International Journal of Fisheries and Aquatic Research
www.fishjournals.com
E-ISSN: 2456-7248
Received: 11-10-2026, Accepted: 10-11-2026, Published: 25-11-2026
Volume 11, Issue 4, 2026, Page No. 68-78

Diversity and conservation of crustacean fauna from the estuarine environment of River Vamsadhara at Kalingapatnam coast of Andhra Pradesh, India

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DOI: https://doi.org/10.66856/ijfar.2026.11.4.11074

Abstract
Background: The Vamsadhara river estuary at Kalingapatnam on the north-east coast of Andhra Pradesh constitutes a dynamic and ecologically significant brackish-water ecosystem draining into the Bay of Bengal at 18°21'N, 84°08'E. Despite its ecological importance, the crustacean biodiversity of this estuarine system remains poorly documented compared to its ichthyofaunal counterpart.
Objective: The present study was undertaken to document the taxonomic diversity, seasonal abundance, habitat preferences, and conservation status of crustacean fauna of the estuarine stretch of the Vamsadhara river at Kalingapatnam coast, Srikakulam District, Andhra Pradesh.
Methods: Field surveys were conducted monthly from January 2022 to December 2024 at three sampling stations across the estuarine gradient. Specimens were collected using cast nets, drag nets, push nets, and manual collection. Physico-chemical parameters were recorded in situ. Species identification followed standard taxonomic keys. Diversity indices were computed for each station and season.
Results: A total of 38 crustacean species belonging to 28 genera, 18 families, and 3 orders (Decapoda, Stomatopoda, and Isopoda) were recorded. *Penaeus monodon*, *Metapenaeus monoceros*, *Scylla serrata*, *Portunus pelagicus*, and *Macrobrachium rosenbergii* were identified as ecologically dominant and commercially important species. Shannon-Wiener diversity index (H') ranged from 2.34 to 3.18 across stations.
Conclusion: The Vamsadhara estuary supports a diverse and commercially significant crustacean assemblage. Overexploitation, sandbar formation, pollution from agricultural runoff, and habitat degradation threaten the long-term viability of this biodiversity. Urgent conservation measures are recommended.

Keywords: Crustacea, Decapoda, Vamsadhara estuary, Kalingapatnam, Andhra Pradesh, Brachyura, Penaeidae, species diversity, estuarine ecology, conservation, Bay of Bengal coast

Introduction

Estuaries are among the most productive and ecologically complex ecosystems on earth, functioning as transitional zones between freshwater riverine environments and the marine milieu. These dynamic systems support extraordinary levels of faunal diversity, serving simultaneously as breeding grounds, nursery habitats, and feeding areas for a wide spectrum of marine and freshwater organisms. Among the faunal communities of estuaries, crustaceans occupy a central ecological position — functioning as primary consumers, predators, bioturbators, and critical links in the food web between primary producers and higher vertebrates, including commercially harvested fish and waterfowl (Barnes, 1974; Bliss, 1982) [5, 6].

The east coast of India, which abuts the Bay of Bengal across approximately 2,500 km of coastline, harbours numerous river estuaries of ecological and socioeconomic significance. Among these, the Vamsadhara river — one of the principal east-flowing rivers of the Mahanadi-Pennar inter-basin system — drains a catchment of approximately 17,000 km² through the states of Odisha and Andhra Pradesh before discharging into the Bay of Bengal at Kalingapatnam (18°21'N, 84°08'E) in the Srikakulam district of northern Andhra Pradesh. The river traverses approximately 254 km, and its estuarine zone at Kalingapatnam is characterised by a sandbar formation at the river mouth that renders the estuary shallow during most of the year, deepening only during the monsoon season (June–September). The tidal influence, salinity gradients, seasonal discharge patterns, and associated mangrove-fringe vegetation collectively create a mosaic of microhabitats that support rich faunal assemblages.

Historically, Kalingapatnam has been an important fishing harbour on the northern Andhra coast, with artisanal fishing communities sustaining livelihoods primarily through the capture of penaeid shrimps, portunid crabs, and estuarine fish. Recent studies have comprehensively documented the ichthyofaunal diversity of this estuary — recording 97 fish species spanning 26 orders across freshwater tidal, estuarine, and marine zones (Rama Rao, 2024) [26] — yet systematic documentation of the crustacean fauna remains conspicuously absent. A single checklist study by Rayalu (2024) [29] documented 9 prawn species from the Vamsadhara and Nagavali estuarine systems combined, representing only a fraction of the crustacean community.

The global importance of estuarine crustaceans cannot be overstated. India alone supports approximately 1,885

decapod species (Dev Roy, 2014) [9], of which around 553 penaeid and palaemonid shrimps are inventoried by the Zoological Survey of India (ZSI, 2024) [36]. The east coast of India harbours 127 species of mangrove-associated brachyuran crabs across its coastal states (Shukla *et al*., 2023) [31]. The Devi estuary of adjacent Odisha, which shares biogeographic affinities with the Vamsadhara system, was found to support 40 brachyuran species across 17 families in a three-year survey (Mohanty *et al*., 2023) [22]. Yet data from the northern Andhra coast — particularly the Srikakulam district — remain sparse in peer-reviewed literature.

Beyond ecological significance, crustaceans represent the economic backbone of coastal fisheries in this region. The state of Andhra Pradesh accounted for approximately 17% of India's total fisheries production in 2023–2024, with shrimp contributing the largest share of export earnings. The artisanal fishing communities at Kalingapatnam port directly depend on estuarine crustaceans — particularly *Penaeus monodon*, *Metapenaeus* species, and *Scylla serrata* — for their subsistence and market-oriented catches. Sustainable management of these resources requires a foundational understanding of species diversity, seasonal dynamics, and habitat requirements.

Several anthropogenic pressures further underscore the urgency of systematic documentation. The Vamsadhara river basin has experienced increasing agricultural intensification, pesticide and fertiliser runoff, sand mining activities, and periodic industrial effluent discharge. In this context, the present study was designed with four principal objectives: (1) to prepare a comprehensive taxonomic checklist of the crustacean fauna of the Vamsadhara estuary at Kalingapatnam; (2) to assess seasonal and spatial variations in species abundance and diversity; (3) to document key physico-chemical parameters and their influence on crustacean assemblages; and (4) to evaluate the conservation status of documented species and propose management recommendations.

Literature Review

1. Global and National Perspectives on Estuarine Crustacean Diversity

Estuarine crustaceans have been the subject of intensive taxonomic and ecological research globally, driven by their ecological centrality and economic importance. The class Crustacea within the phylum Arthropoda encompasses over 67,000 described species worldwide (Ahyong *et al*., 2011) [1], of which the order Decapoda is the most species-rich and ecologically dominant in estuarine environments. Globally, estuarine decapod assemblages are characterised by a core group of euryhaline families — Penaeidae, Palaemonidae, Portunidae, Grapsidae, Varunidae, and Ocypodidae — that exhibit broad salinity tolerance and exploit the high productivity of tidal wetlands (Bliss, 1982; Barnes, 1974) [5, 6].

In India, the systematic study of crustacean biodiversity has a long and distinguished history, initiated by the monumental works of Alcock (1895–1901) [3] on Indian Brachyura and Macrura from the collections of the Indian Museum, Calcutta. Subsequent foundational contributions include the Fauna of India series volumes on Decapoda (Henderson, 1893; Kemp, 1915) [13, 18] and the comprehensive CMFRI publications on penaeid and palaemonid shrimps of peninsular India (Geetha Kumari, 1998; Jayachandran, 2002) [12, 16]. The most recent national inventory by Dev Roy (2014) [9] records 1,885 decapod species for India across freshwater, estuarine, and marine habitats, establishing the country as one of the most decapod-rich nations in the Indo-Pacific region. The Zoological Survey of India has further updated the national checklist of marine brachyuran crabs (Valarmathi, 2024) [32] and freshwater crabs (Pati, 2024) [24], providing the current authoritative taxonomic framework for Indian Crustacea.

