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The Spatiotemporal Dynamics of Benthic Macrofaunal Communities in a Seasonal Paddy Wetland, Kerala, India.

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Abstract: *The seasonal paddy cultivation in wetlands is common practice in many parts of the world. The shift from water body to paddy field involves a series of processes, which is expected to cause disturbance to the inhabitant organisms. Due to the sedentary life style, benthic organisms are prone to the disturbances than the mobile organisms. This study analyzed the macrobenthic community structure in a kole wetland (a part of the Ramsar site Vembanad Kole wetlands), where the agricultural related activities during seasonal paddy cultivation transformed the area as wet, dry, paddy, channel and stable phases. The macrobenthic fauna belonged to the phyla Annelida, Arthropoda, Mollusca and Chordata, and classes Oligochaeta, Insecta, Gastropoda, Bivalvia, Pisces, Crustacea, and Hirudinea. Most of these organisms were characterized by survival mechanisms against dry periods which maintained their existence through different phases. Oligochaetes formed the most abundant group in all the phases except dry phase and paddy phase, where insects were the most abundant. The habitat fragmentation would have impacted the insect fauna less compared to oligochaetes, as insects have an active flight mode of dispersal instead of the passive crawl mode of dispersal in oligochaetes. Numerical abundance varied significantly among phases (ANOVA $F_{37,154}$=3.87, p< 0.01). Wet, channel and stable phases, resembling aquatic systems were characterized by more abundance as the increased habitable area increased the abundance. Dry and paddy phases showed a reduced abundance. Irrespective of the difference in the physical structure, the diversity indices remained similar between the phases even a marginal increase in macrobenthic diversity was observed in dry phase and paddy phase which were characterized by a significantly reduced numerical abundance.*

Keywords: *Kole wetlands, Macrobenthic fauna, Seasonal paddy field, Vembanad kole wetland*

I. Introduction

Wetlands are one of the earth's most productive ecosystems and provide multiple services to humanity. Wetlands around the globe are being modified, reclaimed and overexploited due to high levels of resource consumption, land conversion and/or upstream developments that alter the quality and flow of water that feeds into them. More than 50% of specific types of wetlands in parts of North America, Europe, Australia, and New Zealand were converted during the twentieth century [1]. In Asia alone, about 5000 $km^2$of wetland area are lost annually to agriculture, dam construction, and other uses [2]. The practice of utilization of wetlands for paddy cultivation is very common especially in Asian countries, yet their ecology is poorly studied. This study is from Kole wetlands (a part of the Ramsar site Vembanad Kole wetlands), which was used for seasonal paddy cultivation, by draining and protecting the paddy fields with bunds during summer season (January to May). Kole wetlands were under seasonal paddy cultivation since last 200 years ago since the erstwhile Maharaja gave permission to utilize this wetland for paddy cultivation in the early 18^{th} century, due to an increased demand for food. The yearly modification of the wetland made the area behave as different systems during short time spans. During this study, the agricultural related activities made the area behave as four different systems during the study period such as normal water bodies, isolated water patches, paddy fields and narrow strips of water bodies. The modification of wetlands could cause major changes affecting the biota. Benthos, the organisms that inhabits the bottom of the water body, forms an integral part of aquatic environment and is of ecological and environmental importance as they maintain various levels of interaction between the community and environment. They have the capability to integrate the environmental effects due to their sensitive life stage, sedentary habits and relatively long life span [3]. This study explored the difference in macrobenthic community structure among the above phases and compared it to a part of the wetland, which remained stable throughout the study period.

II. Materials and Methods

II.I. Study Area

The Kole land 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 [4]. 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. The study area (10^0 72´N 75^0 98´E), with an area of 100 acres, lies in between Maranchery and Veliyamkodu panchayats (a village council is called panchayat) in Malappuram district and forms a part of the Ponnani Kole. Eight stations were selected for monthly sampling.

