Ecological Role of Zooplankton in Regulating Food Web Dynamics within Estuarine Ecosystems a Case Study from Konaseema district Andhra

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Abstract— **Zooplankton play a crucial role in estuarine ecosystems by linking primary producers with higher trophic levels and contributing significantly to fisheries productivity. The present study was carried out in the mangrove-associated estuarine regions of Pora and Pallam villages to examine seasonal variations in zooplankton diversity and their relationship with environmental parameters. Samples were collected during March (summer) and June (monsoon) using a standard zooplankton net, alongside measurements of light intensity, temperature, and water quality. The results revealed higher zooplankton diversity and abundance in the summer season compared to the monsoon. Favorable conditions such as greater light penetration and stable hydrography in summer enhanced phytoplankton productivity, which in turn supported rich zooplankton communities. In contrast, monsoon conditions considered by reduced light intensity due to cloud cover and increased turbidity from freshwater inflows adversely affected phytoplankton growth, leading to a decline in zooplankton populations. The study identified copepods (particularly Calanoid species) and rotifers as dominant taxa across both seasons. Environmental factors, especially light intensity and temperature, strongly influenced zooplankton growth, while phytoplankton abundance emerged as the primary determinant of community structure. The findings emphasize the direct dependence of zooplankton on phytoplankton availability and highlight their role as indicators of estuarine ecosystem health. As plankton populations are directly proportional to fisheries productivity, this study provides important baseline information for the ecological assessment and sustainable management of mangrove estuaries.**

Keywords: Zooplankton, Estuarine ecology, Seasonal variation, Phytoplankton, Copepods, Rotifers, Mangrove ecosystems

I. **Introduction**

Zooplankton are a diverse group of heterotrophic aquatic organisms that drift in water columns and play a pivotal role in aquatic food webs. They act as primary consumers by grazing on phytoplankton and microorganisms, while simultaneously serving as prey for higher trophic levels such as fish and crustaceans (Turner, 2004; Kiørboe, 2011). This dual role makes zooplankton a crucial link in the transfer of energy and matter across trophic levels in both freshwater and marine ecosystems.

In estuarine ecosystems, zooplankton assume particular ecological significance because estuaries function as transition zones between freshwater and marine environments, characterized by strong environmental gradients such as salinity, turbidity, and nutrient fluxes (Elliott & Whitfield, 2011). The abundance, diversity, and community composition of zooplankton in such systems are highly dynamic and respond sensitively to changes in hydrological and physicochemical conditions (Rakocevic-Nedovic & Hollert, 2005; David et al., 2006).

Mangrove-associated estuaries are among the most productive ecosystems globally, providing nursery grounds for commercially important fish and shellfish. Zooplankton within these habitats play a central role in supporting fisheries by regulating energy flow between phytoplankton and juvenile fish (Godhantaraman, 2001; Sarkar et al., 2016). Copepods, particularly Calanoids, are often dominant in estuarine zooplankton communities, followed by rotifers, cladocerans, and protozoans, with their abundance fluctuating seasonally depending on resource availability (Mouny & Dauvin, 2002; Perumal et al., 2009).

Seasonal variation in zooplankton distribution is strongly influenced by climatic conditions. During summer, high light penetration and elevated temperatures favor phytoplankton blooms, leading to increased zooplankton diversity and biomass (Paffenhöfer, 2006). Conversely, monsoon periods often result in decreased light intensity, increased turbidity, and freshwater inflows, which reduce phytoplankton productivity and consequently zooplankton abundance (Nair et al., 1984; Godhantaraman & Uye, 2001). Such variations directly affect fisheries productivity, since zooplankton availability is positively correlated with the survival and recruitment of fish larvae (Parsons et al., 1984)

II. Role of Zooplankton in Estuarine Food Webs

Zooplankton are a highly diverse assemblage of drifting heterotrophic organisms that occupy a pivotal position in aquatic food webs. They function primarily as grazers of phytoplankton, bacteria, and detritus while simultaneously serving as prey for fish larvae, shrimps, crabs, and other secondary consumers. This dual role enables zooplankton to act as a vital link in the transfer of energy and organic matter across trophic levels, thereby sustaining overall ecosystem productivity (Turner, 2004; Kiørboe, 2011). In addition to their role in energy transfer, zooplankton contribute significantly to nutrient cycling by regenerating nitrogen and phosphorus through feeding and excretion, which in turn promotes primary production (Steinberg & Landry, 2017). They also regulate phytoplankton populations through grazing pressure, thereby preventing excessive algal blooms and maintaining ecological balance (Calbet & Landry, 2004).