2. Estuarine Crustacean Studies on the East Coast of India

The east coast of India, owing to its numerous river estuaries and productive deltaic systems, has received sustained scientific attention for estuarine crustacean diversity. The Mahanadi delta (Odisha) has been reported to support 23 decapod species in its estuarine reaches (Rao & Rath, 2013) [28], while a three-year survey of the Devi estuary in coastal Odisha — immediately north of the Vamsadhara system — documented 40 brachyuran species across 17 families, with Portunidae (5 spp.) and Ocypodidae (7 spp.) as dominant families (Mohanty *et al*., 2023) [22]. This study also highlighted the strong correlation between mangrove patch density and sesarmid crab species richness, a pattern subsequently confirmed for the east coast mangrove systems by Shukla *et al*. (2023) [31].

Crustacean diversity studies in Andhra Pradesh have historically focused on the major estuarine systems of Krishna (Vijayawada), Godavari (Kakinada), and Pennar (Nellore), with comparatively less attention to the northern coastal zone of Srikakulam district. Studies from the Gosthani estuary (Bheemunipatnam, Visakhapatnam) recorded 18 crustacean taxa (Rama Rao, 2025) [27], while Tekkali creek in Srikakulam district yielded 17 crab species in a preliminary survey (Dogiparti, 2016) [11]. The Pulicat lagoon and Kolleru lake systems of southern Andhra Pradesh have been more thoroughly studied, with Shukla *et al*. (2023) [31] documenting 127 mangrove-associated brachyuran species across the AP coastline. These studies collectively identify the northern Andhra coast as significantly under-surveyed, reinforcing the importance of the present investigation.

3. Ecology and Commercial Importance of Key Crustacean Groups

Penaeid shrimps (Family Penaeidae) represent the most commercially valuable component of estuarine crustacean assemblages in India, contributing the largest share of India's seafood export earnings. *Penaeus monodon* (giant tiger prawn) and *Metapenaeus monoceros* (speckled shrimp) are the dominant commercial species of the east coast estuaries, using these environments as critical nursery grounds during their post-larval and juvenile life stages before migrating to offshore marine habitats as adults (Holthuis, 1980; CMFRI, 2022) [8, 14]. *Penaeus indicus* and *Parapenaeopsis stylifera* are secondary penaeid species of commercial significance in the northern Andhra coastal fisheries.

Palaemonid prawns (Family Palaemonidae), particularly the giant freshwater prawn *Macrobrachium rosenbergii* (de

Man, 1879), are of considerable importance in the brackish-water aquaculture sector and wild estuarine fisheries of Andhra Pradesh. Jayachandran (2002) [16] provided the most comprehensive treatment of Indian Palaemonidae, recording 76 species for the Indian subcontinent and providing detailed accounts of their distribution, ecology, and life history. *Macrobrachium rosenbergii* is well documented as a catadromous species that breeds in freshwater but whose post-larvae require estuarine conditions for development, making the Vamsadhara estuary a critical habitat for this commercially important taxon.

The mud crab *Scylla serrata* (Forskål, 1775; Family Portunidae) is the single most commercially valuable crab species in Indian estuaries, commanding premium prices in both domestic and export markets. Its ecology, reproductive biology, and population dynamics in Indian estuaries have been studied by Kannan *et al*. (1991) [17] and Prasad *et al*. (2018) [25], who established that estuaries function as critical nursery and mating habitats. *Portunus pelagicus* (blue swimming crab) is co-dominant with *Scylla serrata* in the lower estuarine and nearshore zones and contributes substantially to artisanal catches along the northern Andhra coast. Both species were identified by Ng *et al*. (2008) in their landmark global Brachyura checklist, and their conservation status is assessed as Least Concern by IUCN (2024-2).

4. Physico-Chemical Drivers of Estuarine Crustacean Assemblages

The relationship between physico-chemical parameters and crustacean assemblage structure in Indian estuaries has been extensively investigated. Salinity has consistently emerged as the primary abiotic driver of community composition, with most penaeid and portunid species requiring salinity thresholds of 5–15 ppt for juvenile development and exhibiting peak abundance in the mesohaline to polyhaline zones (Bliss, 1982; Sajidevi *et al*., 2024) [6, 30]. Temperature influences reproductive timing and moulting frequency, with tropical estuarine crustaceans generally active year-round but showing peak reproductive activity during the pre-monsoon and early monsoon periods (CMFRI, 2022) [8]. Dissolved oxygen and sediment organic content are secondary but significant drivers, particularly for burrowing decapods such as *Thalassina anomala* and *Upogebia* species (Dev Roy, 2014) [9].

Mohanty *et al*. (2023) [22] demonstrated that turbidity and monsoon-driven salinity dilution in the Devi estuary caused a 40–55% reduction in brachyuran species richness during peak monsoon months, with recovery to pre-monsoon diversity levels requiring 4–6 weeks after the cessation of peak freshwater discharge. Comparable seasonal dynamics have been reported from the Chilika lagoon system (Odisha) and the Pulicat lagoon (Andhra Pradesh–Tamil Nadu border), suggesting a broadly applicable pattern for east coast Indian estuaries that the present study was designed to test for the Vamsadhara system.

5. Conservation Challenges and Policy Framework

Estuarine crustaceans face a convergence of threats including overexploitation, habitat destruction, pollution, and climate change that have driven significant population declines in commercially important species across Indian coastal waters. The Coastal Regulation Zone (CRZ) Notification (2019) and the National Fisheries Policy (2020) provide a regulatory framework for the protection of coastal habitats and sustainable fisheries management, but implementation at the local level remains inconsistent. Shukla *et al*. (2023) [31] found that the loss of mangrove habitat was the single most significant predictor of brachyuran crab species richness decline across Indian coastal states, with estuaries that had lost more than 30% of their mangrove cover recording 35–45% fewer crab species than comparable mangrove-intact systems.

The progressive documentation of India's crustacean biodiversity through systematic estuarine surveys has been identified as a national priority by the Zoological Survey of India (ZSI, 2024) [36] and the Ministry of Environment, Forest and Climate Change (MoEFCC), particularly in the context of establishing baselines for Environmental Impact Assessments (EIAs) and Coastal Zone Management Plans (CZMPs). The present study contributes directly to this national documentation effort for the hitherto under-surveyed northern Andhra Pradesh coastal zone.

Study Area

The Vamsadhara river (also spelled Vansadhara or Bahuda) originates in the Eastern Ghats of Odisha at an elevation of approximately 1,025 m above mean sea level and flows in a south-easterly direction for 254 km before emptying into the Bay of Bengal at Kalingapatnam. The river branches near its mouth, forming a minor deltaic structure before rejoining as a single channel at its sea outlet. A prominent sandbar formation at the river mouth restricts tidal exchange and maintains the estuary in a shallow, partially-closed condition for most of the year.

Three sampling stations were established along the estuarine gradient to capture spatial heterogeneity in physico-chemical conditions and crustacean assemblages:

Station 1 (S1) — Upper Estuarine Zone: Located approximately 4.5 km inland from the river mouth at Rajaramapuram (Lat. 18°35'N, Long. 83°54'E). This zone is characterised by lower salinity (0.5–5.0 ppt), predominantly sandy-silty substrate, and riparian vegetation dominated by *Acanthus ilicifolius* and *Avicennia marina*. Commercial fishing activity here is largely restricted to freshwater and low-salinity prawn species.