II.II. The Hydrological regime and Phases

In January 2010, water was drained using the indigenous pumping device '*petti* and *para'* from sites 1,2,3,4,5 to sites 6,7,8 as the preparation for paddy cultivation. In February, these sites were again filled with water due to the accidental breaching of an adjacent earthen bund. March to June, there was no water in sites 1 to 5. Paddy cultivation was not done due to breech of the bund so the land was covered with grass. The stations 1 to 5, from January 2010 to June 2010 was considered as the dry phase since the area was dry with grasses and shrubs where cattle pastured. February 2010 was excluded because it was inundated due to the breach of a bund hence it could not be considered as dry phase. Stations 1,2,3,4,5 were inundated again by the end of June 2010 with the advent of South West monsoon. The period from July 2010 to December 2010 was considered as wet phase. During the similar period, the stations 6 to 8 were considered as stable phase for a comparison as it remained unaltered throughout the study period. In stations 6-8, paddy cultivation was practiced years back but since last few years it was kept fallow so the hydrological regime remained unaltered there. In January 2011, the dewatering for paddy cultivation started again, and during the year paddy cultivation was practiced in stations 1 to 3 so it was considered as paddy phase. During the same period, the stations 4 to 5 were the narrow channels connecting the paddy fields so it was considered as channel phase (Fig.1).

Fig.1. Different phases in Maranchery Kole wetland

II.III. Sample collection and analysis

The sediment samples for the analysis of macrobenthos were collected using a Van Veen grab of size $45cm^2$. In order to ensure precision, duplicate samples were taken for macrobenthic study. These samples were washed in the field itself through a sieve of mesh size 500 µm for macro fauna and those that are retained in the sieve were collected and preserved in 5% buffered formalin [5,6]. Macrobenthic samples were sorted to different benthic groups by hand sorting. This was done in transparent plastic trays placed on a white back ground for easily distinguishing different benthic groups [6]. Family level identification was done using standard keys [7,8]. Identification was followed by a count of individuals per groups. For the comparison of between phases, the average abundance for each phase was calculated separately.

II.IV. Data Analysis

The software programmes SPSS 16 (Statistical Programme for Social Sciences, version 16) and PRIMER 6 (Plymouth Routines in Multivariate Ecological Research, version 6) were used for statistical analyses. One way ANOVA was used to determine the significant difference in numerical abundance of benthos between the phases using SPSS 16.0. Abundance data was square root transformed to meet the ANOVA assumptions. The data on macrobenthic groups was subjected to multivariate and univariate analysis by using the Primer software version 6.0 [9]. Non metric multi-dimensional scaling, a hierarchical cluster analysis was used for the pictorial representation of the pattern of benthic family assemblage in the phases (relative abundance). Ordinations were based on distance matrices, which were computed using Bray Curtis coefficient. The univariate indices of diversity such as species richness by Margalefs index [10], species evenness by Pielou's index [11], species diversity by Shannon index [12] and species dominance by Simpson’s index [13] were calculated for all the phases.

III. Results and Discussions

The macrobenthic fauna in Maranchery wetlands belonged to 4 phyla (Annelida, Arthropoda, Mollusca and Chordata), and 7 classes (Oligochaeta, Insecta, Gastropoda, Bivalvia, Pisces, Crustacea, and Hirudinea). Naididae, Tubificidae and Lumbriculidae were the oligochaete families present. The class insecta was represented by Diptera (true flies), Coleoptera (beetles), Trichoptera (Caddisflies), Hemiptera (True bugs), Odonata (Dragon flies and Damselflies), Ephemeroptera (May flies) and Megaloptera (Alder flies). Molluscs were represented by the families Unionidae and Lymnea. The comparison among the phases showed that oligochaetes formed 74.11% of the benthic fauna in wet phase where insects contributed 25.68% and pisces 0.21%; that in dry phase oligochaetes formed 24.08% of the benthic fauna, insects contributed 74.87% and molluscs 1.07%; that in paddy phase oligochaetes formed 39.31% of the benthic fauna, insects contributed 60.39%; that in channel phase oligochaetes formed 60.39% of the benthic fauna, insects contributed 39.31% and molluscs 0.15%; that stable phase oligochaetes formed 88.76% of the benthic fauna, insects contributed 10.86% and crustaceans 0.37%.

