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Distribution and Habitat Preference of Tanaids (Peracarida - Crustacea) in the Kadalundi Estuary on the Southwest Coast of India

SUHANA SUHARA NASAR AND HABEEBREHMAN HAMEED*
PG and Research Department of Zoology, Farook College (Autonomous), Affiliated to University of Calicut, Kozhikode, 673632, Kerala, India
E-mail: suhasuhana@gmail.com, habeebrehman@farookcollege.ac.in
***Corresponding author**

ABSTRACT
In this study, we investigated the distribution and abundance of macrobenthos, particularly tanaids, in the Kadalundi Estuary, southwest coast of India, across three seasons. Tanaids were found to be the dominant macrobenthic group, with a strong preference for clayey mangrove habitats. The study highlights the vital role of mangroves in supporting macrobenthic communities and emphasizes the importance of conserving these habitats. Litterfall was identified as a crucial factor in nutrient cycling within the mangrove ecosystem. Sandbar formation near the estuary mouth poses a significant threat to mangrove ecosystems and associated fauna. This research contributes valuable insights for informed conservation strategies and ecosystem management.

Key words: Macrobenthos, mangrove, litterfall, sandbar, conservation, ecosystem

INTRODUCTION

Estuaries are the most productive ecosystems on Earth (Alongi 1997). They encompass various types of habitats, such as diverse varieties of mangroves, sandbanks, mud banks, and coastal lakes. Estuarine ecosystems are the most complex aquatic ecosystems as they serve as a link between marine water, freshwater, and terrestrial ecosystems. Mangroves, in particular, form detritus-based ecosystems supporting communities of various mangrove plants, fungi, algae, bacteria, fish, birds, and other animals. Key components of this ecosystem include water, sediment, flora, and fauna. The unique root system of mangroves reduces wave action, traps sediments, and acts as a storehouse of organic matter (Kumar 1993). Organic matter is exported from the mangroves to the surrounding water, enriching the coastal water's organic productivity, and leading to dense populations of secondary and tertiary consumers (Kumar 1993). The high productivity resulting from mangrove litter fall supports a diverse array of detritus-feeding animals (McKee 1993). Many anaerobic bacteria, such as *Methanobacterium*, *Methanococcus*, and *Ethanospirillum*, as well as free-living nitrogen-fixing bacteria like *Azotobacter* and *Desulforibries*, along with different microfauna and fungi, actively degrade cellulose, lignin, resin, and carotenoids found in leaf litter. Consequently, these microorganisms transform litter into protein and carbohydrate-enriched detritus particles, forming a suitable environment for degradation by various faunal groups. The inherent biological productivity within mangroves results in an abundance of organic matter in the mangrove sediment.

Litterfall plays a crucial role in nutrient cycling within mangroves, fostering not only nutrient cycling within these ecosystems but also reinforcing the interconnectedness between various trophic levels in the mangrove chain (Srisunant et al. 2018). Woodroffe (1982) highlighted the significance of measuring litter fall as a key determinant of primary productivity and organic matter contribution to estuaries. Additionally, Bosire et al. (2005) observed variations in decay rates across different macrofaunal communities at specific sites. Furthermore, Andreetta (2014) emphasized that the accumulation of organic matter on mangrove forest floors is influenced by factors such as tidal magnitude and frequency, micro and macro-organism activities, tree species, and litter composition.

The benthos comprises a wide variety of organisms, ranging from microscopic bacteria to large megafauna. Macrobenthos, which are part of this assemblage, facilitate multiple interactions between the community and the environment. These communities enhancing aquatic resources, serves as an important component in both the food chain and the biological purification of water (Sheeba 2000). Due to their limited mobility, macrobenthos are considered preferred indicators of long-term water quality (McLusky and Elliott,2004). They significantly impact water column processes and trophic transfer. As macrobenthos rely on their surrounding environment, they serve as biological indicators that reflect the overall condition of the aquatic ecosystem (Matin et al. 2018). Among the main groups of crustaceans, Tanaids stand out. They function as efficient micro scavengers, consuming detritus and microorganisms, and serve as a vital food source for fishes, crustaceans, and birds, thus constituting an essential trophic linkage in food webs (Edgar 2008).