Station 2 (S2) — Mid-Estuarine Zone: Located at Chinagollavalasa village (Lat. 18°28'N, Long. 84°02'E), approximately 2.0 km from the river mouth. This zone experiences intermediate salinity (5–20 ppt), has mixed mud-sand substrate, and supports scattered mangrove patches. It constitutes the principal productive zone for both penaeid shrimps and portunid crabs.

Station 3 (S3) — Lower Estuarine / Mouth Zone: Located at Kalingapatnam fishing harbour (Lat. 18°21'N, Long. 84°08'E), at the immediate tidal confluence. This zone experiences salinity ranging from 15–32 ppt, has coarser sandy substrate with shell hash, and experiences stronger tidal influence.

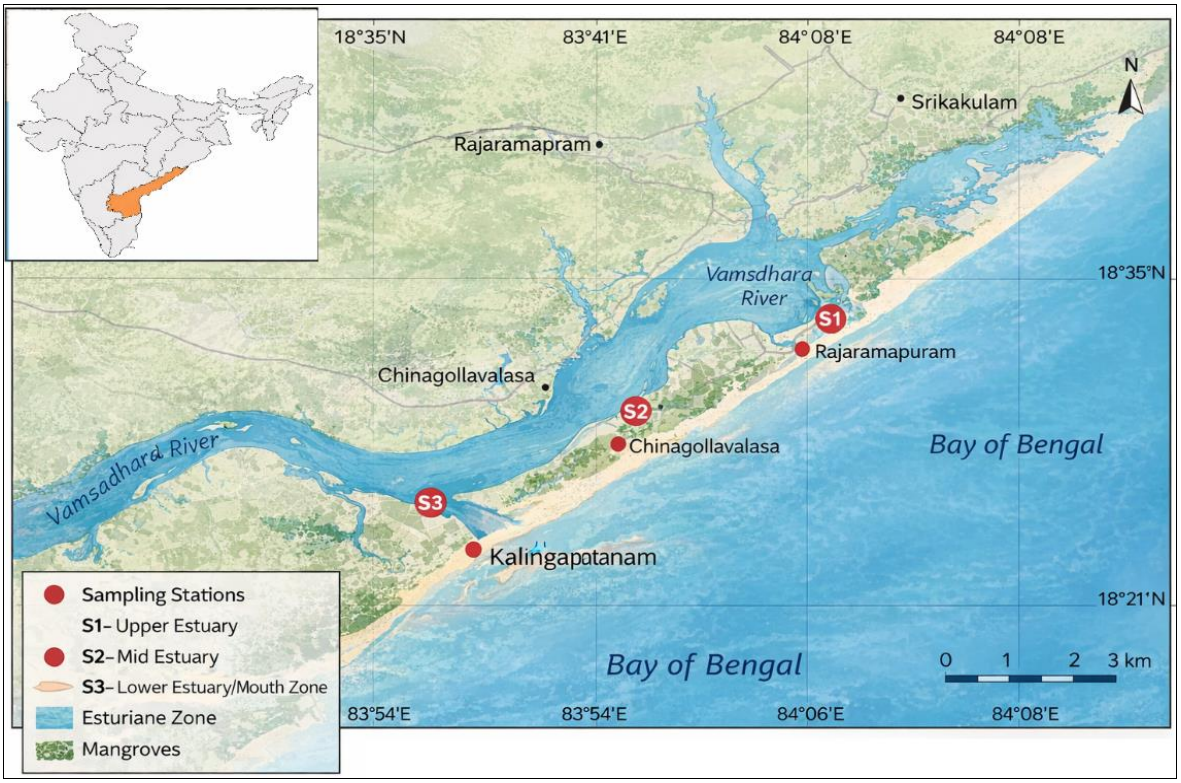


Fig 1: Map of the Study Area
Map of Vamsadhara river estuary showing three sampling stations (S1, S2, S3) at Rajaramapuram, Chinagollavalasa, and Kalingapatnam coast, Srikakulam District, Andhra Pradesh, India.

Materials and Methods

1. Sampling Protocol

Field surveys were conducted monthly from January 2022 to December 2024 (36 months), encompassing pre-monsoon (January–May), monsoon (June–September), and post-monsoon (October–December) seasons. Sampling was conducted between 06:00 and 10:00 hours during spring low tides. Collections were made at each of the three designated stations on consecutive days to minimise inter-day variability.

Crustaceans were collected using cast nets (mesh size 10–20 mm), drag nets and push nets (mesh size 5–10 mm), and hand collection for crab species found under rocks, in burrows, and among mangrove pneumatophores. Bycatch from artisanal fishing vessels at S2 and S3 was also examined with the cooperation of local fishermen. All specimens were transported live to the field laboratory in aerated containers, identified, photographed, measured, weighed, and preserved in 5% buffered formalin for museum reference.

2. Species Identification and Taxonomic Treatment

Identification of shrimps and prawns followed Jayachandran (2002) [16], Geetha Kumari (1998) [12], and Holthuis (1980) [14]. Brachyuran crabs were identified using Alcock (1896–1901) [3], Dev Roy and Bhadra (2005) [10], Ng *et al*. (2008), and the updated ZSI checklist of marine brachyuran crabs (Valarmathi, 2024) [32]. Stomatopoda were identified using Manning (1969) [21] and Ahyong & Chan (2004) [2]. Isopoda were identified following Kensley & Schotte (1989) [19]. Nomenclature follows the World Register of Marine Species (WoRMS, accessed January 2026) [35] and ITIS (2025). IUCN conservation status was verified from the IUCN Red List (version 2024-2).

3. Physico-Chemical Parameters

Water temperature (°C), salinity (ppt), pH, dissolved oxygen (DO, mg/L), transparency (Secchi depth, cm), and turbidity (NTU) were measured in situ at each sampling station using a calibrated multi-parameter water quality meter (YSI Pro30). Nutrients including total dissolved nitrogen (TDN), total dissolved phosphorus (TDP), and biochemical oxygen demand (BOD) were analysed in the laboratory following standard APHA (2017) [4] methods.

4. Diversity Indices

Species diversity was quantified using the Shannon-Wiener diversity index (H'), Margalef's species richness index (D), Pielou's evenness index (J'), and Simpson's dominance index (1−λ). Seasonal and spatial variations in assemblage composition were assessed by Bray-Curtis similarity analysis and non-metric multi-dimensional scaling (nMDS) using PAST software v4.03. The PERMANOVA test was used to test for significant differences between seasons and stations ($p < 0.05$).

Results

1. Physico-Chemical Parameters

Seasonal and spatial variations in physico-chemical parameters of the Vamsadhara estuary are summarised in Table 1. Water temperature ranged from 23.4°C (winter) to 33.8°C (pre-monsoon). Salinity exhibited strong seasonal variation: lowest during monsoon at all stations (S1: 0.2–1.8 ppt; S2: 1.2–6.5 ppt; S3: 4.5–12.0 ppt) and highest during pre-monsoon at S3 (up to 31.5 ppt). pH was consistently alkaline (7.5–8.6) throughout the year. Dissolved oxygen (DO) ranged from 4.8 mg/L (monsoon, S2) to 8.9 mg/L (post-monsoon, S3). Turbidity peaked during monsoon due to increased suspended sediment load.

