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RESEARCH ARTICLE

COMPOSITION, ABUNDANCE AND DIVERSITY OF MACROBENTHIC FAUNA IN KOLE PADDY FIELDS, VEMBANAD KOLE WETLAND, INDIA

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ABSTRACT

Macrobenthic fauna is important in paddy fields (man managed temporary wetlands) due to its significant role in nutrient cycling. Macrobenthos in Maranchery Kole paddy fields, Vembanad Kole wetland, a Ramsar site in Kerala, India was studied during *Punja* (summer crop season) 2011. Macrbenthos belonged to 3 phyla, 4 classes [Insecta (78%), Oligochaeta (20%), Bivalvia (1%), Crustacean (1%)] and fifteen families. The average benthic abundance was 399±581 ind./m^2, showing a decreasing trend from the beginning of the crop season to the end. As paddy plants grow up, shading by paddy plants reduced the sunlight penetration to the bottom of the paddy field thus reducing decomposition rates resulting in decrease in detritus quantity, which lead to decreased abundance as detritus feeders were the predominant group there. Further the growth of paddy plants leads to the increase in paddy root structures thus gradually decreasing habitable area for benthic fauna resulting in decreased abundance as the crop season progressed. No significant correlation emerged between benthic abundance and environmental parameters, Available limited habitable area and agricultural practices might have determined abundance. Further the narrow range of environmental variables (as paddy fields were man managed) also might have resulted in insignificant correlation.

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INTRODUCTION

Rice cultivation is considered as the oldest form of intense agriculture by man that would have been practiced long before the era for which there is historical evidence (Fernando, 1977; Grist, 1965). Paddy fields are characterized by the presence of a standing water body that is temporary seasonal. Hence they were defined as temporary seasonal wetland ecosystems agronomically managed with variable degree of intensity (Bambrdeniya, 2000; Halwart, 1994) or as man managed temporary wetlands (Lupi *et al.,* 2013). Even researchers opined that paddy fields could proxy the loss of natural wetlands because of its rich biological diversity (Angelini *et al.,* 2008; Nathuhara, 2013). Benthic invertebrates play an important role in the ecology of aquatic ecosystems. Apart from being a vital link in food chain, they release dissolved nutrients by their feeding activities, excretion and burrowing into sediments and increase the rate of decomposition of particulate matter (Covich *et al.,* 1999; Stripari and Henry, 2002). Due to its significant roles in nutrient translocation and organic matter decomposition they are considered key components of rice field fertility (Roger *et al.,* 1987). Considerable work has been done on paddy field benthic community in different countries (Roger, 1989; Roger *et al.,* 1992 and 1995; Pereira *et al.,* 2000; Al-Shami *et al.,* 2008) but very little information is available from India though India stands first in area under rice cultivation, second in rice production and has an agricultural based economy (Balachandran, 2007).

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This study analyzed the macrobenthic community structure in Kole paddy fields, a part of Vembanad kole wetlands, a Ramsar site. Kole wetlands are among the water-logged, paddy cultivating areas in Kerala such as Kuttanad (in Alappuzha, Kottayam and Pathanamthitta), Pokkali (in Alappuzha, Ernakulam and Thrissur) and Kaipad (in Kozhikode and Kannur) (Jayan and Sathyanathan, 2010). Kole wetlands were under rice cultivation for the past 200 years since the erstwhile Maharaja permitted to convert this wetland into paddy fields in the early 18th century (Anon., 1989). They are distinguished for its high rice production, even the term Kole in Malayalam (the regional language in Kerala, India) means 'bumper yield of high returns in case flood does not damage the crops' (Johnkutty and Venugopal, 1993). Moreover this wetland comes under Central Asian- Indian flyway of migratory birds where water birds halt for short periods to rest and feed during their annual migrations, and these 'stepping stones' are essential for their survival (Anon, 1996; Sivaperuman and Jayson, 2000). The role of benthic invertebrates as food for avian fauna also emphasizes the need for benthic study.

MATERIALS AND METHODS

Study area

Maranchery Kole paddy fields (10^0 72'N 75^0 98'E) lies between Maranchery and Veliyamkodu panchayats (a village council is called panchayat) in Malappuram district and is a part of the Ponnani Kole (Fig.1).

