Ecosystem Monitoring and Modelling of Benthic fauna in Maranchery Kole wetland, Kerala

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Certificate

This is to certify that the thesis entitled "**Ecosystem Monitoring and Modelling of Benthic fauna in Maranchery Kole wetland, Kerala**" is an authentic research record of research work carried out by Mrs.Vineetha.S under my scientific supervision and guidance in School of Marine Sciences, Cochin University of Science and Technology, and that no part thereof has been presented before for the award of any other degree, diploma or associateship in any university.

Kochi
March 2015

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Declaration

*I hereby declare that the thesis entitled "**Ecosystem Monitoring and Modelling of Benthic fauna in Maranchery Kole wetland, Kerala**" is an authentic record of research work conducted by me under the supervision of Dr. S.Bijoy Nandan, Associate Professor, Department of Marine Biology, Microbiology & Biochemistry, Cochin University of Science & Technology and no part of it has been presented for any other degree or diploma in any university.*

Kochi

March 2015 *Vineetha.S*

Dedicated for
those who have been my
'footprints in the sand'...

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Vineetha.S

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ABBREVIATIONS

N	-	North
E	-	East
sp.	-	Species
Fig.	-	Figure
No.	-	Number
ml	-	Millilitre
et al.	-	And others
%	-	Percentage
°C	-	Degree Celsius
m	-	Meter
mm	-	Millimeter
g	-	Gram
kg	-	Kilogram
USA	-	United States of America
Anon.	-	Anonymous
ha.	-	Hectares
nm	-	Nanometer
WWF	-	World Wildlife Fund

Chapter - 1
INTRODUCTION

Many of the human civilizations developed within or in immediate proximity to the wetlands like Indus valley civilization by the Indus river, Mesopotamia by the Nile delta in Egypt, Alexander's Macedonia by the Axios marshes, Rome by the Pontine marshes etc. In spite of this, wetlands have remained in disrepute throughout the whole of human history. Wetlands were considered as sources of disease and obstacles to positive developments. Drainage and reclamation have always been considered civilized actions. Thus over thousands of years, and especially over the past few centuries and far into the twentieth century, most and the vastest wetlands have disappeared. The disappearance of wetlands resulted in undesirable consequences including the 'dust bowl or dirty thirties'; a period of severe dust storms and drought in 1930s in the Midwest (Matthews 2013). Slowly the importance of wetlands for ground water protection, regulation of the water cycle, water storage, water purification, and as an ecological basis for many forms of life had been recognized. The proposal for an international treaty to conserve wetlands first emanated from ornithological circles because they wished to maintain the diversity of migratory waterfowl. Subsequently this resulted in the Ramsar Convention the 'Convention on wetlands of International Importance especially as Waterfowl Habitat' the international treaty for wetland conservation adopted in 1971 in Ramsar, Iran, which is the only treaty for the conservation of a particular ecosystem. This has resulted in re-designating some of the wetlands as 'Wetlands of International Importance'.

The Ramsar convention defined wetlands in Article 1 as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Moreover, the area of coverage is broadened by Article 2, which provides that wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands" (Ramsar Convention Secretariat 2013). Wetlands were defined in various ways by individuals or agencies depending on their objectives. As wetlands characteristics grade continuously from aquatic to terrestrial and due to the diversity of types, sizes, locations and conditions of wetlands any definition is to some extent arbitrary which has caused confusion and inconsistencies in the management, classification and inventorying of wetland ecosystems (Mitsch and Gosselink 1986).

Wetlands are highly productive due to the accumulation of nutrients and high water table, the two limiting factors in terrestrial systems. High rates of primary production provide raw materials for the construction of other life forms also. Wetlands provide an immense storage of carbon and any change that could affect the storage by drying etc. could result in massive positive feedback of even more emissions of carbon dioxide to the atmosphere. Due to the role they play in improving water quality, they are referred to as *nature's kidney*. Coastal wetlands protect coastlines from hurricanes and tsunamis. The subsequent studies after the Indian Ocean tsunami showed that, the places where mangroves were present could protect the shores from tsunami waves whereas the places of drained or destroyed mangroves were devastated. They are known as *nature's supermarket* for the role they play in supporting food chains, both aquatic and terrestrial. As a consequence of the low rates of decay in wetlands, plant and animal debris accumulate, thereby recording the sequence of plant and animal species that occupied the site over millennia (Keddy 2000).

India, with its annual rainfall of over 130 cm, varied topography and climatic regimes support and sustain diverse and unique wetland habitats. Wetlands in India occupy 9.70 million hectares which is around 6.94% of the geographic area. Out of this, total inland wetlands are 5.58 m ha and coastal wetlands are 4.12 m ha. The most dominant type of wetland is intertidal mudflats (2.39 m ha.) occupying around 24.7% of total wetland area. The other major coastal wetlands are mangroves (471,407 ha.), aquaculture ponds (284,589 ha.), lagoons (246,044 ha.), creeks (206,698 ha.), salt pans (148,913 ha.) and coral reefs (142,003 ha.) (Sarkar 2011). It is estimated that wetlands support nearly one fifth of the known range of biodiversity in India (Space Application Centre 2011).

Wetlands in Kerala are distributed all along the coast and in the inlands. The total wetland area estimated is 160590 ha. The major wetland types are river/streams (65162 ha.), lagoons (38442 ha.), reservoirs (26167 ha.) and water logged areas (20305ha.) (Space Application Centre 2010). Geomorphologically the wetlands in Kerala could be classified in to five major systems viz, marine, estuarine, riverine, lacustrine and palustrine. The International Convention of Wetlands designated three wetland ecosystems in Kerala as Ramsar sites on 19th August 2002, for conservation of biological diversity and for sustaining human life through the ecological and hydrological functions they perform. They are the Vembanad–Kole, Ashtamudi and Sasthamkotta wetlands.

Kole wetland is the part of Vembanad-Kole wetlands, the largest brackish, humid and tropical wetland system in the south west coastal state of Kerala. They are saucer shaped tracts, lying 0.5 to 1.5 meters below the mean sea level, spreading over Thrissur and Malappuram districts of Kerala state. Kole wetlands are among the water-logged, paddy cultivating areas in Kerala such as Kuttanad (Alappuzha, Kottayam and Pathanamthitta), Pokkali (Alappuzha, Ernakulam and Thrissur) and Kaipad (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). The cyclical nutrient recharging of the wetland during the flood season made the area as one of the most fertile soils of Kerala. When the average productivity of rice in the State was less than two tonnes per hectare, Kole lands yielded four to five tonnes of rice per hectare. Even the word "Kole" is a term in Malayalam (the regional language in Kerala, India) which means 'bumper yield of high returns in case flood does not damage the crops' (Johnkutty and Venugopal 1993).

Wetland systems, by their very nature, experience dynamic hydrofluxes (Hayworth 2000). Hydrology is a major environmental determinate of ecosystem character, influencing floral and faunal community structure by the frequency and duration of hydrological alterations. Sometimes, due to extreme hydrological fluctuations, the aquatic phase in aquatic ecosystems is shrunk spatially and temporally. Temporary aquatic systems are those in which 'the entire habitat for aquatic organisms shifts from being available to unavailable, for a duration and/or frequently sufficient to substantially affect the entire biota' (Schwartz and Jenkins 2000). The reduced water level leads to habitat loss and habitat fragmentation. The loss of habitable area is the predominant cause of population (Hughes et al. 1997) and species extinctions (Pimm et al. 1995). Isolation of fragments and edge effects associated with such fragmentation can cause further declines in the number of species, changes in their relative abundance and other aspects of biodiversity within remnant habitat patches (Ewers and Didham 2006).

The role of benthos as a link between primary producers, decomposers and higher trophic levels in the ecosystem is well known. The benthic community comprises of phytobenthos; the plant members (various algae and aquatic plants), zoobenthos; the consumers (benthic protozoans and metazoans) and benthic microflora; the decomposer community (bacteria, fungi and many protozoans) involved in the recycling of essential nutrients. Based on the habitat preference, benthos is normally divided into three functional groups, infauna, epifauna and hyper-benthos, i.e., those organisms living within the substratum, on the surface of the substratum and just above it respectively (Pohle and Thomas 2001). Based on the size, benthos are divided into three groups macrobenthos, meiobenthos and microbenthos (Mare 1942). The benthic macroinvertebrate community, particularly standing stock of benthos are valuable index of productivity of water body as fishes, the apex of aquatic productivity, are known to depend on benthos directly or indirectly. The information regarding the qualitatative and quantitative changes in benthos to the changes in habitat has made it an important factor in bio monitoring studies.

The reduction in water depth can affect the benthic fauna directly and indirectly by making the habitat completely inhabitable or reducing the habitable area to a few water patches. This causes habitat isolation and fragmentation. Fragmentation would prevent circulation and interchange of macrofaunal larvae and other propagules between parts of the system; processes governing larval settlement ecology are key structuring agents of benthic communities. Further fragmentation of habitats would impede the spread of various species, and colonization of sediments by negatively affecting larval circulation across the system (Eckman 1996). Fluctuating water levels enhance mechanical mixing of shore line sediments, changing the properties of the sediments and presumably the types of the organisms that inhabit those mixing sediments (Benson and Hudson 1975). For surviving desiccation, macroinvertebrates have several mechanisms. Species can emigrate from the system as adults by timing their life cycle to avoid seasonal drying events (forming spatial metapopulations), which is a viable strategy under a predictable wet-dry seasonality (Batzer and Wissinger 1996, Wiggins et al. 1980, Ims and Yoccoz 1997). When habitat fragmentation is considered, organism with different migration abilities will be differentially affected by habitat isolation (Bowman et al. 2002). Species that have greater adult migration abilities can disperse more easily between habitats (Smith and Brumsickle 1989) and are less likely to be effected by habitat isolation. The impacts of changes in hydrological regimes on each benthic taxa is different based on its different habitat requirements, physiological traits and life history characteristics.

Scope of the study

Most attention in aquatic ecology has been directed to permanent waters (i.e., hydroperiod>1 year) (Schwartz and Jenkins 2000). As a result we know more about communities and ecosystems in permanent waters than we do about those in temporary waters, and thus have fewer bases for protecting these unique, endangered habitats than for other systems. Due to lack of studies, the basic ecological descriptions of temporary water such as environmental characteristics, species composition etc. continues to be vital, especially for unusual systems, which can be used for testing the generality of ecological concepts (Schwartz and Jenkins 2000).

The benthic response to drawdown conditions is also of particular interest as hydrological extremes with enhanced drought and flooding episodes is predicted in the climate changing scenario (EEA 2007). Climate change forecasts characterized by higher temperature and reduced rainfall are likely to increase both spatial and temporal extends of drying events. The increasing stress placed on wetlands also demands similar studies. India has lost more than 38% of its wetlands in just the last decade, at alarmingly high rates as high as 88% in some districts (Vijayan 2004). Like the other threatened wetlands in India such as Wular lake of Kashmir, Loktak Lake of Manipur, Bhoj wetland of Madhya Pradesh and Chilka Lake of Orissa, wetlands in Kerala are also under threat. Converting wetlands and paddy growing areas into built-up areas has become a practice since the late 1980s because of economic development due to NRI remittances (Raj and Azeez 2009). Unlike the other states, the preference of an average Keralite to live in an independent homestead rather than in a flat or colony also contributed for the reclamation of wetlands for residential plots (Thomas 2003). Wetlands are the preferred sites for 'developmental activities' to avoid the trouble of evacuating people from populated areas. Two -thirds of the total area of Vembanad lake and about 63-76% of Kuttanad has been reclaimed (Gopalan 1991, WWF 1993).

Paddy fields are considered as man managed temporary wetlands (Lupi et al. 2013). More than 90% of the world's rice is grown and consumed in Asia. India stands first in area under rice cultivation and second in rice production (Balachandran 2007). The most important feature of paddy field biota is that they have evolved through centuries to adapt themselves to the highly manipulated, eutrophic and transient conditions of these ecosystems (Bahaar and Bhat 2011). The periodic disturbances resulting from agricultural operations and agrochemical uses alter the hydrologic and sediment conditions causing stress to the environmental factors and the biota. Aquatic invertebrates are considered as key components of paddy field fertility due to their significant role in organic matter decomposition and nutrient translocation (Roger et al. 1987). Despite of their recognised contribution in maintaining soil fertility in paddy fields, little is known about the densities, distribution dynamics, compositions, and ecology of field populations.

There were studies on benthos from wetlands, paddy fields/ paddy wetlands and isolated water patches separately, but the seasonal transformations in Maranchery Kole wetland facilitated the study of the same area as different systems during different seasons, which is novel. Most of the similar studies across the world focused on benthic macroinvertebrates giving less emphasis to the benthic infauna. Realising the importance of paddy fields and associated wetlands, the Kerala State Biodiversity Board initiated a research and development programme from August 2009 to July 2011 to study the ecology and production potential (plankton and invertebrates) of the Maranchery Kole wetlands in Ponnani, Northern Kerala for the sustainable development of this ecosystem. It was in this context this pioneering work on benthos from Kole wetlands critically examines the population characteristics, abundance pattern and community structure of the benthic organisms from the Maranchery Kole wetland ecosystem (Northern Kerala) in relation to environmental variables.

Objectives

i) Characterization of the environmental quality of the Maranchery Kole wetland in relation to spatio temporal pattern.

ii) Study the abundance, distribution, diversity of macro benthic fauna, its trophic variability and relationship in the wetland.

iii) The species structure and abundance pattern of oligochaetes in the wetland.

iv) Suggesting suitable ecosystem models for benthic production in the wetland for sustainable livelihood measures.

Chapter - 2

REVIEW OF LITERATURE

Since time immemorial people had viewed wetlands with apprehension. A shift from the view that 'wetlands are wastelands' required awareness of its intrinsic values and functions. In 1964, Fish and Wildlife service, USA published a multi authored, illustrated book "Waterfowl Tomorrow", the water fowl was the primary focus but the conservation and management of wetlands that provide a habitat for water fowls was emphasized in this book (Linduska 1964). A booklet was published to influence policy makers which included the definition, values, economics of dangers and drainage and the management of wetlands by Atkinson-Willes (1964) with the grant from UNESCO. Weller (1981) provided a useful introduction on wetlands. Mitsch and Gosslink (1986) explained in detail the structure and functions of different types of wetlands. Status of wetlands of the world was reported by Maltby and Turner (1983). According to them about 6.4% of the total land area in the world was estimated as wetland area. The causes for deterioration of wetlands were discussed by Parish and Prentice (1989). Following on its wetland's campaign, IUCN published a booklet which was useful for laymen as well as experts (Dugan 1990). Various types of wetlands, adaptations of plants and animals, values and vulnerability to threats were discussed (Finlayson and Moser 1991). Constanza et al. (1997) reported that fresh water wetlands and estuaries were the most valuable ecosystems of the biosphere based on economic analysis. The classification of wetlands was made by Cowardin et al. (1979) and Keddy (2000). Reddy and Deluane (2008) explained the details of biogeochemical aspects of wetlands. A brief account on the history and development of Ramsar convention on wetlands was given by Matthews (2013). Ramsar Secretariat (2013) listed the Ramsar sites across the world consisting of 1052 sites in Europe, 359 sites in Africa, 289 sites in Asia, 211 sites in North America, 175 sites in South America and 79 sites in Oceania region.