By their very nature, aquatic biota is supposed to exist in aquatic habitats. In this regard, artificial or natural drying could stress or even eliminate them. As temporary fresh waters may experience a recurrent dry phase, the inhabitant fauna need adaptations including physiological, behavioral, morphological and life history strategies [14]. The following organisms which were present in the study areas were capable of surviving in dry conditions by specific mechanisms such as in Oligochaeta by diapausing eggs; resistant cysts enclosing young, adults or fragments of individuals; that in Diptera: Chironomidae (insecta) by diapausing eggs, resistant late instar larvae, sometimes in cocoons of silk or mucus; that in Ephemeroptera (insecta) by diapausing eggs; that in Odonata (insecta) by resistant nymphs, recolonising adult; that in Hemiptera (insecta) by recolonising adults; that in Trichoptera (insecta) by diapausing eggs, resistant gelatinous egg mass, terrestrial pupae in some species, recolonising adults, larvae deep in substrate, that in Coleoptera (insecta) by semi-terrestrial pupae, burrowing adults, recolonising adults; that in Bivalvia by diapausing eggs and adult stages; that in Gastropoda by adults forming a protective epiphragm of dried mucus across shell opening, adults and young survive in moist air/soil under algal mats on pond/stream bed and that in Hirudinae by surviving as dehydrated individuals; some species construct small, mucus-lined cells [15]. Apart from pisces and crustaceans whose representation in this wetland was nominal, all the other benthic organisms were found to have survival mechanisms against dry periods which maintained the benthic populations in Maranchery wetland during the different phases of the study. Furthermore, oligochaetes, the most abundant taxa here adopt a non-larval reproductive strategy, and therefore they do not rely on an open mouth state to recruit as would fauna relying on planktonic dispersal stages [16]. Due to this reason, the fragmented water patches that could restrict the planktonic larval distribution did not exert such an effect on oligochaete distribution. Both the properties of desiccation survival and non-larval reproductive strategy made oligochaetes and chironomids survive through the extreme conditions in this wetland ensuring their presence in all the phases. Earlier studies stated that in temporary waters, the water level fluctuations cause less severe impacts, as the fauna is already stressed by harsher environmental conditions caused by the drying out process whereas in stable environments, the fauna are less adapted to fluctuations resulting in more severe impacts [17,18]. The yearly modification of this wetland for agricultural purposes would have made the fauna adapted to a wide range of environmental conditions which would have made less severe impacts on the benthic community.

A close examination of benthic composition among phases showed that in wet, channel and stable phases oligochaetes were the most numerically abundant group whereas in dry and paddy phases insects were the most numerically abundant group (Fig.2). The habitat fragmentation in dry and paddy phases favored insect taxa more due to their active/flight mode of dispersal, also the shallow water in dry and paddy phases favored insects compared to oligochaetes. The reduced competition in these phases from oligochaetes also would have resulted in more abundance of insects.

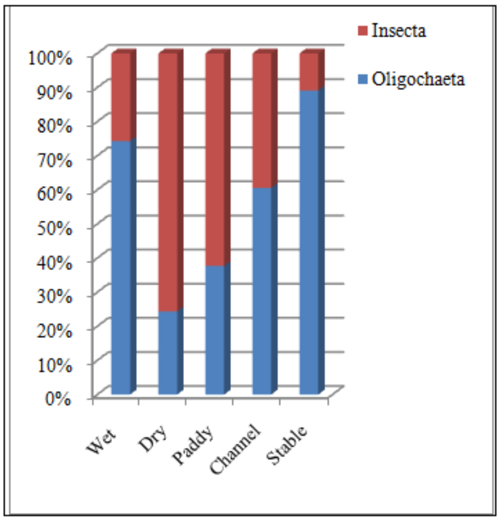

Fig.2. Mean percentage composition of major macrobenthic groups during different phases