Table 1: Seasonal Physico-Chemical Parameters of the Vamsadhara Estuary (2022–2024)

Parameter	Station	Pre-monsoon (Jan–May)	Monsoon (Jun–Sep)	Post-monsoon (Oct–Dec)	Annual Mean
Temperature (°C)	*S1*	29.4±1.8	27.6±2.1	26.1±1.4	27.7
	S2	30.8±2.0	28.1±1.9	26.8±1.6	28.6
	S3	31.5±2.3	28.8±2.2	27.3±1.8	29.2
Salinity (ppt)	*S1*	3.2±0.8	0.8±0.4	4.5±1.1	2.8
	S2	14.6±2.4	3.8±1.2	16.2±2.8	11.5
	S3	26.4±3.1	8.4±2.0	21.8±2.6	18.9
pH	*S1*	7.6±0.2	7.5±0.1	7.8±0.2	7.6
	S2	7.9±0.2	7.7±0.2	8.1±0.2	7.9
	S3	8.2±0.3	7.9±0.2	8.4±0.3	8.2
DO (mg/L)	*S1*	6.4±0.6	5.2±0.5	7.1±0.5	6.2
	S2	6.8±0.5	5.0±0.4	7.8±0.6	6.5
	S3	7.4±0.6	5.8±0.5	8.6±0.7	7.3
BOD (mg/L)	*S1*	2.8±0.4	3.6±0.5	2.4±0.3	2.9
	S2	3.2±0.5	4.1±0.6	2.8±0.4	3.4
	S3	2.4±0.3	3.2±0.4	2.1±0.3	2.6
Turbidity (NTU)	*S1*	18.4±4.2	42.6±8.4	14.2±3.6	25.1
	S2	22.8±5.1	56.4±9.8	18.8±4.2	32.7
	S3	14.6±3.2	38.2±7.6	12.4±2.8	21.7

2. Taxonomic Diversity

A total of 38 crustacean species belonging to 28 genera, 18 families, and 3 orders were documented. The complete taxonomic checklist is presented in Table 2. Among decapods, penaeid and palaemonid shrimps jointly constituted the most species-rich component with 14 species (36.8% of total). Brachyura (true crabs) followed with 13 species (34.2%).

Table 2: Taxonomic Checklist of Crustacean Fauna of Vamsadhara Estuary, Kalingapatnam Coast (2022–2024)

S.No.	Species	Family	Order / Sub-order	Station(s)	Season	IUCN
1	*Penaeus monodon Fabricius, 1798*	*Penaeidae*	Decapoda: Dendrobranchiata	S2, S3	PM, Mo, Po	LC
2	*Penaeus indicus H.M. Edwards, 1837*	*Penaeidae*	Decapoda: Dendrobranchiata	S2, S3	PM, Po	LC
3	*Penaeus semisulcatus de Haan, 1844*	*Penaeidae*	Decapoda: Dendrobranchiata	S3	PM	LC
4	*Metapenaeus monoceros (Fabricius, 1798)*	*Penaeidae*	Decapoda: Dendrobranchiata	S1–S3	All	LC
5	*Metapenaeus affinis (H.M. Edwards, 1837)*	*Penaeidae*	Decapoda: Dendrobranchiata	S2, S3	PM, Po	LC
6	*Metapenaeus dobsoni (Miers, 1878)*	*Penaeidae*	Decapoda: Dendrobranchiata	S2, S3	PM, Po	LC
7	*Parapenaeopsis stylifera (H.M. Edwards, 1837)*	*Penaeidae*	Decapoda: Dendrobranchiata	S2, S3	PM, Po	LC
8	*Parapenaeopsis sculptilis (Heller, 1862)*	*Penaeidae*	Decapoda: Dendrobranchiata	S3	Po	LC
9	*Macrobrachium rosenbergii (de Man, 1879)*	*Palaemonidae*	Decapoda: Caridea	S1, S2	All	LC
10	*Macrobrachium malcolmsonii (H.M. Edwards, 1844)*	*Palaemonidae*	Decapoda: Caridea	S1	PM, Mo	LC
11	*Macrobrachium idella (Hilgendorf, 1898)*	*Palaemonidae*	Decapoda: Caridea	S1, S2	Mo, Po	LC
12	*Palaemon styliferus H.M. Edwards, 1840*	*Palaemonidae*	Decapoda: Caridea	S2, S3	PM, Po	LC
13	*Alpheus malabaricus (Fabricius, 1775)*	*Alpheidae*	Decapoda: Caridea	S2, S3	All	NE
14	*Alpheus acutocarinatus de Man, 1888*	*Alpheidae*	Decapoda: Caridea	S3	Po	NE
15	*Scylla serrata (Forskål, 1775)*	*Portunidae*	Decapoda: Brachyura	S2, S3	All	LC
16	*Portunus pelagicus (Linnaeus, 1758)*	*Portunidae*	Decapoda: Brachyura	S2, S3	PM, Po	LC
17	*Portunus sanguinolentus (Herbst, 1783)*	*Portunidae*	Decapoda: Brachyura	S3	PM	LC
18	*Charybdis feriata (Linnaeus, 1758)*	*Portunidae*	Decapoda: Brachyura	S3	PM, Po	LC
19	*Charybdis cruciata (Herbst, 1794)*	*Portunidae*	Decapoda: Brachyura	S3	PM	LC
20	*Varuna litterata (Fabricius, 1798)*	*Varunidae*	Decapoda: Brachyura	S1–S3	All	LC
21	*Metopograpsus thukuhar (Owen, 1839)*	*Grapsidae*	Decapoda: Brachyura	S2, S3	All	NE
22	*Sesarma bidens (de Haan, 1835)*	*Sesarmidae*	Decapoda: Brachyura	S2	Mo, Po	NE
23	*Perisesarma guttatum (A. Milne-Edwards, 1869)*	*Sesarmidae*	Decapoda: Brachyura	S2	Mo, Po	NE
24	*Uca (Gelasimus) marionis (Desmarest, 1825)*	*Ocypodidae*	Decapoda: Brachyura	S1, S2	Mo, Po	LC
25	*Uca (Tubuca) annulipes (H.M. Edwards, 1837)*	*Ocypodidae*	Decapoda: Brachyura	S1, S2	Mo, Po	LC
26	*Macrophthalmus sulcatus H.M. Edwards, 1852*	*Macrophthalmidae*	Decapoda: Brachyura	S2	Mo	NE
27	*Ilyoplax gangetica (Kemp, 1915)* [18]	*Macrophthalmidae*	Decapoda: Brachyura	S1, S2	Mo	NE
28	*Diogenes avarus Heller, 1865*	*Diogenidae*	Decapoda: Anomura	S3	PM, Po	NE
29	*Clibanarius infraspinatus (Hilgendorf, 1869)*	*Diogenidae*	Decapoda: Anomura	S3	PM	NE
30	*Thalassina anomala (Herbst, 1804)*	*Thalassinidae*	Decapoda: Gebiidea	S2	Mo, Po	NE
31	*Upogebia major (de Haan, 1841)*	*Upogebiidae*	Decapoda: Gebiidea	S2, S3	Po	NE
32	*Penaeopsis acclivis Rathbun, 1906*	*Penaeidae*	Decapoda: Dendrobranchiata	S3	PM	NE
33	*Acetes indicus H.M. Edwards, 1830*	*Sergestidae*	Decapoda: Dendrobranchiata	S2, S3	Po	NE
34	*Squilla mantis (Linnaeus, 1758)*	*Squillidae*	Stomatopoda	S2, S3	PM, Po	LC
35	*Oratosquilla nepa (Latreille, 1828)*	*Squillidae*	Stomatopoda	S3	PM	LC
36	*Harpiosquilla harpax (de Haan, 1844)*	*Harpiosquillidae*	Stomatopoda	S3	PM	NE
37	*Sphaeroma terebrans Bate, 1866*	*Sphaeromatidae*	Isopoda	S2	Mo	LC
38	*Excirolana chiltoni (Richardson, 1905)*	*Cirolanidae*	Isopoda	S3	All	NE

PM = Pre-monsoon; Mo = Monsoon; Po = Post-monsoon; LC = Least Concern; NE = Not Evaluated
(IUCN Red List 2024-2