The pioneering attempt to prepare the inventory of wetlands in India was made between 1980s and early 1990s. The inventory of wetlands in India was made by Woistencroft et al. (1989), World Wide Fund for Nature and Asian Wetland Bureau (1993), the Ministry of Environment and Forests (1990) and Space Applications Centre (Garg et al. 1998), but the area of wetlands documented by various agencies were inconsistent. Inadequacy in understanding the definition and characteristics of wetlands were the suggested reason for these contradictory results (Gopal and Sah 1995). According to the latest inventory on Indian wetlands prepared based on GIS techniques, India has about 757.06 thousand wetlands with a total wetland area of 15.3 million hectares, accounting for nearly 4.7% of the total geographical area of the country, consisting 69% of inland wetlands, 27% of coastal wetlands and 4% of other wetlands (smaller than 2.25 ha.) (Space Applications Centre 2011). However only 26 of these numerous wetlands have been designated as Ramsar sites (Ramsar 2013).

A survey on coastal wetlands of Kerala was done by Kurup (1996). Nayar and Nayar (1997) documented the details on wetland area in Kerala. A detailed database on the status of wetlands of Kerala based on remote sensing techniques was documented by Government of India (Space Applications Centre 2010). The district-wise distribution of wetlands in Kerala showed that Alappuzha district has the highest area under wetland with 26079 ha., mainly due to the presence of Vembnad kole wetland and Wayanad district has the lowest area under wetland (3866 ha.) (Space Applications Centre 2010).

The first study on benthic fauna was in the middle of 18^{th} century, around the year 1750, by two Italians Marsigli and Donati from shallow waters by using dredge (Murray and Hjort 1965). In the Indian basin, the bottom fauna was first studied by Annandale (1907) and Annandale and Kemp (1915). The studies on benthos in the Vellar estuary and Chilka lake were done by Balasubramanian (1961) and Rajan (1964) respectively. The studies on the zoobenthos of the rivers in the Ganga river system, river Kaveri and Eastern Kalinadi was done (Ray et al.

1966, Verma et al. 1984, Kulshreshtha et al. 1989, Sivaramakrishnan et al. 1995). They reported that the benthic fauna was dominated by various arthropods (mainly insecta), gastropods, molluscs and oligochaetes. The species composition and dominance of benthic fauna was affected by stream flow, nature of substratum and organic pollution (Negi and Singh 1990, Arunachalam et al. 1991, Burton and Sivaramakrishnan 1993, Sivaramakrishnan et al. 1995, Gupta and Michael 1983). Sivaramakrishnan et al. (1995) showed that landscape differences in the catchment was an important factor influencing the benthic fauna by analysing data for the entire Kaveri river system using canonical multiple discriminant analysis. Benthic population of Bhoj wetland and Ghot Nimbala reservoir was recorded (Ashwani et al. 2011, Sitre 2013). Habib and Yousuf (2013) observed a greater benthic diversity in summer in Yousmarg stream, Kashmir. In Tons river, Uttarakhand, the maximum genera of benthic macroinvertebrates were reported from the midstream which acts as an ecotone between the upstream and downstream, also the maximum diversity was observed in winter (Negi and Sheetal 2013).

The benthos of Malabar and Trivandrum coasts were studied by Seshappa (1953) and Kurian (1953) respectively. Work on benthos of the mud banks of Kerala coast was done by Damodaran (1973). The macrobenthic production and distribution of bottom fauna of Vembanad lake was carried out (Ansari 1974 and Kurian et al. 1975). The benthic community of Veli lake and Ashtamudi estuary was recorded (Divakaran et al. 1981 and Nair et al. 1984). Bijoy Nandan and Abdul Azis (1995a) have made observations on the benthic polychaetes of the retting zone in Kadinamkulam kayal. Fish mortality from anoxic and sulphide pollution in the estuaries of Kerala was studied by Bijoy Nandan and Abdul Azis (1995b). Studies on the benthic fauna of the mangrove swamps of Cochin area was conducted by Sunilkumar (1999). Menon et al. (2000) gave a review on the composition, distribution and species diversity of macro and meiofauna in the Cochin estuary in relation to various hydrographic factors. Recently the biodiversity of estuarine systems of south west coast of India including the benthic fauna has been discussed in depth by Bijoy Nandan (2007, 2008). The distribution pattern and diversity of macro invertebrates showed that diversity and distribution of certain species were clearly related to the water quality in Kadinamkulam and

Veli backwaters (Latha and Thanga 2010). The reduction in benthic diversity due to deterioration by anthropogenic activities in Cochin estuary was noted (Martin et al. 2011). The diversity pattern of benthic macroinvertebrates in Karamana river and a stream in Koratty has been documented by Santhosh et al. (2011) and Kripa et al. (2013) respectively.

For a number of reasons, most attention in aquatic ecology has been directed to ‘permanent’ (i.e. hydroperiod> 1 year) lentic and lotic waters (Schwartz and Jenkins 2000). Wilbur (1997), Simovich et al. (1997) and Withan et al. (1998) made significant contributions in the field of research in temporary waters. Although more papers on temporary waters are being published currently than in the past, the increase has been very gradual also many authors commented on the paucity of information on temporary aquatic habitats (Schwartz and Jenkins 2000). As the aquatic biota essentially require an aqueous phase to survive, the absence of it puts a stress on them, so many works have done to study the scenario. Wellborn et al. (1996) and Spencer et al. (1999) showed the importance of hydroperiod in determining the community structure in temporary waters. Ims and Yoccoz (1997), Olivieri and Gouyon (1997) mentioned the survival of aquatic organisms in unfavourable conditions. Benson and Hudson (1975) documented the effects of reduced water levels on benthic abundance in Lake Francis. The benthos of Sacramento River along with the environmental parameters were studied during a dry year (Siegfried et al. 1980). Changes in the benthic community structure due to hydrological fluctuations were observed in a coastal lagoon of southern Oman (Victor and Victor 1997). Pires et al. (2000) observed the response of benthic macroinvertebrates to floods and droughts in Guadiana Basin, Portugal. The structure of benthic macroinvertebrate community and its changes along an annual cycle in Lake Tecuitlapasur, Mexico was studied (Alcocer et al. 2001). In a Mediterranean temporary pond, the changes in benthic pattern due to hydrological fluctuations were documented (Boix et al. 2004). Macroinvertebrate community structure across a wetland hydroperiod gradient in Southern Hampshire, USA was studied (Tarr et al. 2005). In Mediterranean streams, all macroinvertebrate communities exhibited high to moderate persistence and moderate to low stability over the study period from 1984 to 2003 (Beche and Resh 2007). The influence of water permanence and high intra and inter annual hydrological variability on macrobenthos was studied using taxonomical and functional approach in Mediterranian salt marsh ponds (Gasscon et al. 2007). The effect of water level manipulation on the benthic invertebrates of a managed reservoir in USA revealed that the changes in macroinvertebrate structure due to water level fluctuations was evident in shallow waters than deep waters (Mcewen and Butler 2009). Stubbington et al. (2009) studied the response of perennial and temporary head water stream invertebrate communities to hydrological extremes in River Lathkill, United Kingdom. In Gnangara mound wetlands, Western Australia, the decline and recovery cycles of macroinvertebrates over 12 years was documented (Sommer and Horwitz 2009). Nkwoji et al. (2010) observed the species diversity of macro invertebrates in a South West lagoon, Lagos. Macroinvertebrate community varied among temporary aquatic habitats including vernal pools, emergent wetlands and intermittent streams in North Eastern Ohio (Hamilton et al. 2013).

Due to the seasonal aquatic phase in rice fields, it was comsidered as temporary or seasonal wetland ecosystems (Halwart 1994, Bambaradeniya 2000). Previous biodiversity studies in the rice fields were focused on agronomic aspects especially on pests, weeds etc. whereas comprehensive studies on the ecology and biodiversity of rice fields are scanty. Meijen (1940) was a pioneer to document invertebrates in rice fields. Weerakoon (1957) gave a brief account on the ecology of rice field animals in Srilanka. The varied fauna of the aquatic phase of traditional rice fields in Laos and Thailand was studied by Heckman (1974, 1979). The biological diversity in rice fields was documented (Fernando 1995, 1996, Bambardaneniya et al. 1998). Roger and Kurihara (1988) have dealt with the aquatic ecology of tropical rice fields in detail. Leitao et al. (2007) documented the spatial and temporal variation of macroinvertebrate communities of Mediterranean rice fields. An account on benthic macroinvertebrates in paddy rice fields Pavia province, Italy was given by Lupi et al. (2013) and that in paddy and fish co–culture system at Dembi Gobu microwater shed at Bako, Ethiopia by Desta et al. (2014). In India, the benthic fauna of paddy fields of Chapra in Bihar was studied by Ojha et al. (2010) and that of Kashmir by Bahar and Bhat (2011).

Drainage ditches are a prominent feature of many intensively managed agricultural areas (Verdonschot et al. 2010). The importance of drainage ditches as drivers of biodiversity was documented by many authors across the world. The studies on the benthic invertebrates of agricultural ditches in South Dakota was done by Broschart (1984), that of Florida by Painter (1999) that of Southern England by Williams (2003) that of California by Verdonschot (2012) that of Denmark by Simon and Travis (2011) that of Maryland by Leslie (2012) and that of Korea by Kim et al. (2013).

In India, many of the water bodies are temporary, showing large water level fluctuations, exposing the basin to drying (Gopal and Zutshi 1998) but no literature on benthos in temporary waters from India could be found. Related works on other biota are mentioned here. The survival strategies of zooplankton have been reported in a few studies (Chatterji and Gopal 1998). Studies on the seed banks and seasonal cycles of macrophytes were done by Misra (1976) and later discussed by Gopal (1986). There was a study on the physicochemical aspects and invertebrates of ephemeral wetlands in costal belt of Thiruvananthapuram, Kerala from where 74 genera of invertebrates were identified (Balaraman 2008).

One of the peculiarities of Kole wetland, which is among the water-logged paddy lands in Kerala is its temporary nature. Though water-logged paddy lands form about twenty five percent of total paddy lands, the ecology of them remains largely unknown. Further very few literatures are available about Kole except some project reports and isolated papers. Some of the available studies from Kole wetlands are mentioned here. Soil fertility in the Kole lands was studied (Abdul Hameed 1975). Project report for the development of Thrissur Kole (Kerala Land Development Corporation 1976) and Ponnani Kole was prepared (Mangalabhanu 1977). Ashok (2001) reported that the construction of permanent bund has augmented the rice production in the Kole area. Jayson (2002) studied the ecology of wetland birds in kole lands of Kerala. A total of 182 species of birds including 44 migratory species and 34 waders were identified. Thomas (2003) studied the phytoplankton, zooplankton and fish diversity of the Muriyad wetland along with its pollution aspects. The ecology of purple moorhen (*Porphyrio porphyrio*) in

Azhinhillam wetland in Malappuram district was studied (Manjula Menon 2008). A preliminary study on flora of Kole wetlands was reported (Sujana and Sivaperuman 2008). The water quality and phytoplankton, zooplankton of Thrissur Kole wetlands was studied (Tessy and Sreekumar 2008). A brief account on the water quality of Maranchery Kole wetlands was given by Vineetha et al. (2010). Jeena (2011) studied the sustainability of rice production in Kole wetlands in Thrissur Malappuram districts. Recently Jyothi and Sureshkumar (2014) have been identified 75 species of aquatic macrophytes belonging to 53 genera and 32 families from Kole wetlands in Thrissur and Malappuram districts. A brief account on the community structure of macrophyte associated invertebrates of Maranchery Kole wetlands was given by Rakhi et al. (2014).

Although agriculturists, bird watchers and fish biologists have attempted to study the different physical and biological characters of Kole wetlands, no benthic studies have been reported from this area, probably the present study is the first of this kind in this direction.

Chapter - 3

MATERIALS AND METHODS

3.1 Study Area

The Kole lands which is a unique ecosystem, covering an area of 13,632 ha. 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 area lies between 10° 20´ and 10° 40´N latitudes and 75° 58´ and 76° 11´E longitudes. The area from Velukkara in the south on the Chalakkudy river bank in Mukundapuran Taluk (Taluk is an administration division of India) and Tholur-Kaiparampa areas of Thrissur Taluk form the Thrissur kole and the contiguous area from Chavakkadu and Choondal to Thavannur, covering Chavakkad and Thalappally taluks of Thrissur district and Ponnani taluk of Malappuram district form the Ponnani Kole. The total geographical area of Ponnani Kole is estimated as 3,445 ha., of this 1,487 ha. are located in Thrissur district and 1,958 ha. in Malappuram disrtict. The Ponnani Kole lies in the Kanjiramukku river basin. The Viyyam dam is situated at the downstream end of Kole lands which prevents the intrusion of salt water to the Kole lands. The Kole lands are believed to be lagoons formed by the recession of 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. The farmers then bunded the fields, dewatered and raised rice in summer months. During the rains, the inflow into the basin submerges all the kole areas. The area is normally flooded from June to January. The main crop is *Punja* (summer crop) raised during January to April. Towards the close of the North East monsoon, water from the rice fields are pumped out and sowing or transplanting is done by January. The kole lands are dewatered after protecting the rice fields (*Padavu* or *Padashekharam*) with

Chapter - 3

MATERIALS AND METHODS

3.1 Study Area

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The study area, with an area of 100 acres, which is a part of the Ponnani Kole lies in between Maranchery and Veliyamkodu panchayaths in Malappuram district. A total of eight stations were selected for monthly sampling (Fig. 3.1). Station 1 was under seasonal paddy cultivation but less aquatic macrophytes were observed here when inundated. Station 2 was also under seasonal paddy cultivation but with less aquatic macrophytes under inundation. This station was more adjacent to residential area. Similarly station 3 was also under seasonal paddy cultivation here also less aquatic macrophytes were observed when inundated. Station 4 was under seasonal paddy cultivation, slightly shallow but was characterized by the presence of more aquatic macrophytes. Station 5 was also similar to station 4, characterized by seasonal paddy cultivation, slightly shallow nature and more aquatic macrophytes. Station 6 was not under seasonal paddy cultivation, it was inundated throughout the year supporting a variety of aquatic macrophytes. Station 7 was not under seasonal paddy cultivation so inundated throughout the year, variety of aquatic macrophytes were present there and it was the channel connecting stations 1,2,3,4,5 to stations 6,7,8. Station 8 was also not under seasonal paddy cultivation, inundated throughout the year, with variety of aquatic macrophytes (Fig. 3.2 to 3.9). The field sampling was undertaken for 24 months from November 2009 to October 2011 on a monthly basis for the collection and analysis of water, sediment and benthic fauna.

3.2 The Hydrological regime and Phases

The agricultural related activities transformed the area into four ecologically different systems, that include normal water bodies, isolated water patches, paddy fields and narrow line shaped water bodies (channels) during the study period (Table 3.1, Fig. 3.10). The monthly sampling began in November 2009. During November and December 2009, the sites 1 to 5 were inundated and under fish farming operations. In January 2010, water was drained using the pumping device '*petti* and *para*' from sites 1 to 5 to sites 6 to 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. During dry phase, the benthic samples were collected from the available small water patches. 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 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. Stations 4 and 5 were channels through the paddy fields. During the same period, the stations 4 to 5 were the narrow channels connecting the paddy fields so it was considered as channel phase. 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. From June to October 2011 all the stations were inundated due to the south west monsoon.