The availability of food within mangroves significantly influences the survival of tanaids. Tanaids exhibit various lifestyles, which may include tube dwelling, burrowing, or free-living behaviors (Gardiner 1975). Geetha and Nandan (2014) further observed that tube-building tanaids and amphipods were most abundant in clayey silt substrata. Moreover, Soheil et al. (2018) found that benthic communities, including tanaids, were regulated by multiple factors, such as temperature, salinity, dissolved oxygen, sediment composition, and organic matter. No single factor alone could be considered the sole ecological determinant. The interactions between bottom water and sediment characteristics play a crucial role in influencing the distribution and diversity of crustaceans, including tanaids, in estuarine environments (Geetha and Nandan 2014). Therefore, to assess the health of a particular ecosystem accurately, a thorough analysis of the benthic fauna is essential. Many researchers (Sasikumar 2009, Bindu and Jaypal 2016, Arif et al. 2011, Varghese et al. 2022) have studied the fauna of Kadalundi estuary, amongst them benthos is not well studied. Pandiyarajan et al. (2020) studied ecology and distribution of tanaids from the water of Kochi Backwaters. Geetha and Nandan (2014) reported 3 species of tanaids from Cochin Estuary. Dev (2015) reported 10 species of tanaids from marine and brackish waters of India. Pandiyarajan et al. (2020) reported 5 species of tanaids from kochi backwaters, which include 2 species recently identified. The present study focuses on the distribution and habitat preference of tanaids in the Kadalundi Estuary on the southwest coast of India, within the Kadalundi-Vallikunnu Community Reserve.

MATERIALS AND METHODS

Study area

The Kadalundi estuary located in Kozhikode and Malappuram districts of Kerala state at the meeting point of the Kadalundi River on the southwest coast of the Arabian Sea. This estuarine region was declared as the first community reserve in Kerala, India, officially designated as the Kadalundi – Vallikkunnu Community Reserve in October 2007 considering the ecological significance, diversity of wetland avian fauna and the burden of heavy anthropogenic pressures. It spread across 153.84 ha. Kadalundi river devides into channels encircling 5 small islands - Cheru thuruthu, Cee pee thuruthu, Bala thuruthu, Mannan thuruthu and Company thuruthu. The estuary consists of different types of habitats including scattered patches of dense mangrove, mud flats, sandbar and estuarine areas bordered by coconut groves and human settlements. Major mangrove species of this estuary are *Avicennia officinalis*, *Avicennia marina, Rhizophora mucronata*, *Sonnaratia alba, Bruguiera cylindrica, Exoecaria agallocha* and *Acanthus ilicifolium*. Mud flats expose during law tide and form suitable foraging habitat for many resident and migratory birds. It is a famous bird sanctuary. Raised sandbar partially separate the estuary from the Sea and hinders the water flow in and out of the estuary.

Sampling stations

Six sampling stations were selected based on different habitats within the Kadalundi estuary: (1) Bird Sanctuary - It is mud flat exposed during low tide, located towards the Barmouth area, (2) True estuary, (3) Cee pee thuruthu - this area is bordered by human habituation, coconut groves and this area is towards the river mouth, (4) Mangrove 1 - representing a dense patch *of Rhizophora mucronata* which is ever green tree characterized by the large stilt roots holds the sediment, (5) Mangrove 2 - characterized by *Avicennia officinalis*, the most dominant mangrove species of Kadalundi estuary situated along western side of Bala thuruth, and (6)

Sandbar - raised sandy area at barmouth region.

