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Composition, Abundance and Community Structure of Oligochaetes during Paddy Cultivating and Fallow (Dry) Seasons in Kole Paddy Fields,Vembanad Kole Wetland, India

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Abstract: *The native fertility of paddy fields depend on replenishment of soil nutrients, related to oligochaete community due to its role in nutrient recycling and translocation. Oligochaete community structure during two contrasting ecological conditions; paddy cultivating (flooded) and fallow (dry) seasons were analyzed in Maranchery Kole paddy fields, a part of the Ramsar site Vembanad Kole wetlands, India. Naididae, Tubificidae and Lumbriculida were the oligochaete families present. In fallow season 13 oligochaete species were present, Aulorilus pluriseta (41%) being the most abundant. In paddy season, 9 oligochaete species were present, Aulodrilus sp. and Aulodrilus pluriseta being the most abundant. ANOSIM showed a similarity in oligochaete species composition among both the seasons could be due to the survival strategies of oligochaetes. No significant difference in numerical abundance of oligochaetes existed among the seasons ($F_{1,38}$=2.43, $p>0.05$). Paddy season exhibited a higher abundance, which could be attributed to the increased area under inundation providing habitable area for benthic organisms. Species richness and diversity were higher in fallow and paddy seasons respectively. The study revealed that though the extended dry period caused stress to the benthic organisms, it maintained the productivity and health through its survival strategies and adaptations, which could be utilized for sustainable agriculture.*

Keywords*: fallow season, Kole paddy fields, oligochaetes, paddy season, Vembanad Kole wetlands*

I. Introduction

Paddy fields existed since the beginning of organized agriculture, as rice was a chief food source since 2500 B.C. But rice production throughout the world (especially in Asia) underwent a dramatic transformation after the mid 1960's, as a result of the green revolution which mainly involved the use of modern high yielding rice varieties responsive to fertilizers and pesticides. In order to achieve maximum crop production, management measures were usually driven not by environmental concerns, but by economic issues, such as increased usage of agrochemicals for maximum yield. Reckless usage of agrochemical lead to soil degradation, ecosystem contamination and rising production costs, eventually resulting in declining agricultural productivity and utility [1,2]. Of late the focus shifted to agricultural sustainability, to simultaneously achieve food security and environmental sustainability. It could be practiced through management and exploitation of agricultural diversity for enhancing agricultural production including enhancement of the soil organism population and their ecological services, such as organic matter decomposition and nutrient mineralization [3].

Oligochaeta is a class of the phylum Annelida (annelid worms) [4].They form an important component of the benthic fauna especially in fresh water ecosystems. The mass populations of oligochaetes are accomplished of extensive reworking of the sediments they occupy. Previous studied documented that oligochaetes could rework the sediments by displacing quantities of mud eight times of their own body weight within 24 hours [5]. Kikuchi and Kurihara observed that oligochaetes accelerate nutrient release from soils and water in paddy fields [6]. Aquatic oligochaetes promoted nutrient mineralization and suppress weed germination under laboratory conditions [7]. These properties make oligochaetes an important asset in agricultural farms. The importance of aquatic oligochaetes in nutrient recycling and translocation is related to their density and activity rates. Population dynamics are impacted by agricultural practices ultimately affecting soil fertility. Paddy fields, due to different ecological phases, are subjected to two contrasting ecological conditions; paddy cultivating (flooded) and fallow (dry) systems. Consequently, the environmental conditions may also differ in these systems; perhaps oligochaete population dynamics also reflect these changes. This study analyzed the composition, abundance and community structure of oligochaetes in Maranchery Kole paddy fields, a part of the Ramsar site Vembanad Kole wetlands, India; a seasonal paddy field during paddy cultivating (flooded) and fallow (dry) seasons.

II. Materials and Methods

II.I Study area

The Kole lands are saucer shaped tracts, lying 0.5 to 1.5 m below the mean sea level, spread 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 which is situated at the downstream of end of Kole lands. The Kole lands are assumed to be lagoons formed by the recession of the seas centuries back. A shallow portion of the sea along the western periphery of the main land was isolated and they were gradually silted up during rains making the lagoons shallow [8]. The farmers then bunded the fields, dewatered and raised rice in summer months. During the rains, the inflow into the basin submerges the kole areas. The cyclical nutrient recharging of the wetland during the flood season made the area as one of the most fertile soils of Kerala. The main crop is *Punja* (Summer crop raised in December/January- April/May).