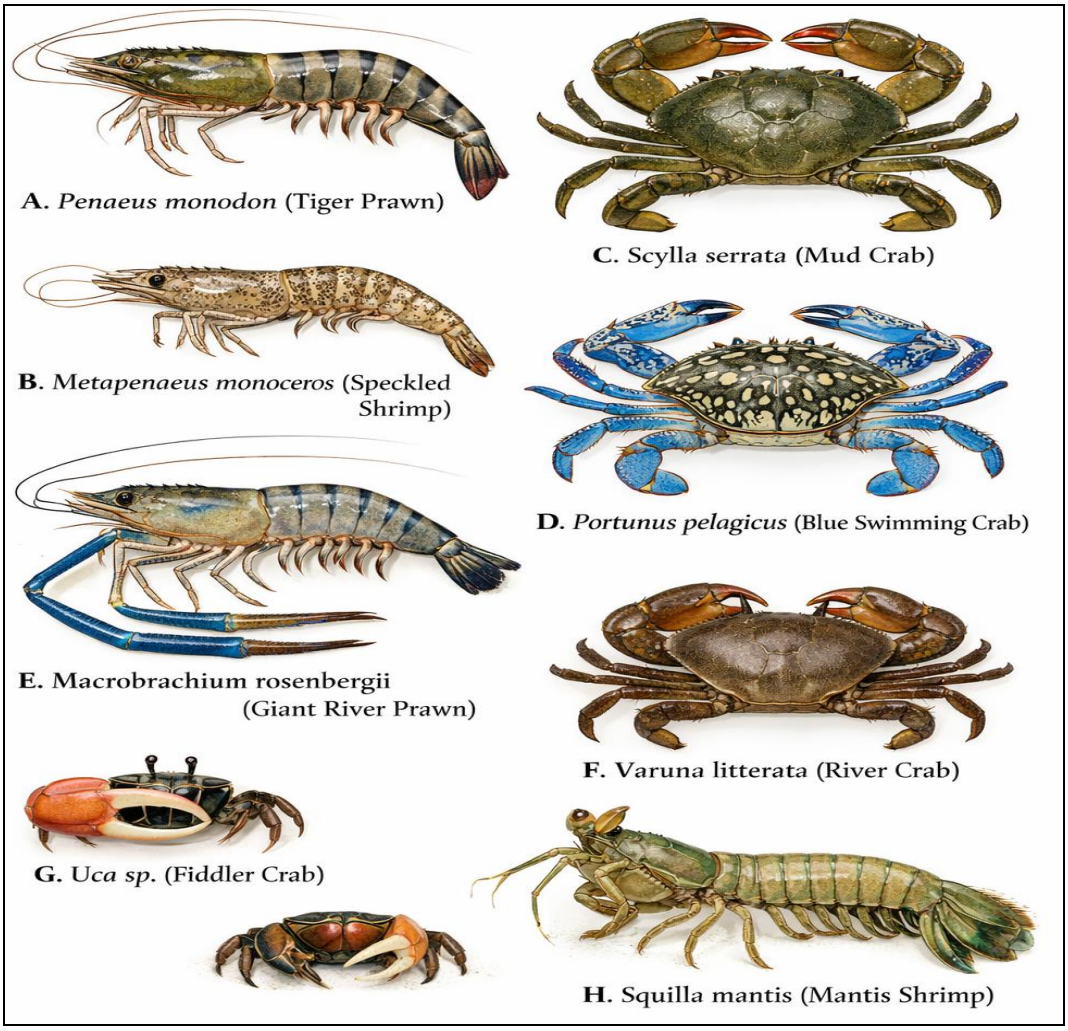


Plate 1: Selected Crustacean Species of the Vamsadhara Estuary

3. Seasonal and Spatial Distribution

Species richness and abundance showed pronounced seasonal and spatial patterns across the three stations (Table 3, Figure 2). Overall species richness was highest at Station S3 (lower estuary, 31 species) and lowest at S1 (upper estuary, 16 species). Station S2 (mid-estuary) recorded 26 species and was characterised by the greatest abundance of commercially important species including *Scylla serrata* and *Penaeus monodon*.

Post-monsoon was the richest season at all three stations (combined total: 34 species). This corresponds with the restoration of optimal salinity gradients (12–22 ppt at S2–S3), increased prey availability, and recruitment of juvenile penaeid shrimps into the estuarine nursery habitat. Monsoon recorded the lowest species richness (21 species) due to near-total elimination of salinity at S1 and very low salinity at S2, which excluded marine-affinity species.

The abundance of *Scylla serrata* peaked strongly in September–November across S2 and S3, consistent with its post-monsoon reproductive migration from offshore spawning grounds into estuarine nursery habitats. *Penaeus monodon* abundance peaked in October–November when juvenile recruitment into the estuary was highest. *Macrobrachium rosenbergii* was recorded throughout the year at S1 and S2, with peak abundance during July–October coinciding with its upstream breeding migration.

Table 3: Species Richness, Abundance, and Diversity Indices at Three Sampling Stations Across Seasons

Station / Season	Total Species (S)	Total Individuals (N)	Shannon H'	Margalef D	Pielou J'	Simpson 1−λ
S1 — Pre-monsoon	12	418	2.08	1.82	0.84	0.81
S1 — Monsoon	8	264	1.74	1.34	0.84	0.76
S1 — Post-monsoon	16	612	2.34	2.18	0.85	0.84
S2 — Pre-monsoon	20	786	2.71	2.88	0.90	0.90
S2 — Monsoon	14	524	2.38	2.24	0.90	0.88
S2 — Post-monsoon	26	1,142	2.98	3.46	0.91	0.92
S3 — Pre-monsoon	24	968	2.92	3.24	0.92	0.92
S3 — Monsoon	18	682	2.58	2.70	0.89	0.89
S3 — Post-monsoon	31	1,486	3.18	4.02	0.92	0.93
Overall (3 yrs)	38	6,882	3.24	4.48	0.89	0.91