Methodology

This study was conducted over three seasons (2021-2022) - post-monsoon, pre-monsoon, and monsoon. Sediment samples were collected from six stations using a grab of 0.04 m^2 and sieved through a 0.5mm sieve to obtain macrobenthos. The sieved organisms were then preserved in a 5% formalin solution, and a drop of rose Bengal was added to the labeled plastic containers for further analysis.

Water samples were collected from five stations using a water sampler. The water and sediment temperatures were recorded using a thermometer. The collected samples were stored in an icebox and transported to the laboratory for subsequent analysis. The physicochemical parameters of water, including salinity, dissolved oxygen (DO), and biochemical oxygen demand (BOD) and Nitrite were analyzed using the Anonymous (1998) method. Percentage organic carbon was estimated by the method of Walkley and Black (1934). Kruskal-Wallis test was used for the statistical analysis.

RESULTS

Physicochemical parameters

The environmental parameters during post-monsoon in the Kadalundi estuary for six sampling stations are given in Table 1. Water temperature ranged from 27 to 29°C, salinity varied from 24.22 to 26.0 ppt, dissolved oxygen (DO) levels ranged from 3.26 to 6.74 mg/l, and biochemical oxygen demand (BOD) values ranged from 0.77 to 3.0 mg/l. Nitrite concentrations in the water samples varied from 0.01 to 0.65 mg/l. Sediment temperature ranged from 26 to 29°C, and the organic carbon (OC) content in the sediment ranged from 0.71 to 6.44%.

During the pre-monsoon season, the water parameters at the five sampling stations and sediment parameters at the six stations in the Kadalundi estuary were recorded (Table 1). Water temperature ranged from 29 to 30°C, salinity varied from 19.41 to 30.54 ppt, dissolved oxygen (DO) levels ranged from 6.33 to 6.78 mg/l, and biochemical oxygen demand (BOD) values ranged from 2.65 to 2.99 mg/l. Nitrite concentrations in the water samples varied from 0.12 to 2.2 mg/l. Regarding sediment parameters,

Table 1. Physico-chemical parameters at sampling stations in different seasons

	Post-monsoon						Pre-monsoon						Monsoon					
Stations	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Water																		
T (°C)	29	29	28	27	28.5		29	29.5	30	29	29		27	27	27	26.5	26	
Salinity (ppt)	25.64	24.36	24.22	26	25.1		19.41	20	19.5	30.54	30		2.47	0.81	1.43	1.98	1.41	
DO (mg/l)	6.74	6.6	5.94	3.26	4.1		6.78	6.65	6.4	6.52	6.33		8.2	7.54	7	6.34	6.91	
BOD (mg/l)	2.53	2.93	3	0.77	1.91		2.99	2.86	2.66	2.73	2.65		1	1.07	1.2	2	1.51	
Nitrite (mg/l)	0.21	0.34	0.65	0.22	0.01		0.13	0.42	0.12	2.2	1.5		1.24	0.86	1.34	0.67	1.02	
Sediment																		
T (°C)	29	28	28	26	28	29	29	29.5	30	29	29	29	27	27	27	26.5	26	28
OC (%)	2.62	1.66	3.99	5.78	6.44	0.71	2.16	2.28	6.64	12.25	2.07	0.2	0.04	0.32	1.43	1.82	1.43	0.43

sediment temperature ranged from 29 to 30°C, and the organic carbon (OC) content in the sediment ranged from 0.20 to 12.25%.

During the monsoon season, the physicochemical parameters at the six sampling stations in the Kadalundi estuary were recorded (Table 1). Water temperature ranged from 26 to 27°C, salinity varied from 0.81 to 2.47 ppt, dissolved oxygen (DO) levels ranged from 6.34 to 8.20 mg/l, and biochemical oxygen demand (BOD) values ranged from 1.0 to 2.0 mg/l. Nitrite concentrations in the water samples varied from 0.67 to 1.34 mg/l. As for the sediment parameters, sediment temperature ranged from 26 to 28°C, and the organic carbon (OC) content in the sediment ranged from 0.04 to 1.82%.