Sampling procedure and methods

A total of three sampling stations were chosen and the field sampling was carried out for a complete crop season '*punja*' extending from January to May 2011 on a monthly basis for the study of macrobenthos and environmental parameters. As the water body was shallow, water samples were collected using a locally fabricated shallow water sampler of 1 liter capacity. The samples were stored in plastic containers and kept frozen till analysis. The sediment samples for the analysis were collected using a Van Veen grab of size $0.45m^2$. Temperature of the water and sediment samples were measured in the field using a standard degree centigrade thermometer of 0°C to 50°C range and 0.1°C accuracy. pH was measured using Systronics digital pH meter model MK VI.

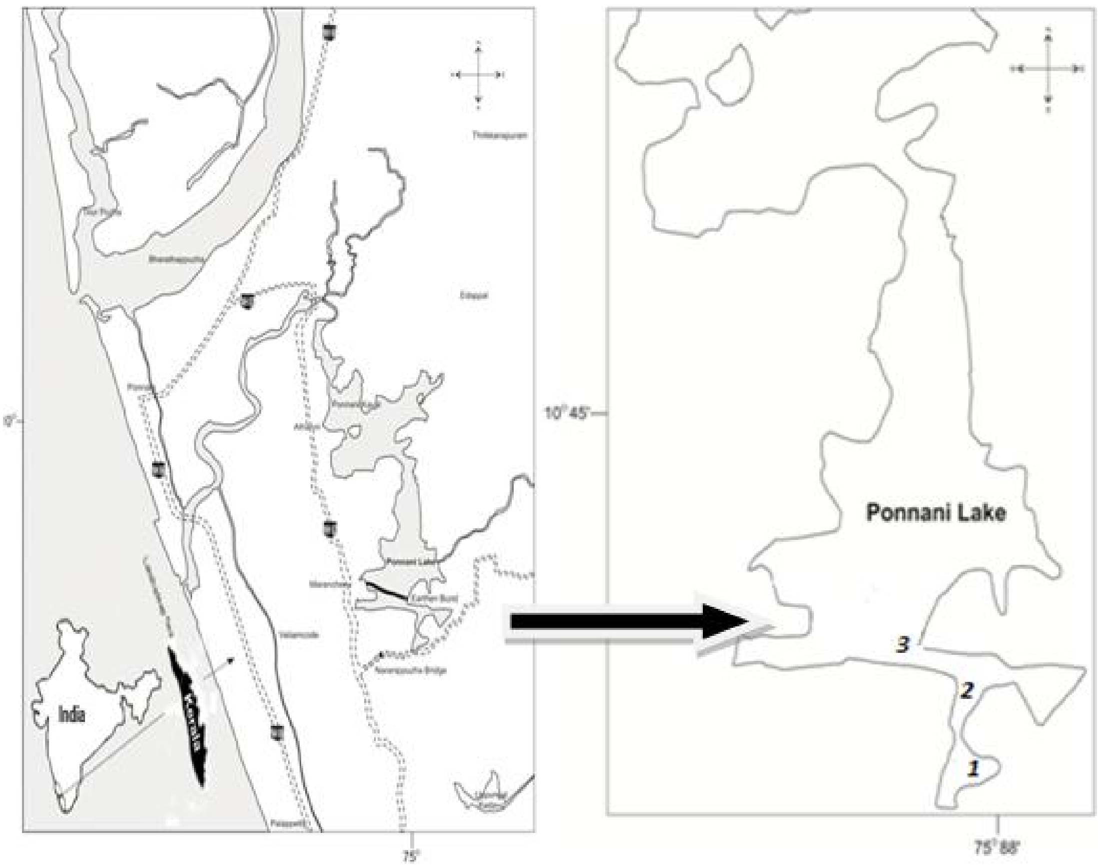

Fig.1. Location of sampling stations in Maranchery Kole paddy fields

The Kole lands has an area of 13,632 ha. spreading over Thrissur and Malappuram districts of Kerala extending from northern bank of Chalakkudy river in the South to the southern bank of Bharathappuzha river in the North. The intrusion of salt water to the paddy fields is prevented by Viyyam dam situated at the downstream end of Kole lands. It is believed that Kole lands were lagoons formed by the recession of the seas centuries ago. A shallow portion of the sea along the western periphery of the main land was secluded and they were slowly silted up during rains making the lagoons shallow (Kurup and Varadachar, 1975). During summer months the farmers bunded the fields, dewatered and cultivated paddy. The main crop is *Punja* (Summer crop) raised between December/January and April/May.