Within estuarine ecosystems, zooplankton assume an even greater ecological importance due to the transitional nature of estuaries, which are subject to dynamic environmental fluctuations such as salinity gradients, freshwater inflows, turbidity, and nutrient enrichment (Elliott & Whitfield, 2011). The diversity and abundance of zooplankton in estuaries are highly sensitive to these physicochemical changes and exhibit pronounced spatial and temporal variations (David et al., 2006). In mangrove-associated estuaries, zooplankton mediate the transfer of energy from primary producers to higher trophic levels, directly supporting the survival and growth of juvenile fish and shrimp that use these habitats as nursery grounds (Godhantaraman, 2001; Sarkar et al., 2016). Among the various groups, copepods particularly calanoids are typically dominant in estuarine systems, followed by rotifers and cladocerans, while meroplanktonic forms such as crab and mollusk larvae play a critical role in replenishing benthic populations (Mouny & Dauvin, 2002; Perumal et al., 2009).

Seasonal dynamics strongly influence estuarine zooplankton populations. During summer, enhanced light penetration and stable hydrographic conditions promote phytoplankton blooms, resulting in elevated zooplankton biomass and diversity. In contrast, the monsoon season is characterized by reduced light availability due to cloud cover, increased turbidity from riverine runoff, and lowered salinity, all of which disrupt phytoplankton productivity and consequently reduce zooplankton abundance (Nair et al., 1984; Godhantaraman & Uye, 2001). Since phytoplankton availability is the primary driver of zooplankton population dynamics, fluctuations in plankton communities directly influence fish recruitment and fisheries productivity in estuarine systems (Parsons et al., 1984). Thus, zooplankton serve not only as trophic intermediaries but also as bio indicators of environmental quality and food web stability. Their monitoring in estuarine ecosystems is therefore crucial for understanding ecosystem operational, managing fisheries resources, and assessing the impacts of environmental change.

Study Area and Sampling Methodology

Zooplankton samples were collected from selected stations within the mangrove-dominated estuarine regions of Pora and Pallam villages. These sites were strategically chosen to represent different hydrological and ecological situations of the estuary. A total of five sampling stations were demarcated (as illustrated in the study area map) to ensure comprehensive spatial coverage of the estuarine system. Sampling was conducted during two distinct seasons, the pre-monsoon (March, representing summer) and the southwest monsoon (June), to assess seasonal variations in zooplankton diversity and lavishness.

Figure 1 Zooplankton Diversity and Environmental Drivers Across Marked Sampling Sites in the Mangrove Estuaries of Pora and Pallam

Zooplankton were collected using a shoot net specifically designed for plankton sampling, with a regulated flow rate of approximately 1000 mL per minute to maintain consistency and minimize sampling bias. At each station, multiple hauls were performed to ensure adequate sample volume and representativeness. The collected samples were immediately preserved in 4% buffered formalin solution for laboratory analysis. Concurrently, in situ measurements of key physicochemical parameters, including water temperature, light intensity, and turbidity, were recorded to evaluate their potential influence on zooplankton distribution. The methodology was designed to capture both the spatial and temporal heterogeneity of zooplankton communities within the estuarine environment, thereby providing reliable data for assessing their ecological role in food web dynamics.
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Results

In the month of March, representing the summer season, zooplankton populations were found to be comparatively richer and more diverse than those recorded during the monsoon season. This enhanced abundance in summer can be attributed to favorable climatic conditions, particularly higher light intensity and relatively stable hydrological parameters, which promote phytoplankton growth the primary food source for zooplankton. In contrast, during the monsoon season, increased turbidity, reduced light penetration due to persistent cloud cover, and higher levels of freshwater inflow disturb the water column, thereby limiting phytoplankton productivity. Since zooplankton populations are directly dependent on phytoplankton availability, these altered conditions in the monsoon season result in a noticeable decline in zooplankton density and diversity. Such seasonal fluctuations highlight the close coupling between environmental variables, primary producers, and secondary consumers in the estuarine food web.