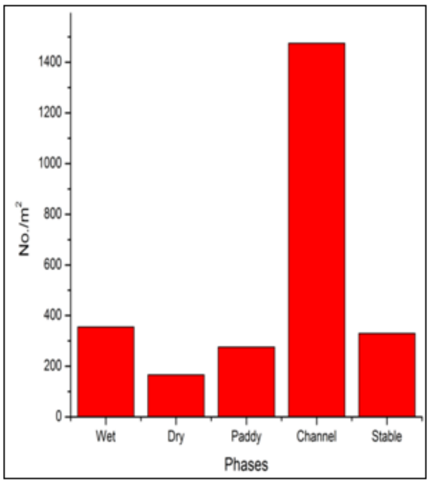

Fig.3. Mean variation in numerical abundance of macrobenthos during different phases

The mean numerical abundance was compared among different phases. In wet phase, it was 355±122 ind./m^2; in dry phase it was 166±60 ind./m^2; in paddy it was 399±581 ind./m^2; in channel phase, it was 1475±2064 ind./m^2 and in stable phase, it was 330±224 ind./m^2. (Fig.3). In wet phase, the total abundance was maximum in September 2010 (35%) and minimum in December 2010 (4%). In the dry phase, total abundance showed a clear gradual declining pattern from January 2010 (46%) to June 2010 (9%) except in April 2010 when it showed an increase in abundance than the previous month. Paddy phase also showed a decrease in total abundance from 39.78% in January 2011 to 13.44% in May 2011 but no consistent pattern was evident. It decreased to the minimum value (12.9%) in February, then increased in March and April, again decreased in May 2011. In the channel phase, abundance was higher in January 2011 (9%) and March 2011(9%) but an unusually high abundance was observed in May 2011 (70%). Lowest abundance in stable phase was observed in December 2010 (7%) and highest abundance in October 2010 (29%). There existed a significant variation in abundance between phases (ANOVA $F_{37,154}$=3.87, p< 0.01).

A comparison of numerical abundance between macro invertebrates in intermittent and permanent waters gave contradictory results by various researchers. In this study, the benthos showed significant fluctuation in numerical abundance during different phases indicating a clear response to the hydrological fluctuations. During dry, paddy and channel phases, the area under inundation where benthic organism live or habitable area for benthic organisms was less compared to the wet and stable phase. The wet and stable phase showed a considerably better numerical abundance compared to the other phases. When the area under inundation is increased, the habitable area increase and the number of organisms increase [19]. Most of the previous studies also documented an increase in benthic abundance with higher water levels [20,21]. In the dry phase, due to habitat desiccation, wet area or habitable area was less which resulted in concentrating the benthic organisms to the available water patches which serve as the only habitable area for benthic organisms. Due to this limited habitable area, greater competition and other abundance-dependent effects results which lead to the reduced numerical abundance in the dry phase. Decreasing in abundance of aquatic organisms may result due to greater competition and other abundance-dependent effects during habitat desiccation [22]. Further in the dry phase, due to shallow nature of the water body, birds and other invertebrates can access the water patches easily thus the threat of predation from birds and other invertebrates are more which can reduce the abundance. There was an unusually high abundance of benthos in May 2011 in the channels. The unusually high benthic abundance could be due to the enriched sediment resulting from reduced consumption and degradation of sinking material [23]. In the case of oligochaetes the faeces of one species of the worm becomes the preferred food for another species resulting in clumping of oligochaetes [24,25].