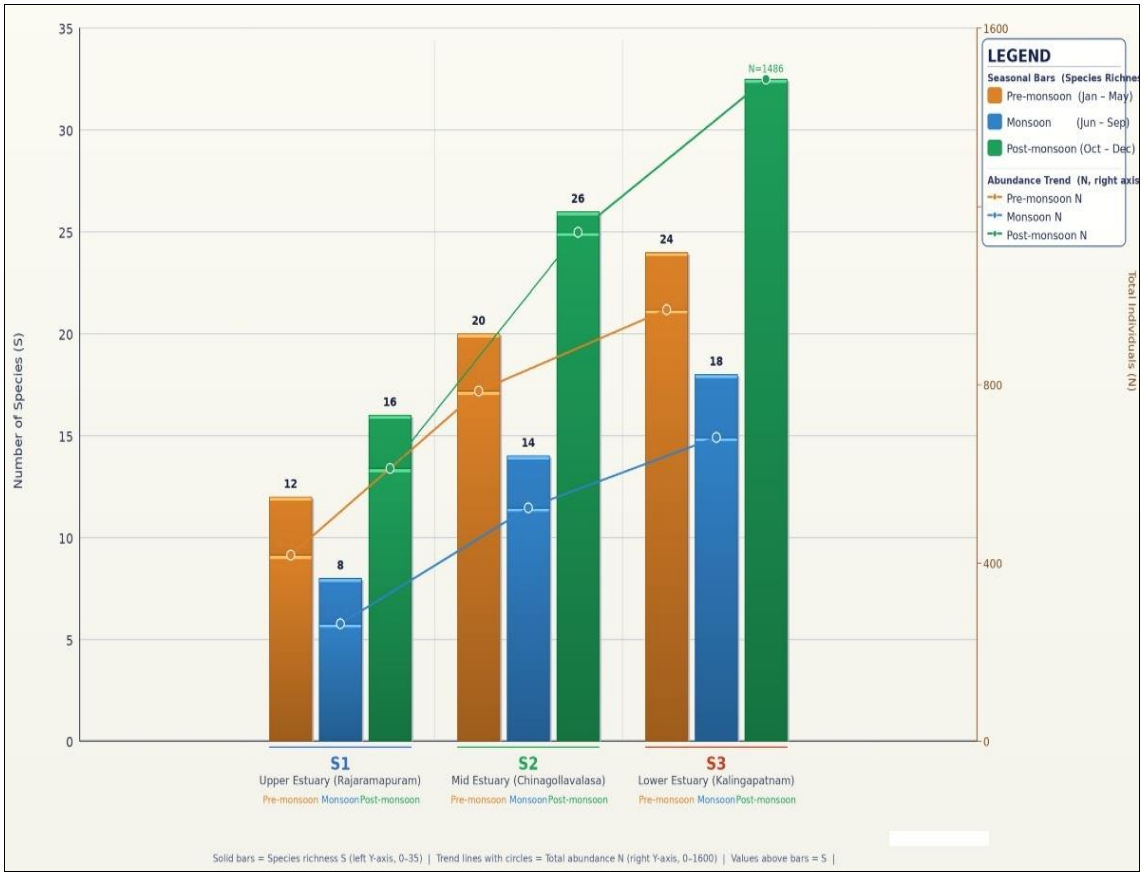


Fig 2: Seasonal Species Richness and Abundance
Bar graph showing total species richness (S) and abundance (N) at S1, S2, and S3 across seasons.

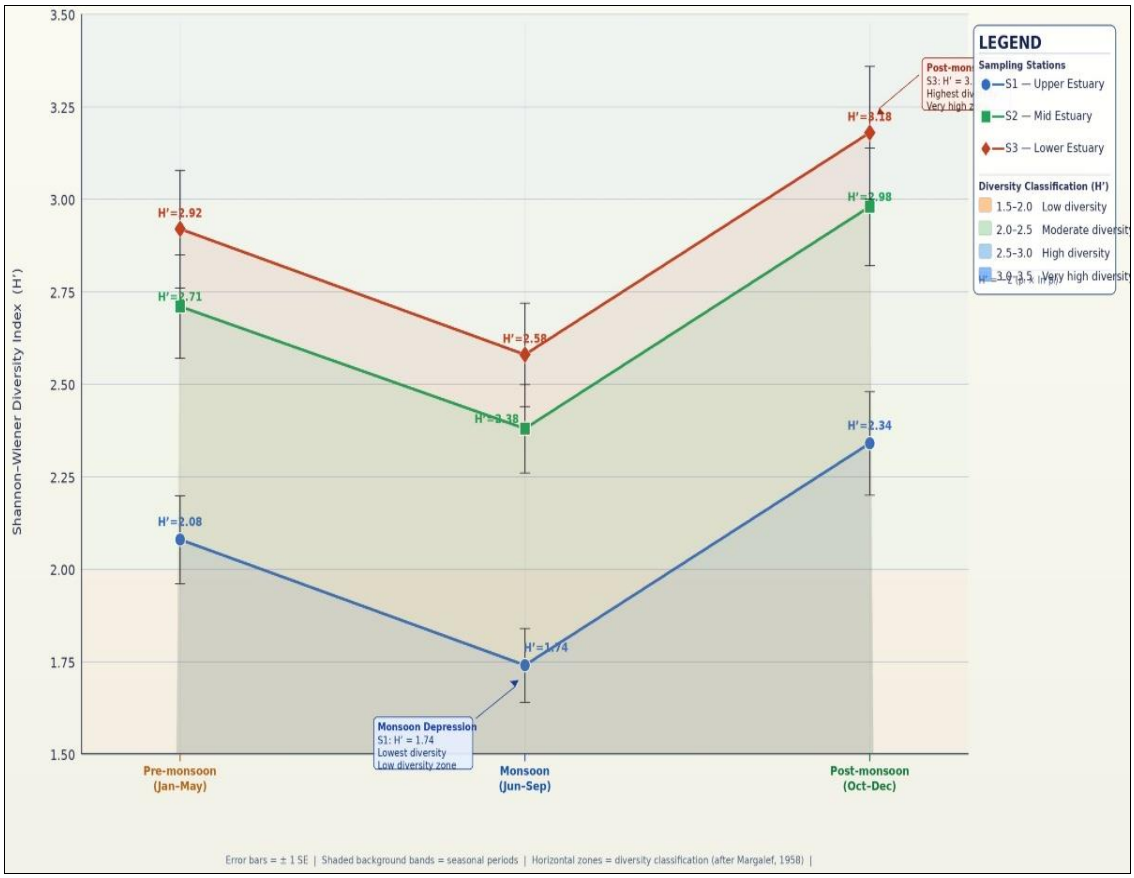


Fig 3: Shannon-Wiener Diversity Index (H') Across Stations and Seasons
Line graph illustrating temporal variation in H' values.

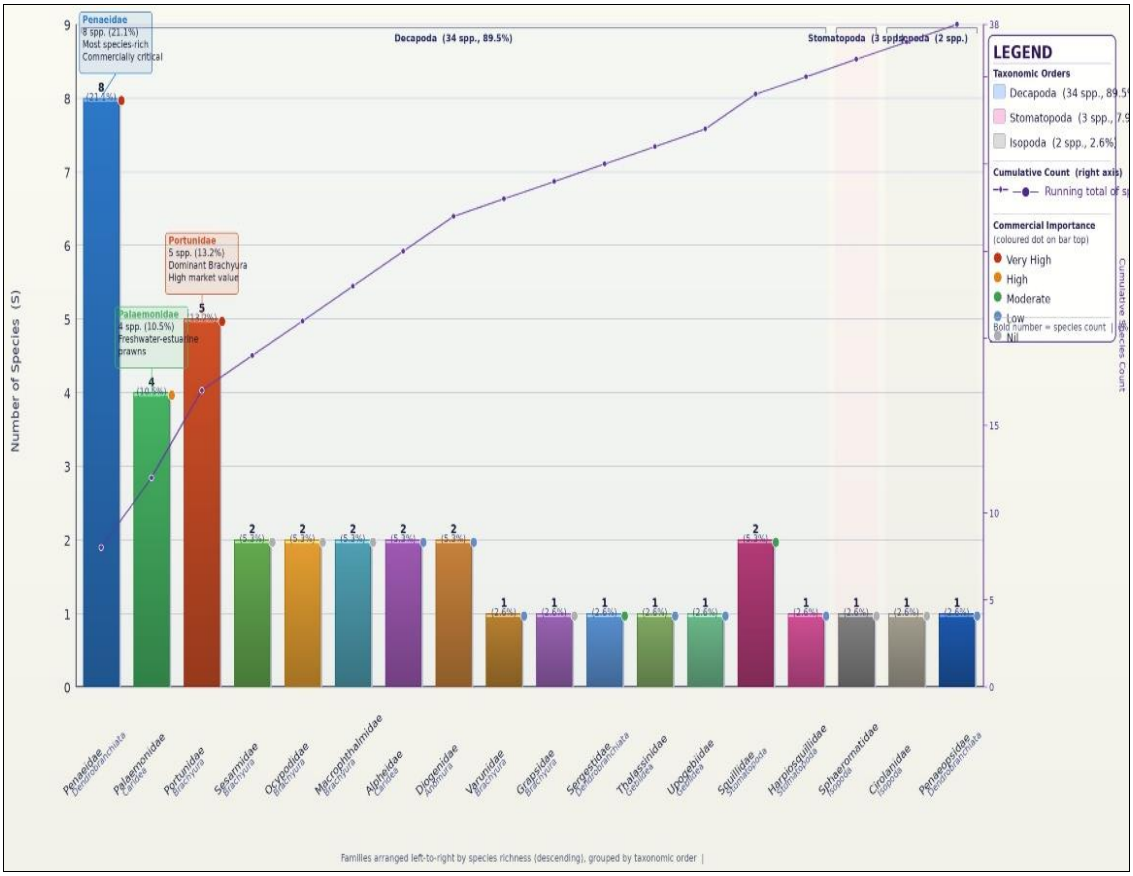


Fig 4: Family-Level Taxonomic Composition
Bar chart showing species richness per family with cumulative line.