The study area, with an area of 100 acres, is a part of the Ponnani Kole lies in between Maranchery and Veliyamkodu panchayats (a village council is called panchayat) in Malappuram district. Five stations that were under seasonal paddy cultivation were selected for monthly sampling (Fig.1). Field sampling for fallow (dry) season was carried out from January to June 2010 (February 2010 was excluded); and for paddy cultivation from January to May 2011. In January 2010, water was drained as the preparation for paddy cultivation but due to the accidental breaching of an adjacent earthen bund, these sites were again filled with water in February. Due to this the paddy fields were left fallow without cultivation so the land was covered with grass where cattle pastured, resembling a terrestrial ecosystem. From July to December 2010, the study area was flooded due to the South West Monsoon (June to September). By the end of the north east monsoon (October to December 2010), water from the area was pumped out for paddy cultivation. Dewatering was done by an indigenous centrifugal pumping device (*petti* and *para)* after protecting the paddy fields (*Padavu* or *Padashekharam*) with permanent or temporary earthen bunds (*Mattoms*). Paddy cultivation was begun by January 2011. The area remained under paddy cultivation from January to May 2011.The crop was harvested by the end of May, soon after which the field gets flooded due to the South West Monsoon.

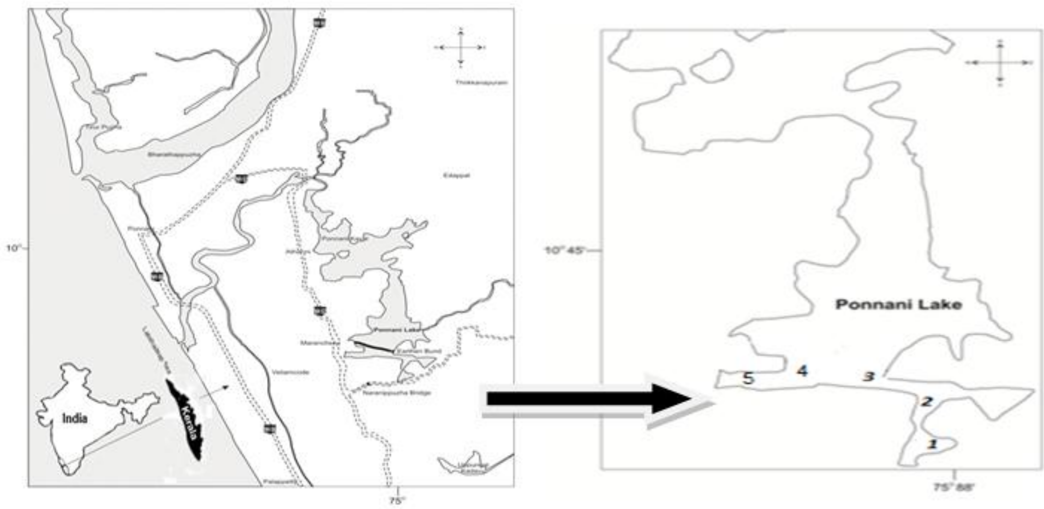

Figure.1. Location of sampling stations in Maranchery Kole paddy fields

II.II Sampling procedure and methods

During fallow season, the samples were collected from isolated water patches, as sampling areas were just muddy enough to collect benthic samples, water could not be sampled. The sediment samples for the analysis were collected using a Van Veen grab of size $0.45m^2$. Temperature was measured in the field using a standard degree centigrade thermometer of 0°C to 50°C range and 0.l°C accuracy. pH was measured using Systronics digital pH meter model MK VI. Organic carbon was determined by Walkley - Black method then converted to organic matter by multiplying with Van Bemmelen factor of 1.742 [9]. 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 [10,11]. The organisms were separated into different taxonomic groups. Oligochaetes were identified up to species level by temporarily mounting the specimens using Amman's Lactophenol (Phenol, Lactic acid, Glycerol, and water in the ratio of 1:1:2:1) using taxonomic keys of [12,13].

II.III. Statistical 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 environmental parameters and numerical abundance of benthos between the flooded phase and paddy season. Abundance data was square root transformed to meet the ANOVA assumptions. ANOSIM was used to analyze the similarity of oligochaete species assemblages between fallow and paddy seasons. The univariate indices of diversity such as species richness by Margalefs index [14], Species evenness by Pielou's index [15], species diversity by Shannon index [16] and species dominance by Simpson’s index [17] were calculated for fallow and paddy seasons.

III. Results and Discussions

The mean depth in fallow season was 0.36±0.14 m whereas it was 0.31±0.11 m in paddy season. Though fallow season showed seems deep, it was only isolated, discontinued water patches separated by vegetation. Sediment temperature was slightly higher in the fallow season (27.66±3.35ºC) than the paddy season (27.30±2.76ºC). Though both fallow and paddy season existed in summer months, the shading by paddy plants would have resulted in lower temperature in sediments in paddy season. Sediment pH was higher in the fallow season (6.45±0.44) than the paddy season (5.5±0.18), the variation in sediment pH was significant (ANOVA $F_{1,38}$=6.93, p< 0.05) between the seasons. Previous studied from Kole paddy fields reported that sediment was slightly acidic in nature [18]. Organic matter was higher in the paddy fields, showing an average value of 6.79±1.33%, in fallow season it was 3.88±1.85%. Decomposing rice straws would have resulted in a higher organic matter in paddy seasons. The sediment was silty clay in fallow season and clayey silt in paddy fields.