Apart from analysing station wise similarities between data, phase wise comparison was also done. For the comparison of the phases, a single season of wet and stable phases were taken because paddy, dry and channel phases existed for a single season. The period (July 2010 to December 2010) was accounted for the comparison because it covered all the months of inundation in stations 1 to 5 whereas November 2009 to December 2010 and June 2011 to October 2011 missed the first and last months of inundation respectively.

3.3 Sampling and Analytical Methods

During wet months, samples were collected on a country boat (*Vallam*). As the water body was shallow, surface and bottom water was not taken separately. In wet months the water samples was collected using a Niskin water sampler (Hydrobios 5 L). In paddy and channel phases, the water samples were collected using a locally fabricated shallow water sampler of 1 L capacity. Due to low water level during the dry phase, water samples could not be taken in dry phase. The samples were stored in plastic containers and kept frozen for analysis. Samples for dissolved oxygen were collected in 125 mL stoppered glass bottles taking care that no air bubbles were trapped in the samples. The samples were fixed immediately with manganous chloride solution (Winkler A) followed by alkaline potassium iodide (Winkler B) solution.

The sediment samples for the analysis of different parameters were collected using a Van Veen grab of size 45 cm^2. Temperature was determined using mercury thermometer in field. The samples were stored in plastic covers. The sediment samples for the analysis of macrobenthos were also 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 (Holme and Mc Intyre 1971, Eleftheriou and McIntyre 2005).

Rain fall data was collected from the Indian Meteorological Department website (imd.gov.in). Rainfall is expressed in millimeter.

Depth was measured by lowering a graduated weighted rope until it touched the bottom floor of the wetland.

Temperature of the water and sediment samples were determined in the field itself using a standard degree centigrade thermometer of the range 0 °C to 50 °C and 0.1 °C accuracy.

Water and sediment pH were measured using Systronics water analyzer model 321 (accuracy ±0.01) (APHA 2005).

Dissolved oxygen was analyzed by modified Winkler method (Strickland and Parsons 1972, Grasshoff et al. 1983). This method depends on the oxidation of manganous dioxide by the oxygen dissolved in the samples resulting in the formation of a tetravalent compound, which on acidification liberates iodine equivalent to the dissolved oxygen present in the sample. The result is expressed in mg/L of dissolved oxygen.

Sediment oxidation reduction potential (Eh) was measured in the laboratory using Systronics digital Eh meter (potentiometer) model 318 (APHA 2005). Oxidation reduction potential (Eh) is generally measured with an electrode pair consisting of an inert electrode and a reference electrode. Eh of the sediment is expressed in mV.

Moisture Content was determined by gravimetric analysis after drying at a maximum temperature of 105 ºC. The temperature was maintained for five hours so that any free form of water was eliminated and no organic matter and unstable salts were lost by volatization (Pansu and Gautheyrou 2006). Moisture content is expressed in percentage.

After analyzing sediment pH, sediment Eh and moisture content of the sediment, the foreign materials such as dirt, dry leaves, plant roots etc. were removed and the sediments were dried in shade by spreading on a clean sheet of plastic paper. The dried sediment samples were divided into 2 parts. One part was stored as such in plastic covers for texture analysis. The other part was powdered using mortar and pestle and sieved through a 2 mm sieve for the analysis of organic carbon, available nitrogen and available phosphorus (Jackson 1973).

Organic carbon was analyzed by Walkley Black method (Jackson 1973). The oxidizable matter in the soil was oxidized by chromic acid in the presence of excess sulphuric acid, the excess of standard chromic acid being titrated back with ferrous ammonium sulphate. The result is expressed in percentage of organic carbon. It was 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. The amount of nitrogen released as ammonia by alkaline permanganate solution was estimated by distillation and the distillate was collected in boric acid indicator solution. The ammonia liberated was determined by titration against standard sulfuric acid (Jackson 1973, Carter 1993). The result is expressed in percentage of available nitrogen.

Available phosphorus was determined by Olsen's method (Olsen et al. 1954). Available phosphorus was extracted with a solution of sodium bicarbonate at a pH of 8.5 for 30 minutes. Interference from organic matter dissolved in the solution has frequently been eliminated by sorbing other organic matter onto activated, acid washed charcoal (carbon black) added to the extract. The phosphomolybdate complex was measures at a wavelength of 712 nm (Carter 1993). Available phosphorus is expressed in parts per million (ppm).

Particle size was analyzed using particle analyzer Sympatrec T 100 laser diffraction granulometer, made in Germany. The aggregarion of particles resulting from cementing action was eliminated by dissolution of the soil into elementary particles by adding the dispersing agent, sodium hexametaphosphate. Measurements were linked to the size of the particles to physical characteristics of the suspension of the soil after dispersion. A dispersing liquid containing suspended particles circulates in a measuring cell intersected by monochromatic laser beam collimated by a condenser on a window of analysis of a defined surface. The light of the laser was diffracted on the outside of the particles and the analysis of the diffraction is inversely proportional to the size of the particles. An optical system collects the signal which were analyzed by Fourier transformation and discriminated on a detector engraved with pre determined angles. The signal was treated to extract the distribution of the particles. The output was in the form of curves: averaging diameter (particle size distribution) expressed as volume (Carter 1993). The result is expressed in percentage of sand, silt and clay.

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 (Eleftheriou and McIntyre 2005). Identification was done up to species level for oligochaetes using taxonomic keys (Brinkhurst and Jamieson 1971, Naidu 2005) and the online identification key. (http://apps.biodiversityireland.ie/OligochaeteIdKey/key. php). Up to family or genus level identification was done for insects, molluscs, crustaceans and pisces (Yule and Sen 2004, Morse et al.1994, Munro 2000). Identification was followed by a count of individuals per species (for oligochaetes) and groups (for other organisms). The wet weight of the organisms in groups was taken to estimate the biomass in mg/m^2. The number and the biomass were extrapolated to 1 m^2. Dry weight was determined by multiplying the wet weight with a conversion factor of 0.1 (Winberg 1971).

3.4 Data Analysis

The software programmes SPSS 16 (Statistical Programme for Social Sciences, version 16), PRIMER 6 (Plymouth Routines in Multivariate Ecological Research, version 6) and ORIGIN 8.5 were used for statistical analyses and representation of data.

Statistical analysis 2 Way ANOVA (Analysis of Variance), standard deviation and correlation was done based on SPSS 16.0 software packages for Windows for testing the presence of significant differences and correlation among the parameters between stations and between phases.

3.4.1 Univariate methods

Univariate analysis uses diversity indices, which attempt to combine the data on abundance within a species in a community into a single number. The state of the community can then be understood from this number.

Species richness- Margalef's index (Margalef 1958)

d = (S-1) / log N

where

d = species richness

S = total number of species

N = total number of individuals

Species evenness- Pielou's index (Pielou 1966)

j' = $H'/\log_2 S$ or $H'/\ln S$

where J' = evenness,

H' = species diversity

S = total number of species

Species diversity-Shannon index (Shannon Wiener 1949)

H' = -ΣS Pi log 2 Pi.....

i = 1

where

H' = the species diversity

S = the number of species

pi = the proportion of individuals of each species belonging to the ith species of the total number of individuals (number of individuals of the ith species)

Species dominance- Simpson's index (Simpson 1949)

D = 1/λ

Where λ = ΣPi2

Pi = ni/N

Where ni = number of individuals of i, i2 etc.

N = total number of individuals.

3.4.2 Multivariate methods

Multivariate analysis uses classification and ordination methods to compare communities on the basis of the identity of the component species and relative importance in terms of abundance or biomass. Classification analyses assign entities to groups, whereas ordinations place them spatially so that similar entities are close and dissimilar ones are distant.

Analysis of similarities (ANOSIM) was used to test statistically whether there is a significant difference between the benthic compositions in different phases. It is denoted by 'R' and calculated using the following formula:

R = $(r_B - r_W) / (M/2)$

Where

r_B = is the average of rank similarities arising from all pairs of replicates between different phases

r_W = is the average of all rank similarities among replicates within phases

M = n (n-1). n represents the total number of samples under consideration.

Cluster analysis

Cluster analysis is indicative of the degree of similarity in species, composition either between stations or at the same station over time. Sites that are grouped into the same cluster are more similar in species composition. The most commonly used clustering technique is the hierarchical agglomerative method. It produces a hierarchy of clusters, ranging from small clusters of very similar items to larger clusters of increasingly dissimilar items. Hierarchical methods produce a graph known as a dendrogram or tree that shows the hierarchical clustering structure in which x- axis represents the full set of samples and the y-axis defines the similarity level at which the samples or groups are fused. The dendrogram was produced using the Bray-Curtis coefficient (Bray and Curtis 1957).

$$S_{jk} = 100 \left\{ 1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})} \right\}$$

$$= 100 \; \frac{\sum_{i=1}^{p} 2\min(y_{ij}, y_{ik})}{\sum_{i=1}^{p} (y_{ij} + y_{ik})}$$

Where

y_{ij} represents the entry in the i th row and j th column of the data matrix i.e.

the abundance or biomass for the i th species in the j th sample;

y_{ik} is the count for the i th species in the k th sample;

| … | represents the absolute value of the difference;

'min' stands for, the minimum of the two counts and

$\sum$ represents the overall rows in the matrix.

SIMPROF Test was used to test the significance of the groups.

MDS Plots (Non metric multi dimension scaling)-The primary outcome of MDS is a spatial configuration in which the objects are represented as points. The points in this spatial representation are arranged in such a way that their distances correspond to the similarities of the objects. Similar objects are represented by points that are close to each other and dissimilar objects by points that are far apart. In metric multi dimension scaling developed by Shepard (1962) and Kruskal (1964) the ordinal information in the proximities is used for constructing the spatial configuration.

Abundance/Biomass comparison (ABC) plots

The ABC method involves the plotting of separate k-dominance curves (cumulative ranked abundances plotted against species rank, or log species rank) for species abundance and species biomass and comparing the shape of the curves (Lambshead et al. 1983, Clarke and Warwick 2001). Species are ranked in order of importance in terms of abundance or biomass on the x-axis (logarithmic scale) with percentage dominance on the y-axis (cumulative scale). In undisturbed communities the k-dominance curve for biomass lies above the k-dominance curve for abundance over its entire length, in moderately disturbed communities biomass and abundance curves are similar, in severely disturbed communities, the abundance curve lies above the biomass curve throughout its length.

PCA

Principal component analysis (PCA) was done on environmental data to analyse the variation in environmental characteristics across the study area. This analysis uses an ordination plot to project the points of more similarities closer together while less similar samples further apart. Unlike biological data, environmental data usually have mixed measurement scales and similarity methods, such as normalised euclidean distance used in PCA, are more appropriate for environmental data (Clarke and Warwick 2001).

BIO-ENV

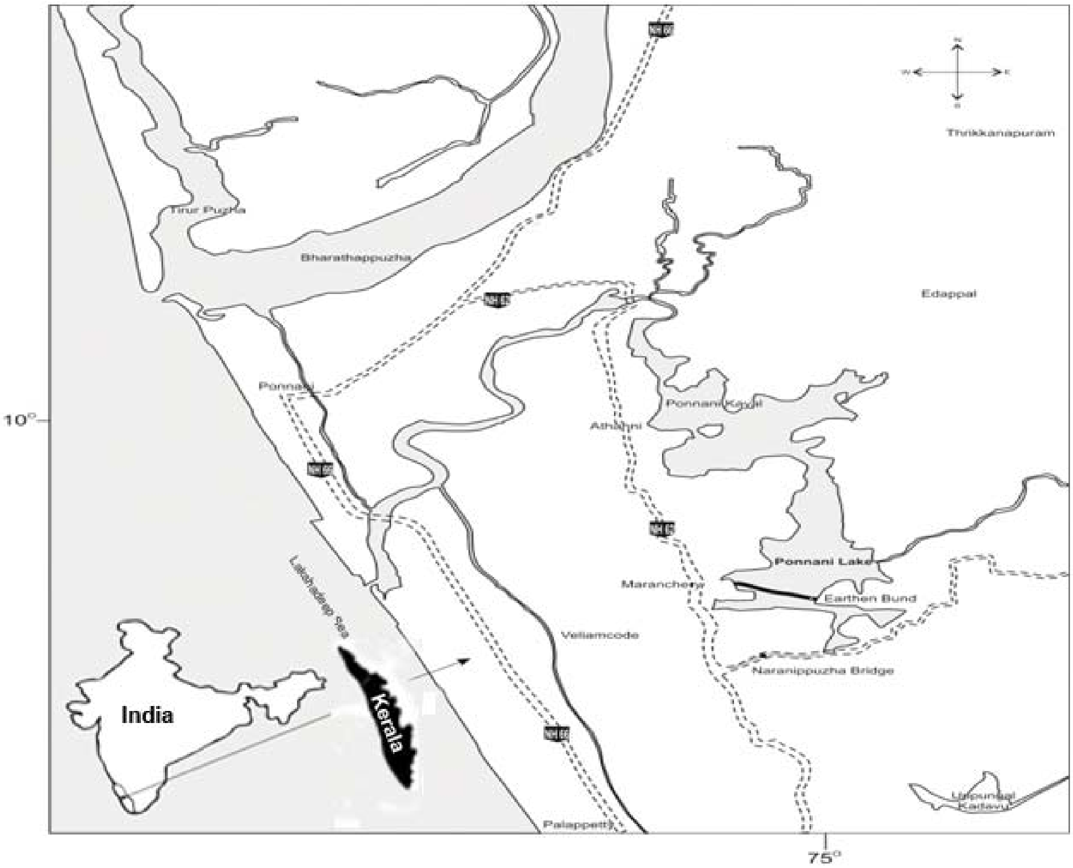
BIO-ENV procedure is used to link biological community analyses to environmental variables or to examine the extent to which environmental data, such as physico chemical data, is related to the observed biological pattern (Clarke and Warwick 2001). The BIO-ENV procedure calculates a measure of agreement between the two similarity matrices: the fixed biotic similarity matrix (using Bray-Curtis similarity on the biotic data) and each of the possible abiotic matrices (PCA on combinations of the abiotic data). This is done by Spearman rank correlation, which ranks the subsets of variables that best 'matches' the biological patterns.

3.5 Multiple regression predictive models

Predictive models based on multiple regression technique (SPSS 16) were used to find the equations representing the best fit between environmental parameters and benthic productivity. The total macrobenthic productivity in terms of the total macrobenthic abundance and oligochaete productivity in terms of oligochaete abundance was predicted using the environmental variables and their first order interactions. Environmental parameters used were depth, water temperature, water pH, dissolved oxygen, sediment temperature, sediment pH, Eh, moisture content, available nitrogen, available phosphorus, organic matter, sand percentage, silt percentage and clay percentage. Regression with 'Enter' option in SPSS 16 version was used in order to find the model. Adjusted R^2 values revealed the predictability of the model. A value of 1 indicates a model that perfectly predicts values in the target field and a value that is less than or equal to 0 indicates a model that has no predictive value. The adjusted R^2 lies between these values (Mateo et al. 2010).

Table 3.1. The seasonal transformations in Maranchery Kole wetland during the study period.