Macrobenthos

The percentage contribution of macrobenthos in the Kadalundi estuary reveals the presence of nine major groups: Polychaeta, Oligochaeta, Amphipoda, Tanaidacea, Gastropoda, Bivalvia, Isopoda, Decapoda, and Foraminifera (Fig. 1). Among these groups, tanaids were found to be the dominant taxa across all sampling stations. In total, 19900m² specimens of tanaids belonging to four species were collected from the Kadalundi estuary. These species include *Ctenapseudes sapensis*, *Pagurapseudopsis kochindica*, *Leptochelia savignyi*, and *Sinelobus stanfordi*.

Distribution of tanaids

The distribution of tanaids in Kadalundi estuary varied significantly across the three seasons. The P value obtained as a result of Kruskal-Wallis test is 0. Since p-valueˆ0.05, there is a statistically significant

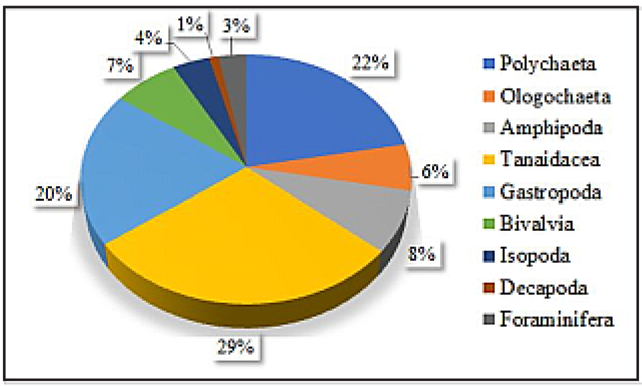

Figure 1. Contribution (%) of mactrobenthos in Kadalundi estuary

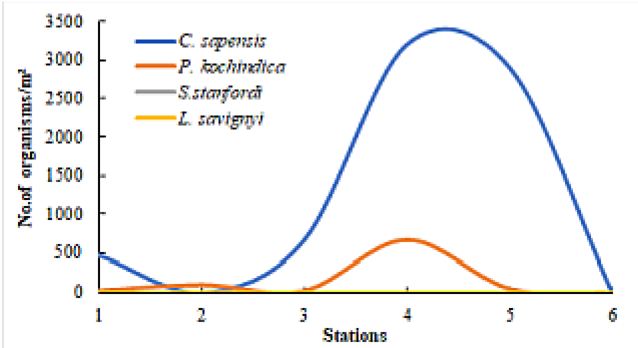

Figure 2. Population status of tanaids during post-monsoon season

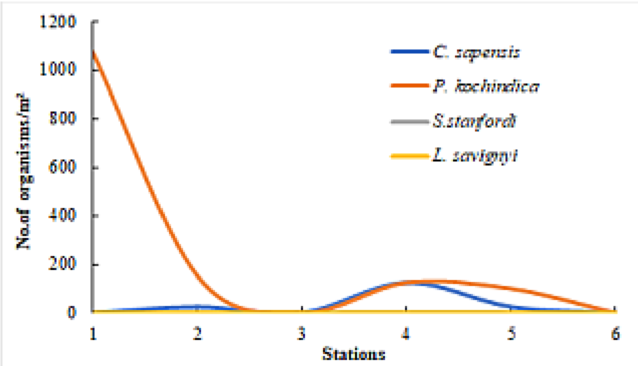

Figure 3. Population status of tanaids during pre-monsoon season

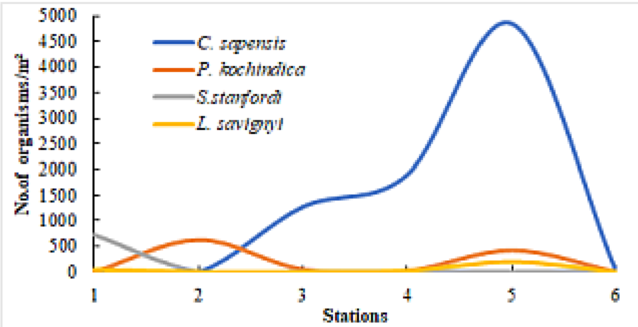

Figure 4. Population status of tanaids during monsoon season

difference in number of organisms between different species. Tanaids were found to be most abundant in the mangrove habitat, while none were obtained from the sandbar habitat.