The oligochaetes present were of the family Naididae (13 species), Tubificidae (3 species) and Lumbriculida (1 species). Fallow season was characterized by the presence of 13 oligochaete species. *Aulodrilus pluriseta* (Piguet, 1906) (41%) was the most abundant species here followed by *Aulodrilus sp*. (19%). (Fig.2). In paddy season, only 9 species of oligochaetes were present. The most abundant taxa was *Aulodrilus sp.* (23%) and *Aulodrilus pluriseta* (20%) (Fig.3). The taxa common to both seasons were *Aulodrilus pluriseta, Aulodrilus pigueti (*Kowalewski, 1914), *Aulodrilus sp.*, *Branchiodrilus hortensis* (Stephenson, 1910) and *Pristinella jenkinae* (Stephenson, 1931). The species specific to fallow season was *Pristinella acuminate* (Liang, 1958), *Lumbriculus variegates* (Muller, 1773), *Haemonais waldvogeli* (Bretscher, 1900), *Nais andhrensis* (Naidu and Naidu, 1981), *Allonais gwaliorensis* (Stephenson, 1920), *Dero dorsalis* (Ferroniere, 1899), *Dero nivea (*Aiyer, 1929) and *Aulophorus hymnae* (Naidu, 1963). The taxa specific to paddy cultivating season was *Pristinella minuta* (Stephenson, 1914), *Stephansonia trivandriana* (Aiyer, 1926), *Branchiodrilus semperi (*Bourne, 1890) and *Homochaeta sp.* Similar studies across the world also revealed that the largest number of species belonged to the families Naididae or Tubificidae and the species of other families were represented nominally. Oligochaete composition of paddy fields from various studies showed that, in Philippines oligochaete populations was dominated by *Limnodrilus hoffmeisteri* and *Branchiodrilus sowerbyi* of the family Tubificidae [19]. Heckman recorded oligochaete species exclusively of the family Nadidae from the paddy fields from Laos and Thailand respectively [20, 21]. According to Senapati [22], the earthworm *Darwida willsi* dominated the paddy fields in India. The families Aeolosomatidae, Tubificidae and Megascolecidae constituted oligochaete fauna in Chapra, Bihar [23]. A recent study from the paddy fields of Dakshin Kannada revealed a very high density of *Aulophorus furcata* of the family Naididae [24].

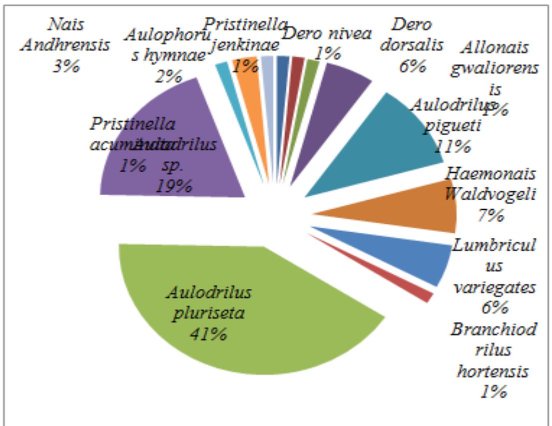

Figure. 2. Mean Percentage composition of oligochaetes in fallow season

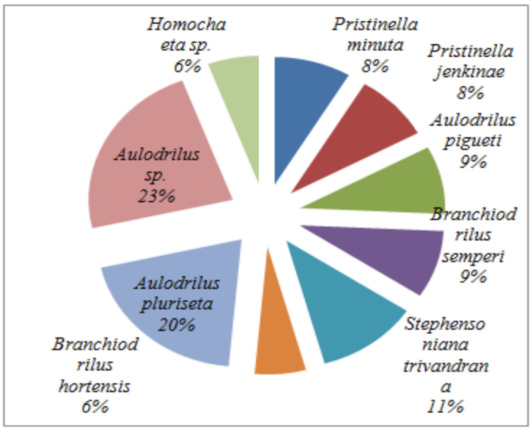

Figure.3. Mean percentage composition of oligochaetes in paddy season

The number of oligochaete species recorded in this study was more compared to similar studies from India. A similar study from Dakshin Kannada revealed 3 oligochaete species from paddy fields [24]. A difference in the sampling strategy would have resulted in a higher number of species from Maranchery paddy fields. The sampling was done using Van Veen grab in this study whereas in studies from Dakshin Kannada, the sampling was done from the water and algal mats in paddy fields, not from the benthic substrate, in that case the chance of getting phytophilous naidids are more and the chance of getting other oligochaete families that prefer staying within the substrate like tubificids are less. In paddy fields in Chapra, Bihar revealed 4 oligochaete species where sampling was done with a scoop [23]. Ten oligochaete species belonging to 8 genera were identified in ponds from Thiruvananthapuram, Kerala [25].