Dissolved oxygen was analyzed by modified Winkler method (Strickland and Parsons, 1972). Organic carbon was determined by Walkley - Black method, then converted to organic matter by multiplying with Van Bemmelen factor of 1.742 (Jackson, 1973). Available nitrogen of sediment was analyzed by Kjeldhal method (Jackson, 1973; Carter, 1993). Available phosphorus was determined by Olsen's method (Olsen *et al.,* 1954). Particle size was analyzed using particle analyzer Sympatrec T 100 laser diffraction granulometer, made in Germany. Sediment samples in replicate were collected for the analysis of macrobenthos using a VanVeen grab of size $0.45m^2$. The samples were washed in the field itself through a sieve of mesh size 500 μm and those that were retained in the sieve were collected and preserved in 5% formalin (Holme and McIntyre, 1971;

McIntyre and Eleftheriou, 2005). The organisms were sorted into different taxonomic groups. Identification was done using standard keys (Yule and Sen, 2004; Morse *et al.,* 1994).

Statistical Analysis

Diversity indices such as species richness by Margalef's index (Margalef, 1958), species diversity by Shannon index (Shannon Wiener, 1949), species evenness by Pielou's index (Pielou, 1966) and species dominance by Simpson's index (Simpson, 1949) were calculated for macrobenthic fauna in paddy fields using PRIMER 6 (Plymouth Routines in Multivariate Ecological Research, version 6). The software programmes SPSS 16 (Statistical Programme for Social Sciences, version 16) was used for correlation analysis to check the relationship between environmental parameters and benthic abundance.

RESULTS

Depth of the paddy fields ranged from 0.20 m in April to 0.50 m in May with an average value of 0.31m. Water temperature showed an average of 27.30°C, the range being 23.63°C in January to 29.60°C in April. The average water pH was 5.57, the lowest and highest values were 5.99 in May and 6.93 in February respectively. Lowest dissolved oxygen recorded was 5.30mg/L in April and highest was 6.53mg/L in January with an average of 6.37mg/L. Sediment temperature showed an average of 27.51°C, the range being 23.76°C in January to 29.6°C in March. Sediment pH varied between 6.16 in March to 6.55 in April showing an average of 6.39 whereas sediment Eh varied between -254mV in March to -196mV in May showing an average of -225.46mV. The average value of moisture content was 24.96%, the range being 21.64% in May to 26.53% in January.

Organic matter was lowest in May (4.48%) and highest in January (8.22%), the mean value being 6.43%. The average available nitrogen was 0.015%, the lowest and highest values were 0.012% in January and 0.018% in February respectively. Available phosphorus of the paddy fields ranged from 0.21 ppm in February to 0.46 ppm in April with an average value of 0.33 ppm. The sediment texture in paddy fields showed clay, silt and sand percentages as 26.45, 46.47 and 27.07 respectively.

The macrobenthic fauna in Maranchery Kole paddy fields belonged to 3 phyla (Annelida, Arthropoda and Mollusca) and 4 classes (Oligochaeta, Insecta, Bivalvia, Crustacean) and fifteen families. The faunal groups observed were insects (78%), oligochaetes (20%), molluscs (1%) and crustaceans (1%). The class Insecta consisted of Diptera (true flies) represented by Chironomidae, Ceratopogonidae, Tipulidae; Coleoptera (aquatic beetle) represented by Gyrinidae, Dysticidae, Hydrophilidae; Hemiptera (True bugs) represented by Aphelecherinidae; Odonata (Dragon fly and Damsel fly nymph) represented by Chlorocyphidae, Calopterygidae; Megaloptera (Alderflies) represented by Corydalidae. The class Oligochaeta consisted of Tubificidae and Naididae. The class Gastropoda was represented by Bithinidae and Lymnaeidae. The class Crustacea consisted of Palaemonidae (Fig.2). The monthly variation in the composition of macrobenthos showed that January 2011, the beginning of the paddy crop season showed the maximum number of macroinvertebrate families. Out of the fifteen families, 11 macroinvertebrate families including Chironomidae, Ceratopogonidae, Calopterygidae, Tipulidae, Hydrophilidae, Aphelecherinidae, Chlorocyphidae, Tubificidae, Naididae, Bithinidae and Lymnaeidae. The minimum number of macroinvertebrate families were observed in February and May 2011(the end of the crop season).