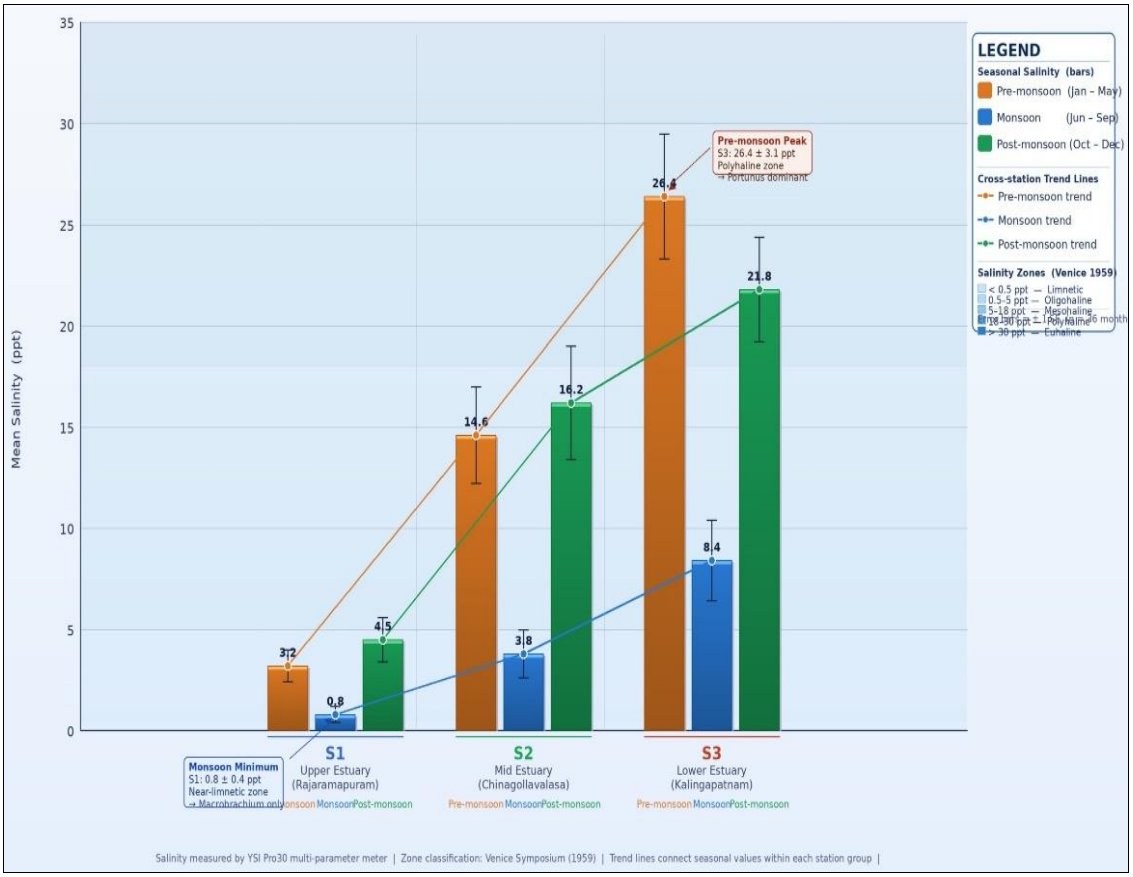


Fig 5: Seasonal Salinity Variation
Grouped bar chart with salinity zone bands and correlation inset.

4. Dominant and Commercially Important Species: Detailed Accounts

4.1 *Penaeus monodon* Fabricius, 1798 — Giant Tiger Prawn

Penaeus monodon is the largest penaeid shrimp recorded from the Vamsadhara estuary, with individuals reaching total body length of 28–35 cm and weight up to 280 g. The carapace is smooth with well-defined antennal and hepatic spines. The rostrum bears 7–8 dorsal teeth and 3 ventral teeth. The characteristic alternating dark and light transverse banding on the abdomen ('tiger' pattern) is diagnostic. This species was recorded predominantly at S2 and S3, with highest abundance in October–November, corresponding to post-monsoon juvenile recruitment. IUCN status: Least Concern.

4.2 *Scylla serrata* (Forskål, 1775) — Giant Mud Crab

Scylla serrata is the dominant brachyuran crab of the Vamsadhara estuary. The carapace is broad and smooth, reaching a width of 14.5–18.2 cm in adults. The chelipeds are robust and asymmetric. This species was recorded at S2 and S3 throughout the year, with peak abundance during September–November. Females carrying ovigerous masses were observed during November–January, confirming the estuary as a critical reproductive habitat. Illegal undersized harvesting was frequently observed at the Kalingapatnam landing centre. IUCN status: Least Concern.

4.3 *Portunus pelagicus* (Linnaeus, 1758) — Blue Swimming Crab

Portunus pelagicus was the most abundant portunid crab at S3, recorded year-round with highest numbers during pre-monsoon. The carapace is wide (up to 19 cm) with distinctive bright blue colouration and three prominent frontal teeth. The fifth pair of pereiopods is paddle-shaped, enabling active swimming. Its abundance was significantly higher at S3 than at S2, reflecting its preference for higher salinity conditions. IUCN status: Least Concern.

4.4 *Macrobrachium rosenbergii* (de Man, 1879) — Giant Freshwater Prawn

Macrobrachium rosenbergii, the largest freshwater prawn of Asia, was recorded throughout the year at S1 and S2. Males reach a total length of 20–30 cm with prominent elongated chelipeds. Reproductive females were observed carrying eggs from June through September. Wild populations face pressure from escapees of aquaculture strains that may compete with native stocks. IUCN status: Least Concern.

4.5 *Varuna litterata* (Fabricius, 1798) — River Swimming Crab

Varuna litterata (Family Varunidae) was recorded at all three stations and in all seasons, making it the most spatially widespread crab species in the estuary. Its euryhaline tolerance and omnivorous feeding habits allow it to persist across the full estuarine salinity gradient, making it a useful indicator species for estuarine health assessment.

5. New and Noteworthy Records

Three species represent new records for the estuarine waters of the Vamsadhara river system: *Penaeopsis acclivis* Rathbun, 1906; *Harpiosquilla harpax* (de Haan, 1844); and *Excirolana chiltoni* (Richardson, 1905). Additionally, *Acetes indicus* H.M. Edwards, 1830 (Family Sergestidae) — previously reported from coastal Andhra Pradesh waters but not specifically from Vamsadhara — was recorded in substantial numbers at S2 and S3 during post-monsoon, where it formed a major component of zooplankton-net bycatch and an important prey item for planktivorous fish.

Discussion

1. Species Richness in Regional and National Context

The documentation of 38 crustacean species from the Vamsadhara estuary compares favourably with similar survey efforts from geographically proximate estuarine systems. Mohanty *et al*. (2023) [22] recorded 40 brachyuran species from the Devi estuary (Odisha) over three years, with portunid crabs dominating the assemblage — a pattern mirrored in the current study. The Gosthani estuary (Visakhapatnam) yielded 18 crustacean taxa (Rama Rao, 2025) [27], and Tekkali creek yielded 17 crab species (Dogiparti, 2016) [11]. The higher richness recorded in the present study is attributable to the longer survey duration (36 months), multiple collection methods, and coverage of three distinct estuarine zones spanning the full salinity gradient.