<table>
<tr><th></th><th>Station 1</th><th>Station 2</th><th>Station 3</th><th>Station 4</th><th>Station 5</th><th>Station 6</th><th>Station 7</th><th>Station 8</th></tr>
<tr><td>Nov-09</td><td colspan="5" rowspan="2">Inundated</td><td colspan="3" rowspan="24">Stable Phase
Inundated</td></tr>
<tr><td>Dec-09</td></tr>
<tr><td>Jan-10</td><td colspan="5">Dry</td></tr>
<tr><td>Feb-10</td><td colspan="5">Inundated (bund breach)</td></tr>
<tr><td>Mar-10</td><td colspan="5" rowspan="4">Dry Phase
Dry/fallow</td></tr>
<tr><td>Apr-10</td></tr>
<tr><td>May-10</td></tr>
<tr><td>Jun-10</td></tr>
<tr><td>Jul-10</td><td colspan="5" rowspan="6">Wet Phase
Inundated</td></tr>
<tr><td>Aug-10</td></tr>
<tr><td>Sep-10</td></tr>
<tr><td>Oct-10</td></tr>
<tr><td>Nov-10</td></tr>
<tr><td>Dec-10</td></tr>
<tr><td>Jan-11</td><td colspan="3" rowspan="5">Paddy Phase
Paddy cultivation</td><td colspan="2" rowspan="5">Channel Phase
Channels</td></tr>
<tr><td>Feb-11</td></tr>
<tr><td>Mar-11</td></tr>
<tr><td>Apr-11</td></tr>
<tr><td>May-11</td></tr>
<tr><td>Jun-11</td><td colspan="5" rowspan="5">Inundated</td></tr>
<tr><td>Jul-11</td></tr>
<tr><td>Aug-11</td></tr>
<tr><td>Sep-11</td></tr>
<tr><td>Oct-11</td></tr>
</table>



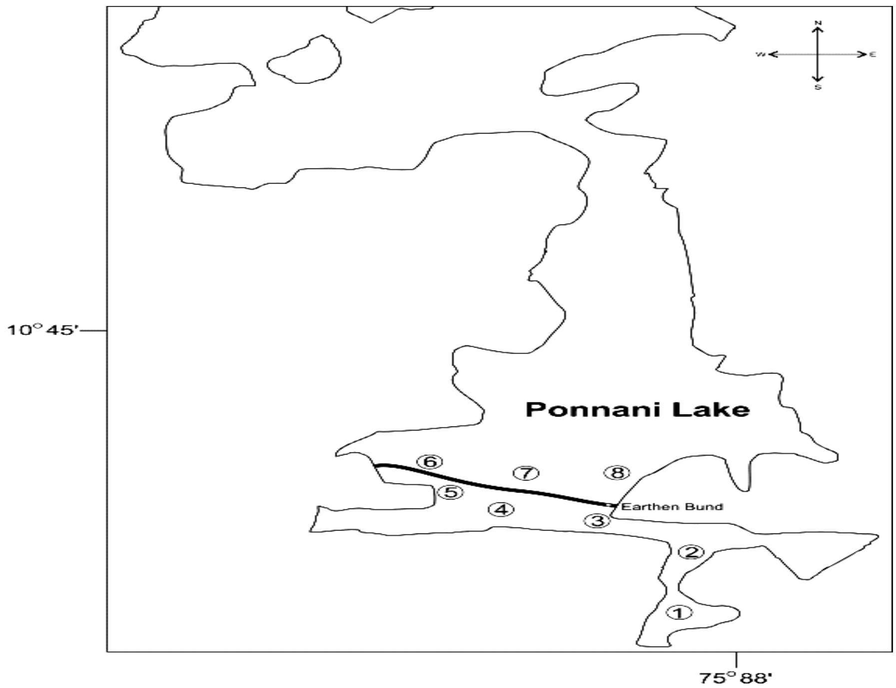


Fig. 3.1. Map showing Stations 1 to 8 in Maranchery Kole wetland.

Station 1- Under full inundation for the period
July- December 2009, February 2010, June-October 2011 (wet phase).

Station 1 - During dry period resembling grassland for the period
January, March-June 2010 (dry phase).

Station 1 - With luxuriant paddy cultivation for the period
January-May 2011 (paddy phase).

Fig. 3.2. Field photographs of Station 1 (10°726´N 75°988´E)

Station 2 - Under full inundation for the period
July -December 2009, February 2010, June-October 2011 (wet phase).

Station 2 - During dry period resembling grassland for the period
January, March-June 2010 (dry phase).

Station 2 - With luxuriant paddy cultivation for the period
January-May 2011 (paddy phase).

Fig. 3.3. Field photographs of Station 2 (10°725´N 75°986´E)

Station 3 - Under full inundation for the period
July -December 2009, February 2010, June-October 2011 (wet phase).

Station 3 - At the beginning of dry period for the period
January, March-June 2010 (dry phase).

Station 3 - At the beginning of stages of paddy cultivation for the period
January-May 2011 (paddy phase).

Fig.3. 4. Field photographs of Station 3 (10°723´N 75° 986´E)

Station 4 - under inundation with aquatic macrophytes for the period
July -December 2009, February 2010, June-October 2011(wet phase).

Station 4 - During dry period resembling grassland where cattle pastured,
for the period January, March-June 2010 (dry phase).

Station 4 - Serving as a channel connecting paddy fields for the period
January-May 2011 (channel phase).

Fig.3. 5. Field photographs of Station 4 (10° 723´N 75° 983´E)

Station 5 - Under inundation, covered with aquatic macrophytes for the period July -December 2009, February 2010, June-October 2011(wet phase).

Station 5 - During dry period resembling grassland (isolated water patches visible) for the period January, March-June 2010 (dry phase).

Station 5 serving as a channel connecting paddy fields for the period January-May 2011 (channel phase).

Fig. 3.6. Field photographs of Station 5 (10° 722´N 75° 982´E)

Fig. 3.7. Field photograph of Station 6 (10°727´N 75°985´E)
under inundation throughout the period Nov 2009 – Oct 2011 (stable phase).

Fig. 3.8. Field photograph of Station 7 (10^{0}727'N 75^{0}986'E)
under inundation throughout the period Nov 2009 – Oct 2011 (stable phase).

Fig.3.9. Field photograph of Station 8 (10°728´N 75°989´E)
under inundation throughout the period Nov 2009 – Oct 2011 (stable phase).

Wet Phase

Dry Phase

Paddy Phase

Channel Phase

Stable phase

Fig. 3.10. Different phases in Maranchery Kole wetland during the study period.

Chapter - 4

ENVIRONMENTAL PARAMETERS

4.1. Introduction

Wetlands are complex ecosystems, their ecosystem functions are driven by physical, chemical and biological processes. Due to the role played by wetlands as sinks, sources, and transformers of nutrients and other chemicals, they have a significant impact on water and sediment quality and ecosystem productivity. Sediments also forms an integral part of an aquatic ecosystem, equally important for determining the physico- chemical nature of water bodies and play a significant role in the functioning of ecosystem. Sediments are dynamic due to the various biogeochemical reactions occurring inside the water body, and they play a crucial role in limnological studies of the overlying waters (Stronkhorst et al. 2001). They act as the natural buffer, source and sink of the nutrients to the overlying waters (Stronkhorst et al. 2001, Mucha et al. 2003). They form the habitat for benthic macroinvertebrates whose metabolic activities contribute to the aquatic productivity (Ezekiel et al. 2011).

In contrast to upland systems, the type of biogeochemical transformation occurring in wetlands is strongly governed by hydrology. As wetlands experience wide hydrological variations from drying to flooding, severe changes in its physico chemical character is also expected. Prolonged dry conditions alter soil character in wetlands by promoting oxidation, shrinkage and compaction of the usually well-developed organic layer (Parker 1960, Reddy and Patrick 1998). Díaz-Espejo et al. (1999) and Tran et al. (2003) showed that nutrient concentration in water and sediment may be related to flooding or confinement situations. Souchu et al. (1997), Quintana et al. (1998) and Trobajo et al. (2002) observed that water nutrient concentration may increase during flooding by external supplies, also decrease in nutrient concentration with low water levels. The differences in sediment nutrient concentration have been related to physical properties of the sediment (Poach and Faulkner 1998, Slomp et al. 1998).

The physiographical studies revealed that the regression and transgression of the coastal waters followed by an upheaval of the shoreline resulted in the formation of Kole lands along with the Vembanad estuarine areas (Anon. 1997). The alluvium deposits brought down by Karuvannur and Keechery rivers from the surrounding hills silted up the submerged plain Kole lands. The presence of deep sand layers in many areas indicates that the area would have been under the sea in the recent geological past (Kurup and Varadachar 1975). Moderate climatic conditions are experienced in the Kole land area. Similar to the other areas of Kerala, Kole lands also receive two well-defined rainy seasons, the South West and North West monsoons, the phenomenon of depression rains from October to November is also another source of water for the Kole lands (Johnkutty and Venugopal 1993).

The abiotic environment plays a crucial role in shaping the distribution and community patterns of benthic organisms (Weatherhead and James 2001). Moreover, environmental factors (physical or/and chemical) can have direct and indirect effects on the macroinvertebrate community (Varga 2003). The distribution and density of benthic community depends upon, dissolved oxygen concentration, the nature of sediment such as organic matter contents and the textural property of sediments. (Boulton and Lake 1992, West et al. 1993). The variation of inundation should profoundly affect the physico chemical processes in these systems. This study also explores the effect of various hydrologic regimes on some of the physico chemical characters in Maranchery kole wetland.

The environmental characteristics of different kinds of wetlands were studied across the world. The environmental parameters of Parana river in Argentina (Marchese 1987) and lake Takkobu in the Kushiro wetland, Japan (Stora et al. 1995) was studied. Poach and Faulkner (1998) and Slomp et al. (1998) recorded the sediment nutrients in relation to the physical properties of the sediment. Verdonschot (1999) documented the particle size, mineral and organic component of a low land stream of Elsbeek, the Netherlands. A detailed account of the influence of organic carbon on nitrogen transformation in wetland soils in southern Sweden was given by Davidsson and Stahl (2000). The soil characteristics in a constructed salt marsh along the North Carolina (Craft 2003) and the nutrient dynamics especially of sulphur and carbon in a hypersaline lagoon was studied (Cotner 2003). The sediment and water quality from Lakes Pamvotis Greece was recorded by Kagalou et al. (2006). A difference in environmental quality is expected in different kinds of wetlands. Takamura et al. (2008) studied some of the environmental factors influencing benthic organisms in lake Takkobu, Kushiro wetland, Japan. The physico chemical variables of Lake Gala in Turkey was recorded by Camur-Elipek (2010), in constructed wetlands on Maryland, United States by Culler et al. (2013) and in Anzali international wetland, north-western Iran by Nazarhaghighia et al. (2014).

As wetlands are subjected to hydrological changes and subsequent droughts more often, many studies were conducted to understand its influence on the environmental parameters. Gascon et al. (2007) analyzed the carbon and nitrogen content in different types of Mediterranean coastal wetlands during two hydroperiods. Díaz-Espejo et al. (1999) studied the changes in phosphate composition in sediments of seasonal ponds during the time of water filling. The changes in the water quality due to hydrological fluctuation was studied in South Florida cypress system (Hayworth 2000). Hamilton et al. (2013) studied the physicochemical characteristics of temporary aquatic habitats including vernal pools, emergent wetlands and intermittent streams in north eastern Ohio. The environmental variables driving the biotic communities in isolated and ephemeral wetlands of Southern Appalachia in the south eastern United States was documented by Howard (2014).

The impact of dry conditions in soil character in wetlands was documented (Parker 1960, Reddy and Patrick 1998). A dramatic change in the sediment composition of Sacramento river was recorded during a dry year (Siegfried 1980). The variation in surface water quality due to droughts and floods were studied in the Gulf plain stream in Georgia (Golladay and Battle 2002). The water chemistry and sediment quality of Port Curtis estuary, Australia during dry season was documented (Currie and Small 2006). A detailed description of the impacts of drying and rewetting of sediment was given by Sommer and Horwitz (2009). Beumer et al. (2007) extensively studied the water and sediment chemistry after winter flooding in Brooks valley. The acidification resulted from drought in Swan coastal plain, Australia was studied by Sommer and Horwitz (2009). Mackay et al. (2010) discussed the environmental impacts associated with a drought in St Lucia estuary, Africa. The changes in nutrient concentration in two Mediterranean lakes due to a drought was compared (Ozen et al. 2010). Temporary aquatic habitats including vernal pools, other emergent wetlands and intermittent streams in northeastern Ohio was studied, the study revealed that dissolved oxygen, oxidation reduction potential and conductivity differed among habitat types (Hamilton et al. 2012). Recently the effects of wet-dry cycles on nutrient release from constructed wetlands in the United States Midwest were studied (Smith and Jacinthe 2014).

Paddy fields are referred to as managed wetlands, some of the researchers have tried to analyse the environmental quality of paddy fields. Watanabe and Inubushi (1986) documented the dynamics of available nitrogen in the paddy soils of Philippines. Extensive study on the biogeochemistry of paddy soils was reported (Kogel-Knabner et al. 2010). The water and sediment analysis in rice fields with different management practice in Italy showed a significant difference in the water and sediment quality among the rice fields (Lupi et al. 2013). The physico-chemical parameters in the water and soil in the paddy cum tilapia integrated culture fields in Bako, Ethiopia was reported by Desta et al. (2014).

The physico chemical characteristics of wetlands in India was documented by many researchers. Shanti et al. (2003) recorded the physico chemical character in the sediments of Singallur lake. The sediment characteristics in Madhurantakam Lake, Tamilnadu was reported by Moorthy et al. (2005). A description of environmental parameters of Ninglad stream, Uttarakhand (Rawat and Sharma 1997), Ken river, Central India (Nautiyala and Mishra 2013), Yamuna river (Ishaq and Khan 2014) was reported. Sarkar et al. (2011) studied the water and sediment quality in Sundarban biosphere reserve. The physico chemical parameters of

Shallabagh wetland of Kashmir was documented (Siraj et al. 2010). Anitha and Kumar (2013) reported the physicochemical characteristics of water and sediment in Thengapattanam estuary, Tamilnadu. The sediment chemistry of river Yamuna with special reference to industrial effluents in Yamunanagar was studied by Malhotra et al. (2014). Bijoy Nandan and Abdul Azis (1996) studied the organic matter of retting and non retting areas in Kerala. The studies on physico chemical parameters of Ashtamudi and Vembanadu lake showed that Vembanad lake was more deteriorated compared to Ashtamudi lake (Sujatha et al. 2009). Raju et al. (2013) documented the water and sediment quality of Ashtamudi estuary, Kerala. Though wetlands were the area of interest to the researchers, the information from Kole wetlands were limited. The distribution and availability of phosphorus in the Kole soils of Kerala was studied by Sheela (1988). Hameed (1975) and Thomas (2003) studied the soil texture in different parts of Kole wetlands. Preliminary information on water quality of Maranchery Kole wetlands was documented by Vineetha et al. (2010) and Rakhi et al. (2014).

4.2 Results

4.2.1 Rainfall

The main source of water in the wetland was rainfall. The maximum rainfall of 925.3 mm during the study period was observed in June 2011 and the minimum was 0.5 mm in March 2010. The average rainfall for the study period was 237 mm (±246.56) (Table 4.1). Year wise variation in rainfall showed an average rainfall of 173.2 mm (±135) in 2009, 220.5 mm (± 217.5) in 2010 and 296.1 mm (±280) in 2011.The South West monsoon contributed to the major share of rainfall (70 %).

