioning and long-term resilience (Oliver et al., 2015).

Local ecological knowledge (LEK) gathered from fishers during fieldwork provided valuable insights into the seasonal patterns of shrimp availability, complementing the quantitative data. For instance, the reported increase in *M. rosenbergii* catches following freshwater discharges, and the higher abundance of *P. monodon* during full moon phases, reflect natural reproductive and migratory behaviours. These patterns highlight the importance of incorporating LEK into management strategies, particularly in data-limited contexts. As demonstrated by Silas et al. (2023), LEK can serve as a reliable and cost-effective source of ecological information, supporting more adaptive and locally grounded conservation and fisheries planning in small-scale systems. These findings are in agreement with studies conducted in other tropical regions (Galappaththi & Nayak, 2017; Das et al., 2016), where intensive shrimp farming has led to the loss of wetland biodiversity, reduced wild broodstock availability, and weakened coastal ecosystem services.

To mitigate the ecological impacts of shrimp farming, strict regulatory measures need to implemented. These measures could include strict enforcement of effluent treatment and discharge standards, protection and restoration of mangrove buffer zones, promotion of ecosystem-based approaches such as integrated multi-trophic aquaculture (IMTA) and regular environmental monitoring programs to assess water quality and biodiversity (Macusi et al., 2022; Páez-Osuna, 2001). These steps are crucial for achieving a sustainable balance between shrimp farming and the conservation of lagoon ecosystems.

CONCLUSION

There is a clear ecological distinction between shrimp farming and non-farming areas in the Batticaloa District, with non-farming sites consistently exhibiting high wild shrimp abundance and biodiversity. Low diversity indices in farming zones suggest potential impacts from intensive aquaculture activities.

There is need for strengthened environmental safeguards, including effluent management protocols, habitat restoration, particularly of mangrove buffers, and routine environmental monitoring. Incorporating local ecological knowledge and promoting ecosystem-based aquaculture practices will be crucial for balancing shrimp farming development with the conservation of wild shrimp populations and the long-term ecological integrity of coastal lagoons. Future studies integrating hydrological, water quality, and habitat mapping data are essential to substantiate and expand upon these initial findings.

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