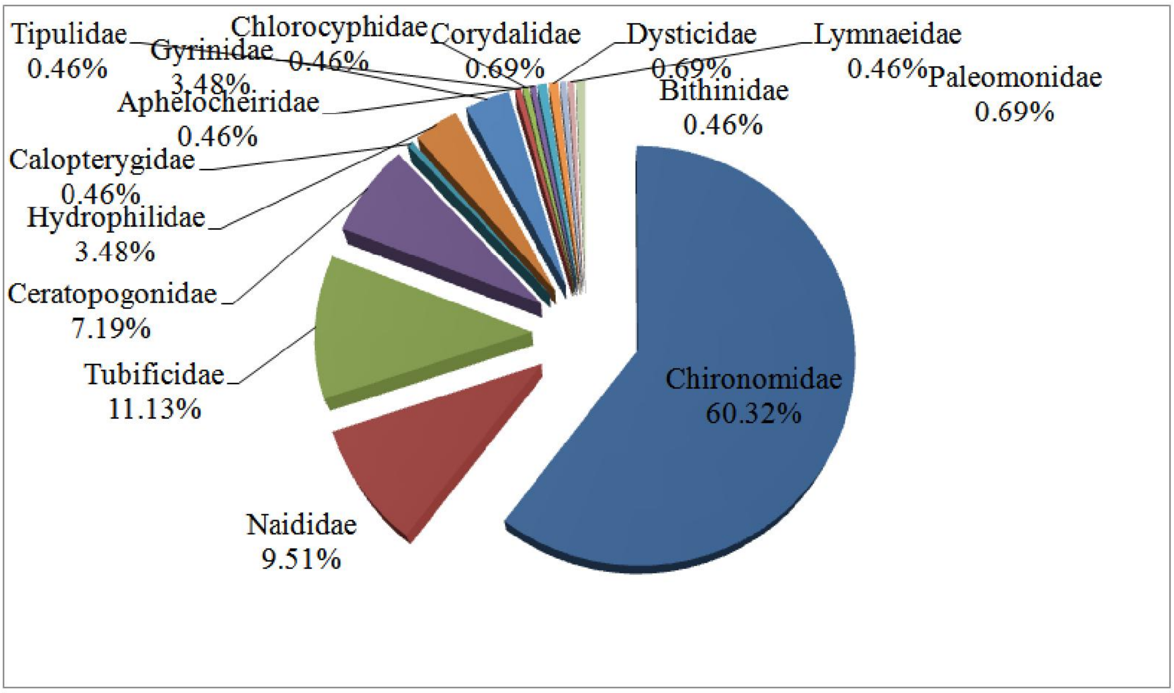

Fig.2. Mean percentage composition of macrobenthic families in Maranchery Kole paddy fields during *Punja* season 2011

The average number of macrobenthos during *Punja* crop season was 399±581 ind./m^2. A declining trend in numerical abundance was evident from the beginning of the crop season (474 ind./m^2 in January 2011) to the end of the crop season (233 ind./m^2 in May 2011) though the minimum abundance was in February 2011 (211 ind./m^2). Oligochaetes and Insects, the most abundant class in the paddy fields showed almost similar trend in abundance pattern throughout the crop season. Molluscs (15 ind./m^2) and Crustacea (11 ind./m^2) showed a random appearance in January and February respectively (Fig.3).

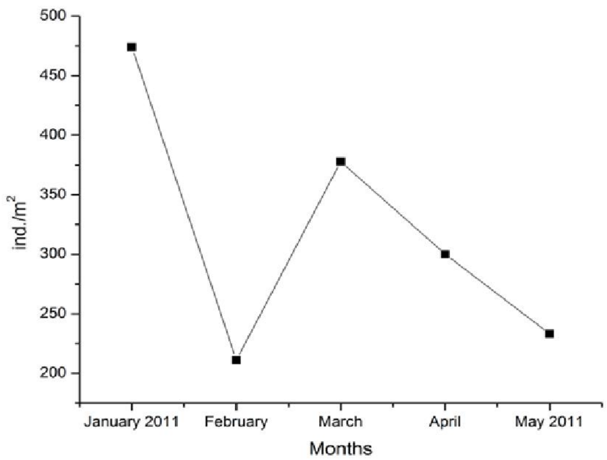

Fig.3. Monthly mean variation in numerical abundance (ind./m^2) of macrobenthos in Maranchery Kole paddy fields during *Punja* season 2011

Diversity analysis revealed that the highest species richness (1.62) and species diversity (2.20) in January 2011, the beginning of the crop season and species dominance (0.37) in May 2011, the end of the crop season. The lowest species richness (0.37) and species diversity (1.35) was recorded in February 2011 and species dominance (0.36) in January 2011(Fig.4).