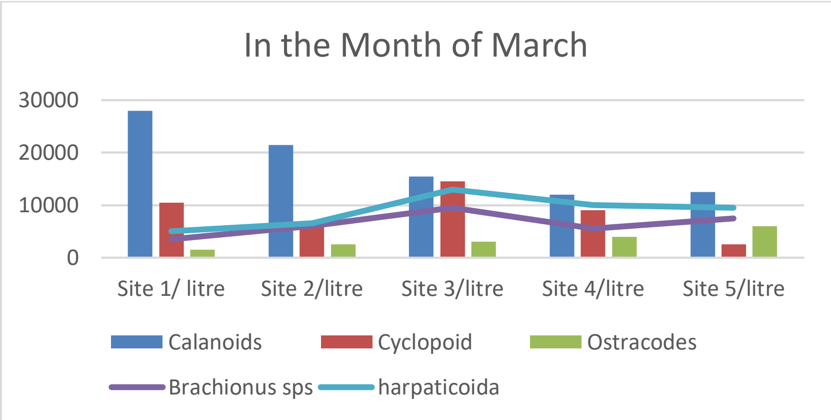

Figure 2 Graph data of zooplankton in the month of march

In the Month of March								
sps	**Site 1/ litre**	**Site 2/litre**	**Site 3/litre**	**Site 4/litre**	**Site 5/litre**	**Total**	**avg**	**percentage**
Calanoids	28000	21500	15500	12000	12500	89500	29833.33	39.6895787
Cyclopoid	10500	6500	14500	9000	2500	43000	14333.33	19.0687361
Ostracodes	1500	2500	3000	4000	6000	17000	5666.667	7.53880266
Brachionus sps	3500	6000	9500	5500	7500	32000	10666.67	14.1906874
harpaticoida	5000	6500	13000	10000	9500	44000	14666.67	19.5121951

Figure 3 data of zooplankton in selected area

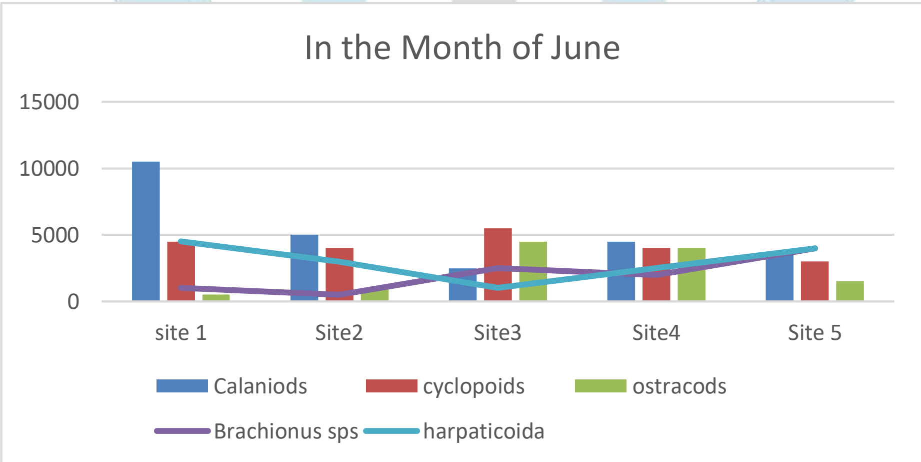

Figure 4 Graph data of zooplankton in the month of June

in the month of june								
zooplankton	site 1	Site2	Site3	Site4	Site 5	total	avg	percentage
Calaniods	10500	5000	2500	4500	3500	26000	5200	31.1377246
cyclopoids	4500	4000	5500	4000	3000	21000	4200	25.1497006
ostracods	500	1000	4500	4000	1500	11500	2300	13.7724551
Brachionus sps	1000	500	2500	2000	4000	10000	2000	11.9760479
harpaticoida	4500	3000	1000	2500	4000	15000	3000	17.9640719

Figure 5 zooplankton data of month June

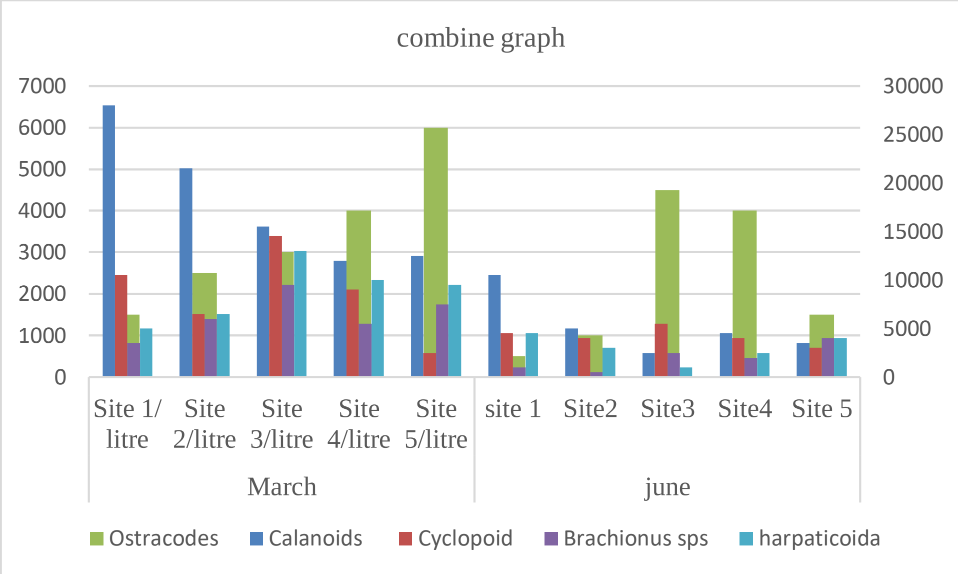

Figure 6 Graph data of both months

III. ACKNOWLEDGMENT

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