When richness was compared among different phases, the maximum richness was observed in the paddy phase (d=0.53) and minimum richness was observed in the wet phase (d=0.34). Evenness index ranged from (j'=0.33) in stable phase to (j'=0.55) in dry phase when the phases were compared. The maximum diversity was in paddy phase (H'=1.07) closely followed by the channel phase (H'=0.99) and dry phase (H'=0.87). The lowest diversity was seen in the stable phase (H'=0.53). The minimum dominance value was observed in the paddy phase (λ'=0.5116), the channel phase also showed a similar value (λ'=0.5189), whereas the maximum dominance was observed in the stable phase (λ'=0.79) (Fig.4). Diversity analysis showed that the maximum diversity was observed in paddy phase. The unique characteristics of rice fields render them as ideal habitats for many diverse organisms. The difference in the growth phase of the paddy and the associated environmental conditions, weeds, nutrients, primary productivity etc. would have provided heterogeneity of habitat in time and space. These vast arrays of micro habitats provide shelter, food, breeding and nesting grounds thus resulting in thriving of different benthic groups leading to the higher diversity in paddy phase. The shallow nature of the paddy fields also allowed more light penetration up to the bottom of the field, which in turn facilitated the accumulation of relatively more amount of food material for macrofaunal species in the fields. Apart from the above reasons, in Maranchery Kole wetland, organic farming was practiced. The threat from agro chemicals which was normally experienced in rice fields was not there. It also would have contributed to the high diversity here.

The MDS plots for total numerical abundance between phases showed that the wet phase and stable phase were clustered together at 80% similarity. Similarly dry and paddy phase also were clustered together at 80% similarity. Channel phase was standing apart with overall similarity of 40% with the other phases. MDS plots gave a good ordination having a stress value of 0 for phase wise distribution (Fig.5).

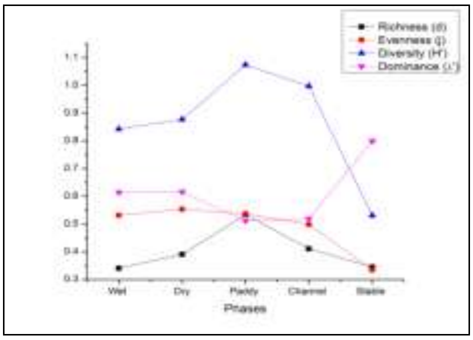

Fig. 4. Variation in diversity indices of Macrobenthos during different phases

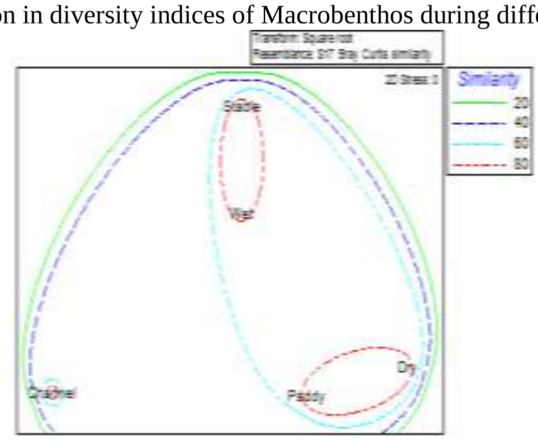

Fig.5.Non-metric Multi Dimensional Scaling (MDS) ordination plot during different phases

The cluster groupings between phases closely reflected the difference in depth and habitat type. Wet and stable phases characterized by comparatively deep, large and continuous water body were included in a group, dry and paddy phases which were shallow and discontinuous in nature in another group and channel phase of intermediate depth separated from them. Similarity analysis showed that the unusually high abundance in channel phase and the presence of hirudinae lead to the separation of channel phase from the other phases. Dry and paddy phases were characterized by the dominance of insects unlike the other phases where oligochaetes were dominant which resulted in clustering of dry and paddy phases together. A similarity in total benthic abundance existed between wet and stable phases a clear domination of oligochaetes also was apparent resulting in clustering of wet and stable phases together. The MDS plots showed a lower stress value indicating good biological ordination [27].

IV. Conclusion

The benthic response to hydrological extremes is of particular interest in the climate changing scenario, also the increasing stress placed on wetlands demands such studies. As most attention in aquatic ecology has been directed to permanent waters (i.e., hydroperiod>1 year), there is a lacunae in the vital ecological data bases that are essential for protecting and managing temporary waters. Though there were studies on benthos from wetlands, paddy fields/ paddy wetlands and isolated water patches separately, the seasonal transformations in Maranchery Kole wetland facilitated the study of the same area as different systems during different seasons, which is novel.

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