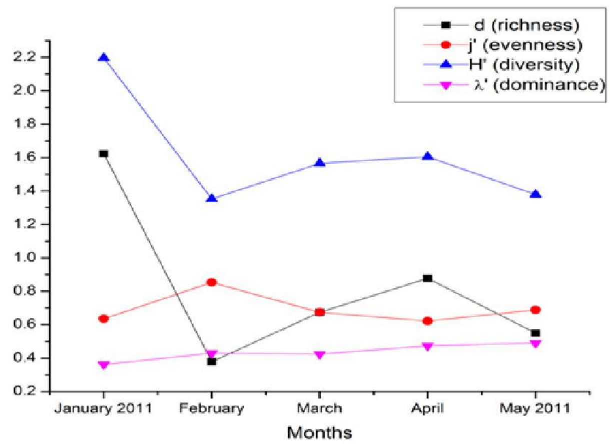

Fig.4. Monthly mean variation in diversity indices of macrobenthic families in Maranchery Kole paddy fields during *Punja* season 2011

About the functional feeding groups of the benthic fauna in Maranchery Kole wetland, the predominant feeding group was collector gatherers (82.11%) represented by Naididae, Tubificidae, Chironomide that feed on deposited fine particulate organic material followed by predators (19.94%) represented by Ceratopogonidae, Tipulidae, Gyrinidae, Hydrophilidae, Dysticidae, Chlorocyphidae, Aphelocheiridae, Calopterygidae that feed on other macroinvertebrate fauna by engulfing prey; scrapers (0.47%) represented by Bithynidae that feed on aufwuchs from various substratum surfaces; collector filters (0.47%) represented by Lymnaeidae that feed on entrained materials (detrital, microbial, algal, or animal) in the water column (Fig.5).

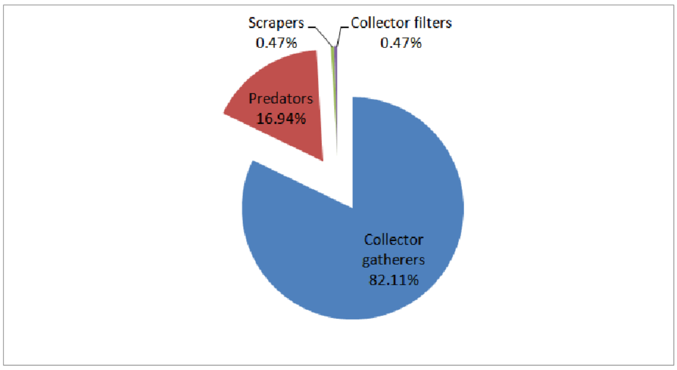

Fig.5. Mean percentage composition of functional feeding groups of macrobenthic families in Maranchery Kole paddy fields during *Punja* season 2011

The interactions between macrobenthic abundance and environmental parameters were analyzed using correlation analysis. The results showed no significant correlation between macrobenthic abundance and environmental parameters, the maximum correlation was observed between silt content and numerical abundance of macrobenthos (r^2=-0.40, p=0.14).

DISCUSSION

The composition of benthic macrobenthos showed that insect larvae were the most abundant in paddy fields. The predominance of insects in paddy fields was reported from various studies such as in Srilanka (Bambardaneniya, 2000), in Bako, Ethiopia (Desta *et al.,* 2014) and Chapra, Bihar (Ojha *et al.,* 2010). The availability of more protected habitable niche by paddy plants would have favored the insect to thrive. The vegetative and reproducing growth stages of the rice plant such as tillering, booting and flowering stages attract a variety of insects (Edirisinghe and Bambaradeniya, 2006). Previous studies from Maranchery Kole wetland showed that oligochaetes were the dominant benthic group followed by insects in flooded phase when the wetland was inundated whereas the dominant benthic group was insects followed by oligochaetes during the dry phase when the area was dry with fragmented water patches (Vineetha *et al.,* 2015a). Paddy fields also showed a benthic composition similar to that of the dry phase in the wetland. The habitat fragmentation in paddy fields would have favored insect taxa more due to their active/flight mode of dispersal similar to that in dry phase. Further shallow water in paddy fields favor insects more compared to oligochaetes.