4.2.2 Depth

Depth was the most variable parameter during this study. As the water body was very shallow, a drop in few centimetres of depth implies the absence of water in the area. The stations 1 to 5 were the stations showing wide fluctuations, from 0.2 to 3 m. The monthly variation of depth in the eight stations during the study period is given in Table 4.2. Depth at station 1 ranged from 0.02 m in April and

May 2011 to 3 m in July 2011, the mean depth being 1.43 m (±1). In station 2, the minimum depth was 0.2 m in April 2011 and maximum was 2.9 m in July 2011 with a mean depth of 1.44 m (±0.98). Mean depth in station 3 was 1.48 m (±1.02) showing the minimum depth of 0.2 m in April 2011 and maximum of 3 m in July 2011. In station 4 the depth ranged from 0.03 m in April and May 2011 to 2.7 m in July 2011 with a mean value of 1.53 (±0.84). Station 5 was shallowest throughout the study period with a mean depth of 0.73 m (±0.33) and it varied from 0.3 m in March, April, May 2010 to 0.85 m in February 2010. In station 6, the minimum depth was 1.2 m in May 2011 and maximum of 3 m in January 2010, the mean depth being 2.24 m (±0.54). The depth in station 7 ranged from 1.3 m in April and May 2011 to 3.2 m in August 2010 showing a mean depth of 2.31 m (±0.56). In station 8 also the minimum depth was 1.3 m in May 2011 and maximum was 3.1 m in August 2011 with a mean depth of 2.26 m (±0.57) (Figs. 4.1 to 4.2). Due to the varied and peculiar nature of the study area, the depth between the five phases namely wet, dry, paddy, channel and stable phases were compared, the depths during various phases differed widely from stations 1 to 5 throughout the study period. Depth ranged from 0.36 m (±0.14) in the dry phase to 2.27 m (±0.58) in the stable phase (Fig. 4.3). The results of ANOVA showed that there existed a significant variation in depth at 1% level between phases (F=110.64), stations (F=2.82) and stations within phases (F=4.87) (Table 4.3).

4.2.3 Water temperature

The monthly variation of water temperature in the eight stations during the study period is given in Table 4.4. In station 1, the maximum temperature of 33ºC was recorded during July 2011 and minimum of 24.3ºC in January 2011 with a mean value of 28.51ºC (± 1.82). The maximum temperature recorded in station 2 was 31.5ºC during June 2011 and minimum 23.1ºC in January 2011, the mean value being 28.33ºC (±1.97). While in station 3 the maximum temperature recorded was 31ºC during June 2011 and minimum was 23.5ºC in January 2011. The mean temperature in station 3 was 28.29ºC (±1.89). The highest temperature recorded from station 4 was 33ºC during April and May 2011 and lowest was 26ºC in October 2011 with a mean of 28.77ºC (±2.20). In station 5, the highest temperature observed was 33ºC during May 2011 and lowest was 26ºC in October 2011, showing a mean value of 28.73ºC (±2.11). In station 6, the temperature ranged from 26.3ºC in February and December 2010 to 31.3ºC in May 2010. The mean temperature was 29.06ºC (±1.38). The maximum temperature in station 7 was 32.1 ºC during May 2011 and minimum was 26.2ºC in February 2010, 29.29ºC (±1.61) being the mean temperature. Similarly in station 8 also the maximum temperature was 32.5ºC during June 2011 and minimum was 26.1^{o}C in February 2010 showing a mean temperature of 29.29ºC (±1.61) (Figs.4.4 to 4.5). The monthly average values of temperature were analyzed. The maximum mean temperature of 31.8ºC was observed during the month of May 2010 and minimum of 25.9ºC in January 2011. The comparison between phases showed that temperature was maximum in the channel phase showing a mean value of 30.37 ºC (±2.53) and minimum in the stable phase 27.30 ºC (±2.17) (Fig. 4.6). ANOVA of temperature of water showed a variation significant at 1% level between phases (F=6.17) (Table 4.5).

4.2.4 Water pH

The monthly variation in pH of water in all the stations during the study period is given in Table 4.6. The average pH remained neutral in most of the months (mean 6.34±0.59) except for few instances where a slightly acidic pH was noted. In station 1, pH ranged from 3.3 in May 2011 to 7.04 in October 2010 with an average pH of 6.11±0.94, whereas in station 2 the range was between 5.14 in May 2011 to 6.96 in October 2010 and 6.42±0.47 being the mean pH. The pH of water showed the lowest value in August 2011 (5.85) and highest in February 2011 (7.04) with an average pH of 6.45±0.36 in station 3. The mean pH in station 4 was 6.2±1.07 with the minimum and maximum being 4.23 in February 2011 and 8.95 in January 2011 respectively. In station 5 the range of pH was 4.39 in February 2011 in 6.85 in November 2011 with an average pH of 6.17±1.07. The average pH of water in station 6 was 6.22±0.92 ranging from 3.15 in May 2011 to 6.87 in December 2010. In station 7, pH ranged from 3.7 in May 2011 to 7.8 in May 2010 with an average value of 6.35±0.82, whereas in station 8 the range was between 3.96 in May 2011 to 7.2 in April 2010 and 6.40±0.40 being the mean pH (Figs. 4.7 to 4.8). The comparison in water pH between the five phases showed similar value for the wet (6.66) and stable phases (6.57). Paddy (5.97) and channel (5.84) phases were characterized by a slightly lower pH. Wet phase and channel phase showed the maximum and minimum water pH respectively (Fig. 4.9). ANOVA of pH of water showed a significant variation at 1% level between stations within phases (F=4.14) (Table 4.7).

4.2.5 Dissolved oxygen

The monthly variation in dissolved oxygen showed that, the maximum value of 7.93 mg/L was observed in February 2011 and the minimum value of 3.47 mg/L in April 2010 (Table 4.8). The range of dissolved oxygen was from 3.2 mg/L in April 2011 to 8.8 mg/L in February 2011 in station 1, the mean dissolved oxygen being 6.7 mg/L (±1.5). In station 2, the mean dissolved oxygen was 6.7 mg/L (±1.35) with the minimum dissolved oxygen observed in August 2010 (4.8 mg/L) and maximum in August 2011 (9.6 mg/L). Station 3 showed the lowest value of 4.0 mg/L in August 2011 and highest value of 8mg/L in January, February and July 2011 showing a mean of 6.2 mg/L (±1.25). The range of dissolved oxygen varied between 2.4 mg/L in August 2011 to 8 mg/L in September, October, November 2010 and January 2011 in station 4 having mean dissolved oxygen of 5.79 mg/L (±1.7). In station 5 it ranged from 2.4 mg/L in October 2011 to 8.0 mg/L in August, September, and November 2010. The mean dissolved oxygen was 5.66 mg/L (±0.5). In station 6, a mean dissolved oxygen of 5.99 mg/L (±1.7) was recorded with the lowest value in August and June 2010 (3.4 mg/L) and highest in February 2011 (10.0 mg/L). Station 7 showed the minimum value of 4.1 mg/L in June 2010 and the maximum value of 10.2 mg/L in February 2011 with a mean of 6.44 mg/L (±1.93). It ranged from 3.4 mg/L in April 2010 to 9.6 mg/L in April in station 8 showing a mean of 6.55 mg/L (±1.75) (Figs. 4.10 to 4.11). The comparison between the 5 phases showed marginal variation in dissolved oxygen levels with highest value of 6.6 mg/L (±1.3) in wet phase and minimum of 5.16 mg/L (±1.3) in the paddy phase (Fig. 4.12). The results of ANOVA showed that there existed no significant variation in dissolved oxygen among the stations and phases (Table 4.9).

4.2.6 Sediment temperature

Monthly variations in the temperature of the sediment at eight stations are given in Table 4.10. In station 1, the maximum temperature of 31.2ºC was recorded during July 2011 and minimum was 23ºC in January 2011 with a mean temperature of 27.57ºC (± 1.19). The maximum temperature recorded in station 2 was 31ºC during July 2011 and minimum 24.1ºC in January 2011, the mean value being 27.6ºC (±1.2). While in station 3 the maximum temperature recorded was 30.1ºC during May and August 2011 and minimum was 24.1ºC in January 2011. The mean temperature in station 3 was 27.5ºC (±1.33). The highest temperature recorded from station 4 was 31.1ºC during March 2011 and lowest was 24.2ºC in January 2011 with a mean of 27.65ºC (±1.33). Similarly in station 5 also the highest temperature observed was 31.1ºC during March 2011 and lowest of 25.1ºC in January 2011 showing a mean value of 27.69ºC (±1.43). In station 6, the temperature ranged from 25.3 ºC in December 2010 to 31ºC in June 2011. The mean temperature was 27.79ºC (±1.17). The maximum temperature in station 7 was 31.1ºC during July and August 2011 and minimum of 25.3ºC in December 2010, 27.75ºC (±1.32) being the mean temperature. Similarly in station 8 also the maximum temperature was 31.1ºC during July and August 2011 and minimum was 25.3^{o}C in December 2010 showing a mean temperature of 27.72ºC (±1.3) (Fig. 4.13 to 4.14). The monthly average values of temperature were analyzed. The maximum mean temperature of 30.61ºC was observed during the month of July 2011 and minimum of 25.2ºC in December 2010. There was slight variation in temperature between wet, dry, paddy and channel phases. Temperature was maximum in the channel phase showing a mean value of 27.75ºC (±2.08) and minimum in the stable phase 26.88ºC (±1) (Fig. 4.15). ANOVA of temperature in the sediment showed there was no significant difference between stations and phases (Table 4.11).

4.2.7 Sediment pH

Sediment pH showed no much variation during the study period (Table 4.12). The lowest pH recorded in Station 1 was 4.7 in March 2011 and highest was 6.98 in April 2010 and July 2011 having a mean value of 6.39 (±0.53). In station 2, pH ranged from 5.87 in December 2009 to 7.12 in Mach 2011 showing a mean pH of 6.4 (±0.45). In station 3, the mean pH was 6.5 (±0.45) with a minimum pH of 5.06 in December 2009 and maximum pH of 7.37 in November 2010 while in station 4, the minimum pH recorded was 5.32 in October 2011 and the maximum of 7.37 in October 2010. The mean pH was 6.6 (±0.41). In station 5 pH ranged from 5.87 in December 2009 to 7.16 in November 2010, 6.45 (±0.43) being the mean value. Station 6 showed a mean pH of 6.51 (±0.32). The lowest pH recorded was 5.94 in May 2011 and highest was 7.16 in Mach 2011. In station 7 pH ranged from 5.83 in October 2011 to 7.17 in March 2011 having a mean pH of 6.4 (±0.3) while in station 8, the mean pH was 6.69 (±0.49) with a minimum pH of 5.99 in February 2011 and the maximum of 8.01 in April 2010 and July 2011(Fig. 4.16 and 4.17). When sediment pH was analyzed, no much variation was seen between wet, dry, paddy and channel phases. Paddy phase showed the lowest pH of 6.35 (±0.58) and the highest pH was observed in the wet phase 6.73 (±0.33) (Fig. 4.18). ANOVA result of sediment pH showed there was no significant difference between stations and phases (Table 4.13).

4.2.8 Sediment Eh

The Eh values showed a highly reducing trend in all stations throughout the study period (Table 4.14). In station 1 the oxidation reduction potential ranged from -298 mV in December 2009 and August 2011 to -103 mV in March 2011. The mean Eh was -234 mV (±4.48). In station 2, the range of Eh was -298 mV in October 2010 to -107 mV in November 2009 with a mean of -229 mV (±4.44). The range of Eh in station 3 was -298 mV in July 2010 to -185 mV in June 2011, the mean value being -235 mV (±2.9). The mean Eh in station 4 was -243 mV (±3.8) showing a minimum Eh of -298 mV in September 2011 to -132 mV in May 2010. In station 5, the Eh ranged from -324 mV in August 2011 to -143 mV in June 2011, the mean Eh being -238 mV (±4.13). The lowest Eh recorded in station 6 was -298 mV in September 2011 to -188 mV in August 2011 with the mean of -234 mV (±2.86). The mean Eh in station 7 was -232 mV (±2.86), the range varied from -286 mV in March 2011 to -187 mV in September 2011. In station 8, the range of Eh was from -298 mV in September 2010 to -177 mV in February with a mean Eh of -235 mV (±3.4) (Figs. 4.19 to 4.20). The Eh of the wet, dry, paddy and channel phases were compared. The wet phase showed the minimum value of -256 mV (±3.1) and paddy phase showed the maximum value of -225 mV (±4.6) (Fig. 4.21). ANOVA of sediment Eh showed a significant variation at 5% between phases (F=1.94) (Table 4.15).

4.2.9 Moisture content

The monthly mean variation in moisture content showed the maximum value of 45% in July 2010 and minimum of 20.6% in March 2011, the average being 34.8% (Table 4.16). Station 8 showed the highest moisture content (37.6%) and station 4 the lowest value (32.8%) when the mean moisture content of all the stations was compared. The lowest moisture content recorded in station 1 was 11.3% in October 2011 and highest was 48.5% in July 2010 with a mean value of 34.88 % (±11.28). In station 2 the moisture content ranged from 11.7% in October 2011 to 43.2% in October 2010, the mean value was 34.52% (±07.45). The lowest moisture content recorded in station 3 was 23.3% in March 2011 and highest was 42.9% in August 2011 showing a mean value of 35.30% (±7.72). In station 4, the minimum moisture content observed was 16.2% in April 2011 and the maximum was 56.2% in August 2010 with a mean value of 32.80% (±11.27). The moisture content ranged from 16.8% in January 2011 to 49.9% in June 2010 in station 5 showing a mean value of 34.83% (±9.01). While in station 6, the range was between 2.26% in January 2011 to 49.5% in June 2011, the mean value was 33.15% (±7.13). In station 7, the minimum moisture content observed was 16.8% in May 2011 and the maximum was 47.2% in September 2011 with a mean value of 36.57% (±8.14). The lowest moisture content recorded in station 8 was 19.4% in June 2011 and highest was 45.3% in November 2009 showing a mean value of 37.60% (±12.71). (Figs. 4.22 to 4.23). The comparison among the phases showed that the channel phase showed the lowest moisture content 20.66% (±2.71) and highest in the wet phase 37.59% (±6.09) (Fig. 4.24). The results of ANOVA showed that there existed a significant variation in moisture content at 1% level between stations (F=4.67) and stations within phases (F=2.64) (Table 4.17).