During the post-monsoon season, *C. sapensis* tanaids were more numerous, whereas *L. savignyi* and *S. stanfordi* were absent (Fig. 2). Station 4 and 5, which were mangrove areas, had a higher abundance of tanaids, while *P. kochindica* tanaids were less common but distributed across all stations except the sandbar. *C. sapensis* was not recorded at station 2 and 6. During the pre-monsoon season, the number of tanaids was lower compared to other seasons (Fig. 3). *C. sapensis* tanaids were found only at stations 2, 4, and 5, while *P. kochindica tanaids* were obtained from stations 1, 2, 4, and 5, with a higher abundance recorded at station 1.

The monsoon season exhibited the highest number of tanaids (Fig. 4). Geetha and Nandan (2014) also observed that the numerical abundance of benthic crustaceans was low during the pre-monsoon season and high during the monsoon season. Sheeba (2000) studied the distribution of benthos in kochi backwaters and investigated that tanaidaceans were the most abundant and showed the maximum abundance in monsoon followed by post-monsoon and pre-monsoon. During this period, tanaids consisted of *C. sapensis*, *P. kochindica*, *S. stanfordi*, and *L. savignyi*. *C. sapensis* dominated and were more commonly found at station 5, which is situated in the mangrove area with *Avicennia officinalis*. Ismail and Ahmed (1993) observed rich diversity of benthic fauna in the microhabitat of *Avicennia* species as in mangrove ecosystem. *C. sapensis* were also obtained from stations 3, 4, and 5, while *P. kochindica* was recorded at stations 2, 3, and 5. *S. stanfordi* and *L. savignyi* were only encountered during the monsoon season, with *S. stanfordi* found solely at station 1 and *L. savignyi* at stations 1, 4, and 5.

DISCUSSION

In this study, among the nine groups of benthos encountered, tanaids were the most abundant and displayed a strong preference for the mangrove habitat with high percentage of organic carbon and clayey sediment. The entire study area showed a significant positive correlation between tanaids and the mangrove habitat. Notably, tanaids were entirely absent from the sandbar habitat which had very less percentage of organic carbon during all three seasons, and their numbers were lower in stations 1, 2, and 3, which had low percentage organic carbon. Sheeba (2012) previously reported a positive correlation between organic matter and fine-grained sediment, which may explain the association between tanaids and the clayey sediment in this study. Similar findings were reported from Gangavali Estuary, Tanaids were not found in the region where sand dominating and percentage of organic carbon very less (Shirodhkar et al. 2010).

The correlation between benthos and sediment types has been highlighted by Snelgrove (2000), with the feeding type of the organisms playing a crucial role. Tanaids, being euryhaline and raptorial feeders, actively collect detritus and microorganisms from their surrounding medium (Geetha and Nandan 2014). Pandiyarajan (2020) reported high abundance of tanaids in Kochi Backwaters and they occured most abundantly in mesohaline conditions and clayey silt bottom sediment. Additionally, tanaids exhibit a diverse range of feeding behaviors, as pointed out by Larsen et al. (2005), including detritivores, scavengers, browsers, raptorial carnivores, opportunists, and filter feeders. According to Delille et al, (1985) the distribution of tanaids depends on the concentration of benthic food availability.