The composition of oligochaete species in both seasons were compared using ANOSIM. The dissimilarity between the seasons were not very strong (Global R=0.05, p>0.05), revealing that the composition of oligochaete species remained similar in both the seasons. The survival strategy used by oligochaetes during extreme environments by forming cysts etc. would have ensured the presence of oligochaetes during fallow season. Further due to the reduced dispersal ability of oligochaetes, they would not have escaped to other areas. In spite of difference in the physical structure between both seasons, the oligochaete composition did not show a significant difference between them. The less prominent niche specialization of oligochaetes proved by many studies could be a reason for this [26]. Further, the phases explored in this study were very the same site in a different temporal scale, so a very different oligochaete composition among them was not expected.

The mean numerical abundance of oligochaete abundance in fallow and paddy seasons were 40±53ind./m^2 and 102±160ind./m^2 respectively (Fig.4). ANOVA of oligochaete abundance showed no significant difference among the seasons ($F_{1,38}$=2.43, p>0.05). When the area under inundation is increased, the habitable area increase and the number of organisms increase obviously [27]. In fallow season, 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 areas 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 fallow season. According to Aspbury and Juliano [28] habitat desiccation result in decreasing the abundance of organisms as a result of greater competition and other abundance-dependent effects. Further in the fallow season, 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. Another peculiarity in the fallow season is that flocks of ducks were allowed to feed in the area during this period which also would have resulted in a reduced abundance. These findings are in agreement with the observations of Sommer and Horwitz [27] who opined that drying wetlands concentrate aquatic prey for wading birds and mammals that utilize the wetland for feeding thus resulting in less and numerical abundance of benthic organisms.

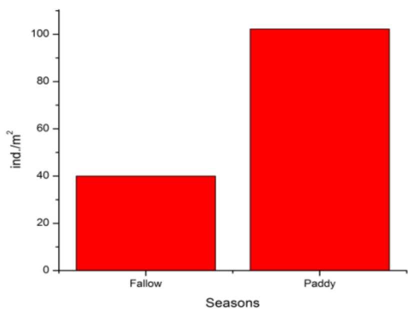

Figure. 4. Mean variation in oligochaete abundance during fallow and paddy seasons

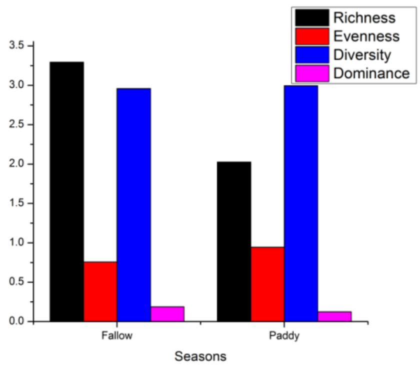

Figure. 5. Diversity indices of oligochaete species during fallow and paddy seasons

In spite of the reduced numerical abundance in the fallow season, diversity analysis of oligochaetes revealed a slightly higher richness in fallow season (d= 3.293) than paddy season (d=2.026) (Fig.5). However diversity values were comparable among fallow (H'= 2.996) and paddy (H'= 2.960) seasons. This could be due to higher dominance of Aulodrilus pluriseta (41%) in fallow season whereas in paddy seasons, a clear domination was lacking. A more even distribution of oligochaetes was observed in paddy season.

IV. Conclusion

Historically, Maranchery and associated kole wetlands had short dry periods which were traditionally useful for the agronomic practices in the wetland. But the extended dry period during this study caused stress to the benthic organisms. Even in this scenario, the benthic communities through its survival strategies and adaptations maintained the productivity and health of the kole wetland. As oligochaetes, promote nutrient mineralization and suppress weed germination, a healthy oligochaete community is sufficient to meet the nutrient needs for the paddy fields thus the usage of agrochemicals can be reduced. Reduced usage of agrochemicals, promoting organic farming can reduce the cost, thus paddy production can be more economical. Though once renowned for rice cultivation, the practice of keeping wetland fallow due to unprofitable rice cultivation, as a prelude to divert it for other uses, is a common practice there. But the area has the potential for long term agrarian livelihood, thus the internationally recognized Ramsar site could be conserved for its ecological importance.

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