4.2.10 Organic matter

Organic matter showed a cosiderable variation throughout the study period. When the monthly mean organic matter values were compared July 2010 showed the minimum value of 3.91% and maximum value of 9.09% in April 2011(Table 4.18). In station 1, February 2010 showed the lowest organic matter value of 3.36% whereas the highest value of 12.24% was in December 2011 showing a mean of 6.47% (±1.94). The minimum organic matter was recorded in May 2011 (1.67%) and maximum in March 2010 (14.65%) from station 2 having a mean organic matter of 6.60% (±2.54). In station 3, the mean organic matter recorded was 6.20% (±1.99) and it ranged from 1.84% in June 2010 to 9.41% in February 2011 whereas in station 4, the range was 2.41% in February 2011 to 15.6% in April 2010 showing a mean of 6.96% (±3.02). The mean organic matter observed in station 5 was 5.88% (±2.64) with the minimum organic matter in May 2011 (1.95%) and maximum in February 2011 (11%). In station 6, May 2010 showed the lowest organic matter value of 2.28% where as the highest value was in June 2011 (12.38%) having a mean organic matter of 6.71% (±2.85). The minimum organic matter was recorded in August 2010 (4.41%) and maximum in December 2010 (13.38%) from station 7 showing a mean value of 7.24% (±1.65). The mean organic matter in station 8 was 7.57% (±2.70), the organic matter ranging from 4.41% in August 2010 to 13.52% in February 2010 (Figs. 4.25 to 4.26). The difference in organic matter in the wet, dry, paddy, channel and stable phase was studied. The paddy phase showed the maximum value of 6.79 % (±1.33) and the channel phase showed the minimum value of 5.57 % (±1.17) (Fig. 4.27). ANOVA of organic matter showed that there existed a significant variation at 1% level between stations within phases (F=2.64) (Table 4.19).

4.2.11 Available phosphorus

Available phosphorus showed considerable variation during the study period. When the monthly variation of available phosphorus during the study period was considered, the maximum value of 2.28 ppm was observed in July 2010 and the minimum of 0.283 ppm in February 2011 (Table 4.20). In station 1, the mean available phosphorus was 0.97 ppm (±0.83) that ranged from 0.031 ppm in

November 2010 to 0.834 ppm in September 2011. Station 2 showed the lowest value of 0.147 ppm in November 2010 and highest value of 2.947 ppm in August 2011 with a mean of 0.84 ppm (±0.59). In station 3, May 2011 showed the lowest available phosphorus value of 0.1 ppm where as the highest value was in August 2011 (2.947 ppm) showing a mean of 0.83 ppm (±0.62). The mean available phosphorus was 0.74 ppm (±0.61) in station 4, the range varied from 0.12 ppm in May 2010 to 2.729 ppm in July 2010. It ranged from 0.169 ppm in March 2011 to 2.684 ppm in July 2010 in station 5 having a mean of 1.09 ppm (±0.87). In station 6, November 2010 showed the lowest available phosphorus value of 0.01 ppm where as the highest value was in July 2010 (2.81 ppm) with a mean value of 0.98 ppm (±0.71). In station 7, the minimum value was recorded in February 2010 (0.15 ppm) and maximum in June 2010 (2.96 ppm) the mean value being 0.98 ppm (±0.81). In station 8 the range of available phosphorus varied between 0.206 ppm in October 2010 to 3.546 ppm in September 2011 showing a mean of 1.07 ppm (±0.94) (Figs. 4.28 to 4.29). The variation in available phosphorus in the wet, dry, paddy, channel and stable phase was studied. The stable phase showed the maximum value of 1.49 ppm (±0.86), dry phase also showed a similar value of 1.07 ppm (±0.76), and the paddy and channel phase showed the minimum value of 0.33 ppm (±0.11) (Fig. 4.30). The results of ANOVA showed that there existed a significant variation in available phosphorus at 1% level between phases (F=7.87) (Table 4.21).

4.2.12 Available nitrogen

The monthly variation in available nitrogen during the study period is given in (Table 4.22). Station 1 showed minimum available nitrogen level of 0.0112% in November 2010 and maximum of 0.033% in August 2011 with a mean value of 0.017% (±0.005). In station 2, it ranged from 0.002% in January 2010 to 0.0324% in September 2011 showing a mean value of 0.02% (±0.004). The mean available nitrogen was 0.018% (±0.006), and ranged from 0.0112% in November 2010 to 0.033% in August 2011 in station 3. In station 4, May 2011 showed the lowest available nitrogen value of 0.0086% whereas the highest value of 0.0436% was observed in August 2011 the mean being 0.021% (±0.005). The minimum available nitrogen was recorded in May 2011 (0.0015%) and maximum in September 2011 (0.0436%) from station 5 having a mean value of 0.021% (±0.005). In station 6, the mean available nitrogen was 0.018% (±0.014) varying from 0.0056% in January 2010 to 0.035% in August 2011. The available nitrogen ranged from 0.0015% in November 2010 to 0.375% in August 2011 in station 7 with a mean of 0.016% (±0.01). In station 8, the mean available nitrogen observed was 0.021% (±0.005) with a minimum value in May 2010 (0.0012%) and maximum in August 2011 (0.375%) (Figs. 4.31 to 4.32). The comparison between the wet, dry, paddy, channel and the stable phase showed that the lowest available nitrogen was in the channel phase showing 0.016% (±0.005) and highest in the dry phase 0.021% (±0.006) (Fig. 4.33). The results of ANOVA showed that there existed a significant variation in available nitrogen at 5% level between stations (F=2.26) (Table 4.23).

4.2.13 Sediment texture

The sediment of the Maranchery Kole wetland was composed of clayey silt, sandy silt, clayey sand, sandy, silty clay and silty sandy fractions during the study period. In station 1, generally the sediment was silty sand in nature. The clay, silt and sand percentage ranged from 7.74 (February and March 2010) to 34.58 (December 2010), 3.95 (January and February 2011) to 56.65 (July 2011) and 13.4 (September and October 2010) to 88.3 (February and March 2010) respectively. The mean values of clay, silt and sand was 23.72 (±7.6), 42.22 (±1.53), 34.05 (±2.1) respectively. The nature of substratum in station 2 was clayey silt. The clay percentage varied from 28.02 in October 2011 to 31.49 in May 2011 whereas that of silt varied from 43.04 in January 2010 to 56.65 in June 2011 and sand from 13.4 in May 2010 to 29.59 in January 2010. The mean clay, silt and sand percentages were 25.5 (±3.04), 52.21 (±4.06), 22.27 (±4.5) respectively. Sandy silt was the general nature of the sediment in station 3 having mean values of clay, silt and sand as 28.03 (±6), 44.09 (±8.95), 27.86 (±1) respectively and their percentage ranged from 21.23 (December and October 2011) to 40.45 (July 2010), 22.11 (January 2011) to 61.6 (May 2010) and 9.2 (May 2010) to 53.72 (January 2011) respectively. In station 4, generally the sediment was clayey silt in nature. The composition of the substratum varied from 22.13 (November 2010) to 34.06

(February 2010), 42.27 (July 2011) to 59.72 (May 2010) and 10.07 (February 2010) to 33.48 (July 2010) for clay, silt and sand respectively with the mean values of 25.25 (±2.8), 51.76 (±4.83), 22.94 (±6) for each. Similarly in station 5 also, the nature of the substratum was clayey silt in nature with mean values of 27 (±3.6), 51.65 (±4.26), 21.3 (±6.98) for clay, silt and sand showing their variation between 20.89 (February 2010) and 33.17 (July 2010), 43.04 (December 2009) and 57.73 (August 2010), 9.8 (August 2010) to 32.1 (February 2010) respectively. Clayey silt was the general nature of the sediment in station 6 also. The clay percentage varied from 20.95 in February 2010 to 37.25 in March 2011 while that of silt was from 42.16 in July 2011 to 59.83 in May 2010 and sand from 14.36 in September 2010 to 33.57 in July 2011. The mean values recorded were 26.54 (±4.17), 50.69 (±5.1), 22.72 (±5.3). Station 7 also was of clayey silt in nature, the composition of clay, silt and sand ranging from 13.27 (February 2010) to 43.43 (June 2010), 35.98 (June 2010) to 55.1 (February and August 2011) and 17.8 (February and August 2011) to 69.89 (February 2010) respectively with mean values as 26.24 (±5.1), 47.2 (±8.1), 26.54 (±1.03). In station 8 also, generally the sediment was clayey silt in nature having the mean values of clay, silt and sand was 24.82 (±3.1), 44.34 (±1.34), 30.82 (±1.42) respectively, the composition of the substratum varied from 18.05 (April 2011) to 30.4 (January 2010), 13.11 (May 2010, January and February 2011) to 59.93 (April 2010) and 11.13 April 2010) to 61 (May 2010, January and February 2011) for clay, silt and sand respectively (Fig. 4.34). The substratum characteristics of the wet, dry, paddy, channel and stable phase showed that the wet, channel and stable phases were sandy silt in nature while the dry and paddy phases were clayey silt in character (Fig. 4.35). ANOVA of clay showed a significant variation at 1% level between stations (F=2.63) (Table 4.24), silt showed a significant variation at 1% level between stations (F=6.44) and stations within phases (F=1.79) (Table 4.25) and sand also showed a significant variation at 1% level between stations (F=6.01) and stations within phases (F=1.75) (Table 4.26).

The correlation between various environmental parameters were analyzed which showed a significant correlation among many of the parameters analyzed (Table 4.27).

4.2.1 Principal Component Analysis (PCA)

Principal component analysis showed a total of 4 canonical axes, 3 of which explained 96.5% of the total variance between the phases (Table 4.28, Fig. 4.36). Water pH, sediment temperature, sediment pH and moisture content contributed significantly to the PC1, which accounted for 46.2% of the variance in the data (eigen value 6.47). PC2, which explained 31.8% of the total variance (eigen value 4.45), consisted primarily of silt, Eh, depth, organic matter content. Dissolved oxygen and clay content were the significant contributors of PC3. In this analysis, Principal axes 1 and 2 were found to be important as they explained 78% of the variance. The deepest phases (wet and stable phases) characterised by lowest sediment temperature, highest moisture content and highest phosphorus content were ordinated on the top left. Phase with medium depth, highest temperature and highest silt content (channel phase) was ordinated towards the top right of the PCA plot. The shallow phases (dry and paddy phases) with the highest organic matter were ordinated on the bottom right.

4.3 Discussion

Water levels in wetlands are rarely stable. There are many studies from various parts of the world about the wet and dry cycles in wetlands. When the water body is shallow, small changes in depth can have severe consequences including habitat loss and habitat fragmentation. Van der Valk (2005) had done long term studies of water level fluctuations in Prairie wetlands. Similar studies in Cottonwood lake area in North Dakota documented wet and dry cycles during which water fluctuated from no standing water during drought years to overflowing basins during wet years. (Eisenlohr et al. 1972, Winter and Rosenberg 1998, Winter 2003). Experimental studies of water level fluctuation confirmed that water depth is the major factor controlling emergent plant species during the wet and dry phases. In India Gopal (1994) found that the low water levels in winter caused stress for littoral organisms. Sharma and Rawat (2009) also recorded similar findings in Asan wetland.

The variation in depth in Maranchery kole wetlands was prominent between the various phases due to the agricultural related activities in the area. A notable difference in depth was seen in station 4 and station 5 from the other stations which could be due to natural undulation of the area. The Maranchery kole wetland was a shallow water body compared to many other aquatic ecosystems. The maximum depth of Lake Mansar, a Ramsar site in Jammu and Kashmir was 38.25 m (Chandrakiran and Kuldeep 2013), that in Asan wetland, Jammu and Kashmir, the depth was 4.3 m (Sharma and Rawat 2009), that in Ashtamudi wetland, one of the Ramsar sites in Kerala, the maximum depth was 6.4 m and in Vembanadu lake the range of depth was 1.5-6 m (Sujatha et al. 2009). Meera and Bijoy Nandan (2007) reported the depth of Valanthakkad backwaters as 2-4 m. Depth showed a positive correlation significant at 1% level to rainfall, as Maranchery Kole wetland is an ombrotrophic (rain fed) wetland, the depth of Maranchery kole wetlands was closely in parallel to the rainfall hence the positively correlation between rainfall and depth is obvious. Gamble and Mitsch (2009) studied the depth and duration of natural and created vernal pools in Ohio and found that inundation was positively correlated to rainfall. Further depth showed a positive correlation significant at 1% level with dissolved oxygen, available phosphorus and a negative correlation with redox potential.

Temperature is a major factor limiting the distribution of animals and plants. It can influence the organism at any stage of the life cycle, reproduction or development (Krebs 1978). In Maranchery Kole wetlands, due to the closer proximity between stations, there was no much variation in temperature among stations. When the temperature between the phases was compared, marked difference was observed between them. The channel phase showed the maximum temperature, the period when channel phase existed was summer months which could be reason. Though paddy phase also belonged to the same season, the shading by the paddy plants would have prevented the temperature to elevate in the paddy phase. The increased temperature with decreased water level in this study agrees with the findings of James et al. (2008) in Kiriwhakapapa stream, New Zealand where he recorded an increased temperature with decrease in water level due to experimental flow reduction. On the contrary, his study from other areas in

New Zealand revealed that reduced water level due to flow reduction had little impact on water temperature. Water temperature in Maranchery Kole wetlands was comparable to that of the wetlands in Bengal where the average water temperature was 22.5 °C, 30.73 °C and 28.56 °C in Mirik lake, Adra reservoir and Rabindra Sarovar respectively (Roy and Nandi 2008). Further it was comparable to that of Cochin estuary and ephemeral wetlands in Trivandrum, Kerala where water temperature ranged from 26 to 33.1°C and 25 to 31°C respectively (Geetha et al. 2010, Balaraman 2008). Contrary to the normal scenario where an inverse correlation between rainfall and temperature is the rule, a positive correlation between water temperature and rainfall was observed in this study. A difference in sampling time could be the reason. In summer months, due to severe heat, sampling was done in early morning hours that resulted in low temperatures during summer months and higher temperature during monsoon periods resulting in a positive correlation between temperature and rainfall. Further a positive correlation significant at 1% with rain fall, sediment temperature, 5% with depth and available phosphorus, negative correlation significant at 1% with water pH was observed.

pH variations in water bodies are mainly due to the factors such as removal of carbon dioxide by photosynthesis through bicarbonate degradation, reduction in salinity and temperature and decomposition of organic matter (Upadhyay 1988, Rajasegar 2003). The average values of water pH in Maranchery Kole wetland showed that the water in all stations were neutral or slightly acidic also it was slightly less compares to similar studies. The studies from wetlands in Tamil Nadu revealed that the average pH of water in Ukkadam was 8.62±0.26, in Perur 7.88±0.56, in Kuruchi 7.64± 0.50 and in Chinnakkulam 7.73± 0 (Chandra et al. 2010). In Shallabugh wetland, Kashmir the range of water pH was 6.6-8.2 (Siraj et al. 2010). In Ashtamudi wetland the pH of water ranged from was 7.3-8.1 and in Vembanad lake the range was 7.2-8.5 (Sujatha et al. 2009). But the findings from Maranchery Kole wetland was in agreement to that from Thrissur Kole wetlands by Tessy and Sreekumar (2008) who observed that the water was slightly acidic or neutral. A negative correlation significant at 1% level was observed between pH of water with sediment temperature and a positive correlation significant at 1% level with depth. It showed a positive correlation significant at 5% level with organic carbon and negative correlation significant at 5% level with redox potential.