The benthic macroinvertbrates in Maranchery Kole paddy fields belonged to 15 families, the paddy fields of Chapra, Bihar also showed a comparable result, from where 14 benthic macroinvertbrate families were recorded (Ojha *et al.,* 2010). Bambardaneniya *et al.* (1998) has documented 77 species of invertebrates from Srilankan rice fields, further in 2000, he recorded 178 aquatic invertebrate species (Bambardaneniya, 2000). In Italian rice fields 176 macroinvertebrate taxa were recorded (Lupi *et al.,* 2013).The number of taxa from Kole paddy fields was less in number but species level analysis would have provided a better result.

Abundance showed a declining trend from the beginning to the end of the crop season. This could be explained by the feeding strategy of organisms present in the Maranchery paddy fields. The dominant functional feeding group was collector gatherers which feed on detritus. When the paddy plants were small, decomposition was more. As paddy plants grow up, shading by larger plants reduced the availability of sunlight thus reduces decomposition (Bambaradeniya and Amerasinghe, 2003) which resulted in lesser amount of detritus available for detritus feeders (Che Salmah and Hassan, 2002). Lowest chironomid density was observed in tiller and pre-harvest phase by Che Salmah and Hassan, (2002). Decline in the amount of detritus available from the beginning of the crop season to the end is supported by the organic matter content values which also showed the declining trend with minimum and maximum values at the beginning and end of the crop season respectively. Further as paddy plants grow up the paddy root structures also grow making the bottom of the paddy field compartmented by paddy root structures providing insufficient space for the proper development of benthic fauna (Ojha *et al.,* 2010, Vineetha *et al.,* 2015b).

The abundance pattern of insects and oligochaetes followed almost similar trend. Insects in this study were represented mostly by chironomids. Chironomids and oligochaetes are alike to some extent as they get their chief source of energy by ingesting large volumes of sediments. Previous studies from Indian conditions have shown a positive correlation between tubificidae and bacteria. Thus in a habitat, where chironomids are abundant, a high population of tubificids may also be expected due to the similarity in factors determining their distribution (Kumar and Bohra, 2005). On the other hand, there is known to be a correlation between the ecological demands and distributions of chironomidae and oligochaeta species and they are sources of nutrients for each other (Darby, 1962). Some studies showed a decrease in oligochaete abundance when there is an increase in chironomid abundance (Arslan and Sahin, 2006; Zeybek, 2013). But there was no such pattern evident in this study. Chironomids belonging to the genus Tanypus, Procladius and Ablabesmyia were considered as predators of oligochaetes (Loden, 1973; Arslan and Sahin, 2006). They were relatively low in abundance in this study to make a reduction in oligochaete abundance.

Diversity and richness also showed the similar trend as that of abundance. Scarcity of detritus which is the food for dertitivores, the most abundant feeding group and the scarcity of habitable space as the paddy plants grow up would have resulted in a declining richness and diversity pattern, similar to decrease in abundance as the crop season progressed.

The results of correlation analysis between environmental parameters and the numerical abundance of the benthic fauna evolved no significant correlation among themselves. Paddy fields were managed by man so the environmental parameters remained similar among rice fields, the narrow range of variables would have resulted in the insignificant correlation between benthic abundance and environmental parameters. Further in paddy fields agricultural practices were more important driving forces for the macroinvertebrate structure unlike the usual factors in wetlands (Stenert *et al.,* 2009). Similar to the findings of this study the absence of correlation between macrobenthos and environmental variables over the cultivating cycle was documented in paddy fields in Brazil also (Stenert *et al.,* 2009). Unlike the bottom of the aquatic bodies, paddy fields were compartmented by paddy root structures thus providing insufficient space for the proper development of benthic fauna (Ojha *et al.,* 2010). The availability of habitable area also would have been an important factor determining the benthic abundance.

The macrobenthic community in Kole paddy fields revealed the predominance of collector gatherers which are good bioturbators indicating the potential for enhanced nutrient replenishment in the paddy fields. As the consequences of agrochemical are revealed gradually, these natural ecosystem components should be utilized for nutrient enrichment. So this baseline information from the field is essential for management and conservation aspects. Most importantly, there was no usage of agrochemicals during the study period, but further researches are needed to evaluate its impacts.

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