Mangroves, being detritus-based ecosystems, contribute a substantial amount of nutrient-rich detritus, with continuous accumulation of fallen vegetative and reproductive parts of the plants (Mchenga and Ali 2017). This nutrient enrichment in the littoral zones of mangrove ecosystems plays a vital role in influencing settlement, growth, population fluctuation, and community interactions among fauna (Odum and Heald 1972). The detritus-rich nature of the mangrove ecosystem aligns well with the feeding preferences of tanaids and other detritivores, contributing to their abundance in these habitats**.**

According to Woodroffe et al. (1988), litter fall plays a crucial role as a major nutrient input to the mangrove substrate and adjacent waters, and it is widely used as a measure of productivity. Fernando et al. (2009) also highlighted that leaves are the dominant form of litter. In our study, we found that tanaids were more abundant during the monsoon and post-monsoon seasons. Tanaids were almost equally present in the sediment of both *Avicennia* sp. and *Rhizophora* sp. during the post-monsoon period. Fernando et al. (2009) reported that the breakdown of leaf litter is seasonal and species-dependent, with faster decomposition occurring during the wet season compared to the dry season. Similar observations were made by Bosire et al. (2005), who noted that litter production and fall vary with seasons. In the monsoon, a higher number of tanaids were found in the sediment of *Rhizophora sp* compared to *Avicennia* sp. Preetha (1991) observed the highest litter fall during the monsoon for *Rhizophora* sp. The litter decomposition rates also vary among different mangrove species, as reported by Sivakaumar and Kathiresan (1990). *Avicennia* leaves, being thinner, fragment and decompose more easily (Wafar et al. 1997), which may explain the observed differences in tanaid abundance between the two species. The preference of tanaids, as detritus feeders, for detritus-rich habitats based on their litter fall and decomposition aligns with their higher abundance in mangrove areas. Quantifying litter fall and decomposition is crucial to assess the overall productivity of the ecosystem (Wafar et al. 1997). Furthermore, large quantities of energy in the form of detritus from mangrove plants are exported to open water bodies (Odum and Heald 1975), transferring mangrove production to other trophic levels through litterfall and the detrital pathway. Mangroves may have stronger trophic linkages with epibenthic invertebrates and fish living in the mangrove and nearby habitats (Kathiresan and Bingham 2001).

The presence of sandbars near the mouth of the Kadalundi estuary, expanding towards the mangrove area, had a noticeable impact on the distribution of macrobenthos, particularly tanaids. None of the tanaids were found at the sandbar during any of the three seasons, and overall, very few macrobenthic fauna were recorded from this sandy habitat. This suggests that the macrobenthic fauna in the estuary did not prefer such sandy environments. Bindu and Jayapal (2016) conducted a case study on sand bar formation and its impact on the mangrove ecosystem in Kadalundi estuary, revealing that the formation of sandbars poses a significant threat to the mangrove ecosystem in Kadalundi. The presence of sandbars leads to the loss of mangroves and negatively affects the fauna inhabiting this ecosystem.

CONCLUSION

In conclusion, this study demonstrates that tanaids exhibit a preference for mangrove habitats, which support higher densities of benthic organisms compared to adjacent habitats. Tanaids play a crucial role in linking the food chain and forming a food web within the marine ecosystem. The nutrient cycling facilitated by litter falls not only promotes the health of mangroves but also strengthens the interactions between different trophic levels in the mangrove food chain. Thus, the presence of mangroves is essential for the overall health of the aquatic ecosystem. However, there is still much to learn about the energy flow and dynamics of food webs in mangrove environments and how these ecosystems connect with others. Further research is needed, particularly focusing on animals highly dependent on mangroves. Such studies are crucial for the effective management of mangroves and associated fishery resources. Moreover, the formation of sandbars near the estuary mouth poses a significant threat to the mangrove ecosystem, as evidenced by the limited presence of macrobenthic fauna in these sandy habitats. The sandbar formation can lead to the elimination of macrobenthos that can only survive in mangrove habitats, further emphasizing the importance of preserving these vital ecosystems. Understanding the complexities of mangrove habitats and their interactions with the surrounding environments is essential for their conservation and sustainable management. Continued research and conservation efforts are necessary to ensure the health and stability of these ecologically important ecosystems.

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