A variety of gases are found dissolved in natural waters. The dissolved oxygen level ranged from 3.4 to 10.2 mg/L in the study area. There was no wide variation observed in 8 selected sampling stations. The dissolved oxygen concentration was higher as compared to similar studies. The studies from wetlands in Tamil Nadu revealed that dissolved oxygen in Ukkadam was 5.26 ±0.94 mg/L, in Perur 5.56±0.26 mg/L, in Kuruchi 4.21±2.86 mg/L and in Chinnakkulam 5.26±1.38 mg/L (Chandra et al. 2010). In Thengapattanam estuary, the dissolved oxygen range was 4-7.6 mg/L (Anitha and Kumar 2013). A comparison with the wetlands in Kerala also showed that dissolved oxygen was higher in Maranchery Kole wetlands. In Ashtamudi wetland dissolved oxygen ranged from was 1.9-5.46 mg/L and in Vembanadu lake the range was 2.02-4.89 mg/L (Sujatha et al. 2009). Dissolved oxygen and depth gave a positive correlation significant at 1% level.

The variation in sediment temperature was closely in parallel to the water temperature which was implied by strong positive correlation between them. The phases also showed a trend similar to that of water temperature but the variation among the phases was less prominent compared to that of water temperature. The channel phase showed the maximum temperature due to its existence in summer months. Shading by the paddy plants prevented the temperature to elevate in the paddy phase. The reduced water level and the summer heat elevated the temperature in the dry phase. The average sediment temperature (28.22°C) was slightly higher to that of Mirik lake, Adra reservoir and Rabinda Sarovar, West Bengal, where the sediment temperature recorded was 23.25°C, 27.8°C and 27.9°C respectively (Roy and Nandi 2008). A positive correlation significant at 1% level was observed between water temperature and sediment temperature, rainfall and sediment temperature showed a positive correlation significant at 5% level with Eh.

The pH of sediment is influenced by several factors such as ionic composition of interstitial water, biochemical reactions, nutrients etc. In Maranchery Kole wetlands the sediment pH remained neutral apart from a very few instances, where the pH levels changed from neutral to acidic. This result agrees with the findings of Reddy and Delaune (2008) who summarized the pH range of freshwater sediments from various studies as 6.0 to 7.0. The reason stated was that high organic carbon in wetlands buffers the soil to neutrality (Reddy and Delaune 2008). In Maranchery Kole wetlands also the high organic carbon could be the reason for the neutrality of sediment pH. Similar to the findings from Maranchery Kole wetlands, many of the studies reported a neutral sediment pH from various wetlands. In Thengapattanam estuary, South west coastal zone, Tamil Nadu, the sediment pH ranged from 6.9-7.78 (Anitha and Kumar 2013). The average pH in lake Mansar, Jammu and Kashmir was 7.55±0.46 (Chandrakiran and Kuldeep 2013) and in Tawi river, a Central Himalayan river in Jammu and Kashmir, the pH range was between 7.7-7.8 (Sharma et al. 2013). However previous studies from Kole wetlands revealed that the soils of Kole area in general are acidic with pH ranging from 4.9 to 6.1 due to the effect of underlying peat horizon (Thomas et al. 2003). The comparison between the wet, dry, paddy and stable phase showed that there was a slight increase in pH levels in the wet and the stable phase. The soil pH tends to increase when soils become more reduced due to water saturation because of the consumption of free protons with reduction processes (Stumm and Morgan 1981, Langmuir 1997). The slightly increased pH values in the wet and stable phase could be related to this observation. pH showed a significant positive correlation at 1% level with moisture content and 5% level with clay and a negative correlation at 5% level with sand.

Moisture content is the water held in spaces between sediment particles, it is critical to the organisms, as they require water to maintain osmotic balance and to facilitate oxygen adsorption through the integument (Gardiner et al. 1972). Moisture is a major limiting factor in distribution of organisms. Many soft-bodied organisms are sensitive to desiccation (Ganihar 1996, Karmegam and Daniel 2007). Some benthic fauna like oligochaetes make vertical movements deeper into moist substrate to escape from drought. They can also enter into inactive stages and reactivated when sufficient moisture level is achieved. Despite of the the different phases in Maranchery wetlands, the moisture content remained comparatively high in this wetlands. Moisture content in Yellow river, China varied from 16.72-

23.89% (Hui Wang et al. 2011), in lake Mansar, Jammu and Kashmir from 31.98-35.77% (Chandrakiran and Kuldeep 2013) and in river Yamuna from 45.4-48.9% (Malhotra et al. 2014). A positive correlation significant at 5% level emerged between moisture content and organic carbon. High organic matter improves water holding capacity of sediments (Reddy and Delaune 2008). Significant positive correlation between moisture content organic carbon was reported from Yellow River Delta, China (Hui Wang et al. 2011), Fougères forest -West France (Eglin et al. 2008) and lake Mansar, Jammu and Kashmir (Chandrakiran and Kuldeep 2013).

Organic matter is a key food source for benthic fauna though excess of it can have a negative effect by oxygen depletion and build up of toxic by-products (Sanders 1958, Gray1974, Gray et al. 2002). In wetland ecosystems, the primary productivity often exceeds the rate of decomposition processes, resulting in net accumulation of organic matter. The decomposition process occurs significantly at slower rates due to the predominance of anaerobic conditions (Reddy and Delaune 2008). No distinct distribution pattern was apparent in organic matter, during the present study, indicating the constant and eternal supply of detritus, irrespective of seasons and phases, which give substantial flux of organic residues to the sediments by the decomposition process. The decay of aquatic macrophytes and the influx of organic matter due to monsoon could be the reason for the high organic matter in the wet and stable phase. Whereas in the dry and paddy phase, though macrophytes and monsoon inputs were not there, the reduced water level could have concentrated the organic matter hence resulted in a higher organic matter level as observed by Lobinske et al. (1996) and Real et al. (2000). Ali et al. (2002) and Walker et al. (2003) observed that higher water levels may dilute the amount of organic matter. In trans-okpoka creek, Nigeria, Davies and Tawari (2010) observed significant variations of organic carbon with a high organic carbon content in dry season and low in wet season, the suggested reason was high temperature and dilution effect (rains and runoff) in wet season. The observed peak values of organic carbon in the monsoon months could be attributed to the influx of land run off containing terrigenous matter (Sankaranarayanan and Panampunnayil 1979). The organic content in Maranchery Kole wetlands was higher compared to that of lake Mansar, Jammu and Kashmir where organic matter was 2.49±0.55%

(Chandrakiran and Kuldeep 2013) and in Cochin estuary where organic matter ranged from 0.89 to 2.57% (Martin et al. 2011). However the results of this study showed a similar trend as observed by Hameed (1975) who reported that in Kole wetlands, the organic matter content of the soil was high ranging from 2.07-4.16% and in subsurface it varied between 1.37-9.70%, even in certain parts the subsurface accumulation of peat was observed and the organic content varied between 28.91-69.91%. In Muriyad wetland, a part of Kole wetlands, the percentage of organic carbon ranged from 0.21 to 1.11% (Thomas et al. 2003). A positive correlation significant at 5% level was observed between organic matter and moisture content. A significant positive correlation between organic matter and moisture content was reported from Yellow River Delta, China (Hui Wang et al. 2011) and Fougères forest -West France (Eglin et al. 2008), where they have found that high moisture conditions leads to exclusion of oxygen thus decreasing decomposition rates resulting in higher organic matter. Rainfall showed a negative correlation significant at 1% level with organic carbon this could be due to incessant stirring up of the sediments releasing organic carbon from the sediment to the water column (Bragadeeswaran et al. 2007). It also showed a negative correlation significant at 5% level with available phosphorus.

Though water level and their patterns of variation are the primary controlling factors in wetlands, when the basic nutrients are short in supply, growth and reproduction of organisms will be curtailed (Keddy 2000). Phosphorus is an essential cellular component for many organisms. Although phosphorus is a limiting nutrient in fresh water ecosystems, in wetlands it is not limiting (Reddy and Delaune 2008). There are several abiotic and biotic processes involved in mobilizing phosphorus between soil and overlying water column. In the present study, the available phosphorus levels in sediments tend to increase during the monsoon period irrespective of the stations. On any given landscape, phosphorus transfer is typically from uplands to wetlands, and then to the aquatic environment. The runoff from the water shed could be the reason for the increased phosphorus level in the monsoon months. The stable phase showed the maximum available phosphorus levels, the comparison was made choosing the monsoon period, the runoff from the nearby areas could be one reason, agreeing with the findings of

Wall et al. (2005) that flooding increased soil nutrient concentration by sedimentation. In stations 6 to 8, the constituent stations of the stable phase, the macrophyte vegetation was less compared to that of others hence the removal of phosphorus from sediments through macrophytes might be less here compared to other sites. Macrophytes may be visualized as pumps that remove nutrients from sediments and return them to open water (Barko and Smart 1980). Wet phase also got the influence from monsoon, but the stations 1 to 5 which are the constituent stations of the wet phase were characterized by more number of aquatic macrophytes. The removal of phosphorus from the sediments through the macrophytes could have resulted in a lesser phosphorus levels than the stable phase. In the dry phase, the drying of anaerobic soils and sediments showed contradictory results with respect to phosphorus sorption characteristics. Phosphate buffering capacity of soils and sediments studies showed an increase in the degree of phosphate adsorption upon drying soils (Barrow and Shaw 1980, Haynes and Swift 1989). In mineral wetland soils, drying potentially decreases the degree of hydration of iron hydroxide gels, hence increasing the surface area, resulting in increased phosphorus adsorption. However, McLaughlin et al. (1981) observed that drying synthetic iron and aluminum oxyhydroxide increased crystallinity and decreased phosphorus sorption capacity. Under flooded-drained conditions, Sah et al. (1989) showed an increase in concentration of amorphous iron at the expense of more crystalline forms, suggesting greater surface area and potential for higher phosphorus sorption. In floodplain-forested soils, Darke and Walbridge (2000) reported a decrease in aluminium and iron oxide crystallinity during seasonal flooding. The observations from the present study showed that the available phosphorus level in the dry phase was comparable to the stable phase, which showed the maximum values among the five phases. The dry phase was characterized by the numerous avian fauna compared to the other phases, agreeing to the observations made on the avian fauna from Kole wetlands by Jayson (2002). The bird faecal matter was observed throughout the stations. The input of nutrients (phosphorus and nitrogen) resulting from avian excrement could have contributed in the dry phase. In lake Grand-Lieu, France, the avian excrement contributed 95% of phosphorus annually (Marion et al. 1994). The significant role played by the avian fauna in nutrient loading is proved (Hobara et al. 2005, Takeda et al. 2009). Further during the dry phase, as the stations were like grassland, many cattle pastured there. The animal excreta could have also contributed to the phosphorus loading in the dry phase. The lowest available phosphorus level was observed in the paddy phase, the transfer of phosphorus through the plants could be the reason. Phosphorus assimilation and storage in plants depends on vegetative type and growth characteristics. Floating and submerged vegetation has limited potential for long-term phosphorus storage. Because of rapid turnover, phosphorus storage in biomass is short term, and much of the phosphorus is released back into water column upon vegetative decomposition. Emergent macrophytes have an extensive network of roots and rhizomes and have great potential for phosphorus storage. As paddy is an emergent plant it accumulated more phosphorus than the submerged plants. Channel phase also had a reduced available phosphorus level. Runoff through rains, resulting in loading phosphorus from the watershed was not there in the channel phase as it was not the monsoon season which could be the reason for less phosphorus level in channel.

Nitrogen is a key resource for animals, along with plants (White 1993). So nitrogen fixation, nitrogen absorption, and nitrogen reduction within plants may thus be the critical limiting steps in the production of the entire biota of wetlands (Keddy 2000). Nitrogen is usually the limiting nutrient in wetlands. The bioavailability of nitrogen in a wetland is influenced by temperature, hydrologic fluctuations, water depth, electron acceptors availability and microbial activity. It is probably the major regulatory nutritional factor in most detritus based system (Tennore 1981). The range of available nitrogen was comparable to that from Thengapattanam estuary where available nitrogen ranged from 0.012-0.052% (Anitha and Kumar 2013). The present study showed significant variations in available nitrogen between different phases. The comparison between phases showed a reduction of available nitrogen in the paddy and channel phases. The absence of nutrient input through monsoon and excrements of avian fauna would have resulted in the reduced nitrogen levels in paddy and channel phase whereas the bird droppings and cattle excreta also might have resulted in the maximum available nitrogen in the dry phase. The input of nutrients from monsoon resulted in a high value in wet and stable phase. Flooding would have increased soil nutrient concentration by sedimentation (Wall et al. 2005). This was contradictory to the results of similar study from Vellar estuary where low nitrogen values were recorded in monsoon (Rajasegar et al. 2002). Available nitrogen showed a positive correlation significant at 5% level with silt.

The sediment in Maranchery wetlands was clayey silt, sandy silt, clayey sand, sandy, silty clay and silty sandy during the study period. In lake Mansar, Jammu and Kashmir sand was predominant followed by silt and clay (Chandrakiran and Kuldeep 2013). In Ashtamudi and Vembanadu wetlands, the sediment texture was mainly clayey sand to silty sand (Sujatha et al. 2009). In Cochin estuary the predominant textural classes were clayey silt in north estuary, silty clay in central estuary and silty sand in south estuary (Martin et al. 2011). Sheela (1988) classified Kole land soil into clay, sandy loam, sandy clay loam, and clay loam. Muriyad wetland, a part of Kole wetlands revealed wide variation in the physical characteristics of soil with variation in texture from clay, sand to gravel (Thomas 2003). Hameed (1975) reported that clay texture predominates in most localities of Kole wetland. According to Trask (1953) fine-grained sediments contains more organic matter than coarse sediments. The hydraulic equivalence of clay and organic particles (Calvert and Pedersen 1992) and the higher surface area to volume ratios of fine-grained particles (Keil et al. 1994, Mayer 1994) were the reason behind it. The predominance of finer sediments (clay and silt) than coarse sediments (sand) in Maranchery wetlands could be a reason for higher organic matter in the study area.

The substratum characteristics of the wet, dry, paddy, channel and stable phase showed that the wet, channel and stable phases were sandy silt in nature while the dry and paddy phases were clayey silt in character. The running water in the wet, channel and stable phases would have moved the finer particles resulting in more sand fractions in these phases. This could be viewed analogous to the winnowing activity of the monsoonal flood facilitating the dominance of sand. Similar observations were made from Vellar estuary (Mohan 2000, Chandran 1982), Coleroon estuary (1990) and Mandovi estuary (Nasnolkar et al. 1990). In the dry and paddy phases the stagnant water would have resulted in deposition of finer clay fractions in these phases. A quite condition, conducive for flocculation and settling of finer fraction is necessary for the deposition of clay (Nehru 1990). A positive correlation significant at 1% level was observed between clay and silt, and 5% between clay and pH. Clay and sand showed a negative correlation significant at 1% level. Silt showed a significant positive correlation at 1% level with clay and at 5% level with available nitrogen. A negative correlation significant at 1% level was observed between silt and sand. Sand showed a positive correlation significant at 1% level between clay and silt, and a negative correlation 5% between sediment pH.

Principal component analysis clearly reflected the variation in environmental quality with respect to the land use pattern by ordinating wet, stable phases together and dry, paddy phases together.

Table 4.1. Monthly variation in rainfall in Maranchery Kole wetlands during the study period.