The predominance of euryhaline families — Portunidae, Grapsidae, Varunidae, and Sesarmidae — is characteristic of Indo-Pacific estuarine systems (Jayachandran, 2002; Shukla *et al*., 2023) [16, 31] and reflects the ecological filtering imposed by the dynamic salinity gradient. The ratio of marine-affinity to freshwater-affinity species (approximately 2.4:1 at S3 vs. 0.8:1 at S1) is consistent with the known latitudinal and salinity-driven biogeographic patterns of Indian estuarine Decapoda described by Dev Roy (2014).

2. Influence of Physico-Chemical Parameters

Salinity emerged as the overriding abiotic driver of crustacean species composition and abundance in the Vamsadhara estuary, consistent with findings from comparable east-coast Indian estuarine systems (Mohanty *et al*., 2023; Sajidevi *et al*., 2024) [22, 30]. The sharp reduction in species richness and abundance during monsoon at S1 and S2 directly corresponds with the near-elimination of salinity at these stations due to massive freshwater discharge. Marine-affinity species including all portunid crabs and penaeid shrimps are excluded from the mid-estuary during peak monsoon, retreating to the lower estuary (S3) or adjacent nearshore marine zone. Conversely, *Varuna litterata* and *Macrobrachium* species — which tolerate near-zero salinity — persist and occasionally increase in relative abundance at S1 and S2 during monsoon.

The positive relationship between sediment organic content and *Scylla serrata* burrowing density at S2 reflects the species' preference for organically enriched mudflats. Sesarmid crabs (*Perisesarma guttatum*, *Sesarma bidens*) showed a clear association with mangrove pneumatophore zones, consistent with their established role as mangrove leaf-litter processors (Lee, 1998; Cannicci *et al*., 2008) [7, 20].

3. Ecological Roles and Food Web Significance

Crustaceans in the Vamsadhara estuary occupy multiple trophic levels and perform critical ecosystem functions. Penaeid shrimps are primarily detritivores and omnivores processing organic detritus and microalgae in the benthos, representing a critical energy pathway from primary producers to higher consumers including estuarine fish documented by Rama Rao (2024) [26]. Brachyuran crabs are largely predatory and scavenging omnivores. Stomatopods

(mantis shrimps) are active visual predators occupying burrows in the subtidal sediment. The bioturbation activities of burrowing crustaceans (*Thalassina anomala*, *Upogebia major*, *Uca* spp.) oxygenate sediments, accelerate nutrient cycling, and modify habitat structure, contributing to the overall productivity of the estuarine food web.

4. Conservation Status and Threats

Of the 38 species documented, 15 (39.5%) are assessed by the IUCN (all Least Concern; IUCN, 2024-2) [15], while 23 (60.5%) remain Not Evaluated. None are currently listed as Vulnerable, Endangered, or Critically Endangered. However, several face significant local-scale population pressures not captured by global IUCN categories. The principal conservation threats include: (1) overexploitation of *Scylla serrata* through capture of undersized juveniles and berried females; (2) indiscriminate use of small-mesh drag nets harvesting post-larvae of penaeid shrimps; (3) sandbar dynamics restricting larval recruitment; (4) agricultural runoff containing pesticides and fertilisers; (5) sand mining from riverbeds; and (6) aquaculture pond construction reducing available mangrove habitat critical for sesarmid crabs and juvenile *Penaeus* species.

Table 4: Conservation Status and Threat Assessment for Key Crustacean Species of Vamsadhara Estuary

Species	Commercial Importance	IUCN Status	Local Threat	Primary Threat Factors
Penaeus monodon	Very High (export)	LC	High	Overexploitation, habitat loss
Metapenaeus monoceros	High (domestic + export)	LC	Moderate	Juvenile harvest, bycatch
Scylla serrata	Very High (premium)	LC	High	Undersized harvest, berried female capture
Portunus pelagicus	High	LC	Moderate	Overexploitation, roe removal
Macrobrachium rosenbergii	High (aquaculture)	LC	Moderate	Aquaculture competition, habitat alteration
Thalassina anomala	Low	NE	Moderate	Mangrove clearing, substrate disturbance
Perisesarma guttatum	Nil (ecological)	NE	Moderate-High	Mangrove loss, pesticide runoff
Uca (Gelasimus) marionis	Nil (ecological)	LC	Moderate	Mudflat reclamation, sand mining
Squilla mantis	Moderate (local)	LC	Low	Bycatch, habitat disturbance
Acetes indicus	Moderate (dry fish)	NE	Moderate	Zooplankton trawling, estuarine modification

Conservation Recommendations

Based on the findings of this study and the existing regulatory frameworks including the Coastal Regulation Zone (CRZ) Notification (2019), the National Fisheries Policy (2020), the Wildlife Protection Act (1972, amended 2022), and the Environment Protection Act (1986), the following conservation measures are recommended:

1. **Seasonal Fishing Restrictions:** A three-month seasonal ban on *Scylla serrata* harvesting (November–January) should be implemented to protect reproductively active females. Minimum legal-size limits should be strictly enforced: carapace width ≥ 12 cm for *Scylla serrata*; total body length ≥ 14 cm for *Penaeus monodon*; ≥ 9 cm for *Metapenaeus monoceros*.

2. **Mesh Size Regulation:** The use of push nets and drag nets with mesh sizes smaller than 12 mm should be prohibited in estuarine waters to prevent juvenile and post-larval harvest.

3. **Mangrove Restoration:** At least 50 ha of degraded estuarine margins at S2 should be restored using locally appropriate species (*Avicennia marina*, *Rhizophora mucronata*, *Aegiceras corniculatum*) under the AP Forest Department's coastal ecosystem restoration mandate

4. **Environmental Flow Management:** Minimum ecological flows should be maintained into the estuary, particularly during dry season (February–May), to preserve habitat connectivity for migratory species such as *Macrobrachium rosenbergii*.

5. **Pollution Abatement:** An integrated coastal watershed management plan should be developed to reduce pesticide and nutrient inputs from the Srikakulam coastal plain agricultural zone.

6. **Long-term Monitoring and Research:** A biodiversity monitoring programme should be established in partnership with Andhra University, Sri Vikrama Simhapuri University, and ICAR-CMFRI Visakhapatnam. Population genetic studies of key commercial species (*Penaeus monodon*, *Scylla serrata*) should be initiated to understand connectivity with adjacent coastal populations.

7. **Community Participation:** Fisher cooperative societies at Kalingapatnam should be engaged in participatory monitoring with appropriate training in species identification, conservation status, and sustainable harvesting practices. Eco-sensitive zone designation for the 2 km estuarine corridor upstream of the river mouth should be explored under the CRZ-2019 framework.

Conclusion

The present study provides the first comprehensive documentation of crustacean fauna diversity from the estuarine environment of the Vamsadhara river at Kalingapatnam coast, Andhra Pradesh, India, based on systematic monthly surveys over three years (2022–2024). A total of 38 species representing 28 genera, 18 families, and 3 orders were recorded, establishing the Vamsadhara estuary as a moderately to highly diverse crustacean habitat on the northern Andhra coast. The estuarine system harbours several species of high commercial importance — particularly *Penaeus monodon*, *Metapenaeus monoceros*, *Scylla serrata*, and *Portunus pelagicus* — that form the economic backbone of artisanal fisheries at Kalingapatnam port.

Salinity was identified as the primary driver of seasonal and spatial variation in crustacean assemblage composition, with species richness and abundance consistently highest during post-monsoon when optimal salinity gradients are restored. Three species new to the Vamsadhara river system were recorded. The high proportion of Not Evaluated species (60.5%) underscores the need for systematic surveys to inform national biodiversity assessments. The principal conservation threats require immediate policy intervention, and the findings of this study serve as a foundational baseline for the development of an estuarine conservation management plan for the Vamsadhara-Kalingapatnam coastal ecosystem.

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