Months	mm
Nov-09	257.5
Dec-09	12.5
Jan-10	1.4
Feb-10	0
Mar-10	0.5
Apr-10	92.7
May-10	118.9
Jun-10	654.5
Jul-10	522.9
Aug-10	302.9
Sep-10	236
Oct-10	408.2
Nov-10	252.3
Dec-10	20
Jan-11	10.9
Feb-11	18.1
Mar-11	11.5
Apr-11	143.5
May-11	59.2
Jun-11	925.3
Jul-11	467.6
Aug-11	484.5
Sep-11	402.2
Oct-11	285.4

Table 4.2. Monthly variation in depth in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	2.1	2.1	2.2	2	2	2.5	2.6	2.5
Dec-09	2.1	2	2.1	2.1	2	2.4	2.6	2.4
Jan-10	0.21	0.34	0.25	0.33	0.51	2.9	3	2.8
Feb-10	1.8	2	1.8	1.7	1.8	2.75	2.9	2.85
Mar-10	0.4	0.4	0.5	0.3	0.3	2.2	2.1	2.2
Apr-10	0.4	0.3	0.4	0.3	0.3	2.1	2.1	2.1
May-10	0.3	0.3	0.4	0.3	0.3	2.1	2.1	2.1
Jun-10	0.8	0.6	0.8	0.6	0.5	2	2.3	2.2
Jul-10	3	2.9	3	2.6	2.8	2.9	3.1	3
Aug-10	2.9	2.8	2.9	2.5	2.6	2.9	3.2	3.1
Sep-10	2.6	2.5	2.5	2.4	2.5	2.8	3	3
Oct-10	2.5	2.4	2.8	2.3	2.5	2.8	3	2.9
Nov-10	2.3	2.2	2.3	2.4	2.5	2.7	2.8	2.8
Dec-10	2.1	2	2.1	2.2	2.4	2.5	2.5	2.6
Jan-11	0.3	0.3	0.4	1.2	1.3	2.8	2.8	2.9
Feb-11	0.3	0.3	0.2	1.2	1.2	2.5	2.6	2.5
Mar-11	0.2	0.3	0.3	1.2	1.3	1.3	1.5	1.5
Apr-11	0.2	0.2	0.2	1.1	1.3	1.5	1.3	1.4
May-11	0.6	0.5	0.4	1.2	1.2	1.2	1.3	1.3
Jun-11	1.6	1.6	1.8	1.4	1.3	1.8	1.9	1.8
Jul-11	3	2.9	3	2.6	2.8	2.9	3.1	3
Aug-11	3	3	2.8	2.7	2.5	2.8	3	3
Sep-11	2.6	2.8	2.8	2.5	2.5	2.8	3	2.9
Oct-11	2.3	2.2	2.3	2.4	2.5	2.7	2.8	2.8

Table 4.3 ANOVA of depth in Maranchery Kole wetlands during the study period

Source	df	Mean Square	F
Corrected Model	17	7.02	35.25
Station	6	0.56	**2.82
Phase	3	22.04	**110.64
Station and Phase	7	0.99	**4.97
Error	174	0.20	
Total	192		
R^2 = .775			

** Variation is significant at 1% level

Table 4.4. Monthly variation in water temperature in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Month	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	29.2	29.3	29.1	29.2	29.2	29.4	29.2	29.1
Dec-09	29.2	29.1	29.2	29.3	29.2	29.1	29.3	29.2
Jan-10	27.1	27.3	26.3	26.2	26.2	27.2	27.2	27.2
Feb-10	26.4	26.1	26.2	26.3	26.2	26.3	26.2	26.1
Mar-10	-	-	-	-	-	29.2	29.4	29.1
Apr-10	-	-	-	-	-	28.3	28.3	28.2
May-10	-	-	-	-	-	31.3	32.1	32
Jun-10	-	-	-	-	-	30.4	30.6	30.6
Jul-10	30.2	30.2	30.3	30.3	30.4	30.5	30.5	30.5
Aug-10	30	30.1	30.1	30.1	30.2	30.2	30.3	30.3
Sep-10	28.3	28.2	28.2	28.3	28.1	28.4	28.4	28.4
Oct-10	29.2	29.3	29.3	28.4	28.5	28.7	28.7	28.6
Nov-10	27.5	27.5	26.4	26.4	27.1	27.4	27.3	27.3
Dec-10	26.3	26.5	26.5	26.4	26.4	26.3	26.3	26.4
Jan-11	24.3	23.1	23.5	27.1	27.1	27.2	27.3	27.3
Feb-11	27	27.2	28.3	31	31.5	29.5	29.5	29.5
Mar-11	27	27	27	28	28	29	29.5	30
Apr-11	29.5	29.8	29.9	33	32	30.1	30	30
May-11	29	28.5	28.5	33	33	30.5	30.5	30.8
Jun-11	31	31.5	31	31	31	31	32	32.5
Jul-11	31	30	29.5	29.5	29	31	31	31
Aug-11	29	28.5	28.5	28	28	29	28	29
Sep-11	30	29.5	30	28	27.5	29	30	31
Oct-11	29	28	28	26	26	28.5	29	29

Table 4.5. ANOVA of water temperature in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	5.93	2.03
Phase	3	18.00	**6.17
Station	6	0.46	0.16
Phase * Station	7	0.13	0.05
Error	154	2.92	
Total	172		
Corrected Total	171		
$R^2 = .183$			

** Variation is significant at 1% level

Table 4.6. Monthly variations in water pH in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	6.29	6.61	6.71	6.58	6.5	6.55	6.71	6.82
Dec-09	6.25	6.47	6.93	6.78	6.61	6.56	6.71	6.63
Jan-10	5.96	6.01	5.77	5.74	5.67	6.18	6.28	6.33
Feb-10	6.14	6.46	6.43	6.32	6.33	6.59	6.82	6.72
Mar-10	-	-	-	-	-	6.3	5.8	6.3
Apr-10	-	-	-	-	-	6.5	7.1	7.2
May-10	-	-	-	-	-	6.45	7.8	6.5
Jun-10	-	-	-	-	-	6.81	7.1	6.21
Jul-10	6.33	6.77	6.88	7.03	6.3	6.5	6.9	7.1
Aug-10	5.9	6.47	6.23	6.48	5.9	5.55	5.87	6.31
Sep-10	6.5	6.4	6.59	6.02	6.03	6.11	6.02	6.04
Oct-10	7.04	6.96	6.88	7.11	6.74	6.77	6.95	6.88
Nov-10	6.58	6.82	6.81	6.64	6.85	6.68	6.43	6.87
Dec-10	6.69	6.6	6.55	6.62	6.63	6.87	6.92	7.14
Jan-11	5.98	6.65	6.83	8.95	6.41	6.74	6.94	6.36
Feb-11	6.88	6.89	7.04	4.23	4.39	6.76	6.6	6.98
Mar-11	5.14	6.76	5.95	5.8	6.34	6.28	6.71	6.6
Apr-11	4.4	5.83	6.34	5.81	5.78	5.2	5.42	4.42
May-11	3.63	5.14	6.2	4.45	6.28	3.15	3.74	3.96
Jun-11	6.23	5.91	5.99	5.89	6.62	5.98	5.65	5.71
Jul-11	6.62	6.45	6.3	6.28	6.21	6.2	6.61	6.45
Aug-11	6.48	6.13	5.85	5.67	5.63	5.88	6.17	6.2
Sep-11	6.57	6.55	6.28	6.19	6.38	6.47	6.56	6.38
Oct-11	6.69	6.55	6.57	6.27	5.96	6.38	6.59	6.4

Table 4.7. ANOVA of water pH in Maranchery Kole wetlands during the study period

Source	df	Mean Square	F
Corrected Model	17	0.69	1.42
Station	6	0.22	0.45
Phase	3	2.02	**4.14
Station * Phase	7	0.46	0.95
Error	154	0.49	
Total	172		
R^2 = .135			

** Variation is significant at 1% level

Table 4.8. Monthly variation in dissolved oxygen in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	5.67	6.43	4.68	5.61	4.78	4.87	4.58	4.81
Dec-09	6.1	6.34	6.29	5.38	5.87	4.03	6.3	4.79
Jan-10	6.42	6.51	6.45	6.43	5.6	5.32	6.2	5.47
Feb-10	6.22	6.43	6.2	6.14	5.69	6.11	5.94	5.86
Mar-10	-	-	-	-	-	3.6	3.6	4.1
Apr-10	-	-	-	-	-	3.4	3.6	3.4
May-10	-	-	-	-	-	3.9	4.8	4.9
Jun-10	-	-	-	-	-	4.8	4.1	4.5
Jul-10	6.4	5.6	4.8	4	5.6	3.4	3.6	4.8
Aug-10	8	4.8	5.6	6	8	6.4	7.2	8
Sep-10	7.6	7.6	7.2	8	8	8	8	8
Oct-10	7.6	7.2	7.25	8	7.2	5.61	4.95	8
Nov-10	8	7.6	6.6	8	8	6.4	8	8
Dec-10	5.2	5.2	5.6	4.4	5.2	4.8	5.6	6
Jan-11	4.4	7.2	8	8	5.2	4.8	7.2	5.6
Feb-11	8.8	8.4	8	5.2	6.4	10	10.2	6.4
Mar-11	5.2	6.4	4.8	7.2	6.6	5.6	8	7.2
Apr-11	3.2	5.6	7.2	7.2	7.2	6.4	8.8	9.6
May-11	5.6	4.8	8	6.4	6.4	8	7.2	7.2
Jun-11	7.2	7.2	4.8	5.6	4	8	8.8	7.2
Jul-11	9.2	9.2	8	3.2	4	8	8.8	8.8
Aug-11	7.2	9.6	4	2.4	4	8	7.2	8
Sep-11	8	8	6.4	5.6	3.2	8.8	8	7.2
Oct-11	8	5.6	5.6	3.2	2.4	5.6	8.8	9.6

Table 4.9. ANOVA of dissolved oxygen in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	3.32	1.21
Station	6	1.70	0.62
Phase	3	1.48	0.54
Station * Phase	7	2.61	0.95
Error	154	2.74	
Total	172		
R^2 = .118			

Table 4.10. Monthly variation in sediment temperature in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	28.1	28	28.1	28.2	28.2	28.1	28.2	28.2
Dec-09	29	29	29.1	28.9	29.1	29	29	29.1
Jan-10	27.2	27.1	27.1	27.2	27.1	27.3	27.1	27.3
Feb-10	28.1	28.4	28.2	28.1	28	28.1	28.1	28.3
Mar-10	28.1	28.1	28.2	28.2	28.2	28.1	28.2	28.2
Apr-10	27.5	27.8	27.9	27.8	27.8	27.9	27.9	27.9
May-10	28.1	27.9	27.7	27.6	27.4	27.9	27.8	27.6
Jun-10	27.6	27.6	27.8	27.4	27.4	27.6	27.7	27.7
Jul-10	27.3	27.4	27.4	27.3	27.2	27.2	27.2	27.3
Aug-10	27.3	27.2	27.3	27.2	27.3	27.3	27.2	27.2
Sep-10	27.1	27	27	27.2	27.2	27.3	27.1	27.1
Oct-10	28.1	28.6	28.4	28.2	28.1	28.1	28.4	28.3
Nov-10	26.3	26.2	26.2	26.1	26	26.6	26.7	26.6
Dec-10	25.3	25.2	25.2	25.1	25.1	25.3	25.3	25.3
Jan-11	23	24.1	24.2	26.1	26.2	26.3	26.3	26.2
Feb-11	27	27.1	27.1	29	29.2	29.2	29.3	28.1
Mar-11	29.1	29.8	29.9	31.1	31.1	27	30.2	30.1
Apr-11	27.5	27.8	27.9	27.8	27.8	27.9	27.9	27.9
May-11	28.3	29.8	30.1	30.1	31.1	30.5	30.5	30.6
Jun-11	28.1	29.8	30	30	30.4	31	30.8	30.5
Jul-11	31.2	31	28.5	31	31	30.2	31	31
Aug-11	30.6	30.2	30.1	30.1	29.5	29.3	31	31
Sep-11	28.3	29.1	28.5	28.4	28.2	28.3	28.5	29
Oct-11	29	29.2	29.2	28.5	28	28.2	29.5	29.5

Table 4.11. ANOVA of sediment temperature in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	0.26	0.15
Station	6	0.02	0.01
Phase	3	0.78	0.46
Station * Phase	7	0.07	0.04
Error	174	1.70	
Total	192		
R^2 = .014			

Table 4.12. Monthly variation in sediment pH in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	6.21	6.32	5.92	5.92	6.01	6.17	6.25	6.21
Dec-09	5.19	5.87	5.06	5.5	5.87	6.29	6.24	6.24
Jan-10	6.15	5.92	6.55	6.36	6.08	6.53	6.42	6.62
Feb-10	6.19	6.48	6.73	6.52	6.29	6.33	6.6	6.42
Mar-10	6.45	6.57	6.46	6.35	6.01	6.17	6.25	6.21
Apr-10	6.98	6.92	6.92	7.06	7	7.13	6.65	8.01
May-10	4.87	6.52	6.43	6.52	6.52	6.49	6.47	6.5
Jun-10	6.56	6.83	6.73	6.39	6.29	6.33	6.6	6.42
Jul-10	6.33	6.77	6.88	7.03	6.3	6.26	6.26	6.39
Aug-10	7	6.63	6.61	6.65	6.16	6.39	6.59	6.62
Sep-10	6.39	6.76	7.1	6.55	7.1	6.32	6.21	7.5
Oct-10	6.7	6.49	6.87	7.37	6.27	6.83	5.99	6.86
Nov-10	6.62	6.34	7.37	6.7	7.37	6.87	6.49	6.7
Dec-10	6.83	6.37	6.61	6.54	5.99	6.77	6.85	6.34
Jan-11	6.09	7.03	5.57	6.57	6.61	6.38	6.75	6.93
Feb-11	6.37	6.83	6.84	6.77	6.83	6.87	6.77	5.99
Mar-11	4.7	7.12	6.94	7.23	7.15	7.16	7.17	6.77
Apr-11	6.06	6.05	6.38	6.59	6.54	6.32	6.16	6.13
May-11	6.47	6.55	6.64	6.65	6.34	5.94	6.48	6.21
Jun-11	6.45	6.57	6.46	6.35	6.01	6.17	6.25	6.21
Jul-11	6.98	6.92	6.92	7.06	7	7.13	6.65	8.01
Aug-11	5.87	6.52	6.43	6.52	6.52	6.49	6.47	6.5
Sep-11	6.56	6.83	6.73	6.39	6.29	6.33	6.6	6.42
Oct-11	6.33	6.77	6.88	7.03	6.3	6.26	6.26	6.39

Table 4.13. ANOVA of sediment pH in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	0.21	1.08
Station	6	0.25	1.30
Phase	3	0.16	0.83
Station * Phase	7	0.18	0.96
Error	174	0.19	
Total	192		
R^2= .096			

Table 4.14. Monthly variation in sediment Eh in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	-293	-107	-254	-210	-206	-214	-233	-218
Dec-09	-297	-259	-201	-225	-200	-213	-247	-198
Jan-10	-223	-176	-243	-200	-221	-223	-198	-185
Feb-10	-220	-200	-244	-196	-195	-239	-177	-186
Mar-10	-244	-245	-225	-239	-209	-280	-201	-214
Apr-10	-225	-229	-261	-283	-279	-274	-266	-243
May-10	-198	-231	-132	-254	-250	-201	-215	-211
Jun-10	-226	-212	-213	-224	-221	-210	-287	-201
Jul-10	-218	-298	-225	-233	-254	-226	-258	-285
Aug-10	-218	-235	-221	-210	-245	-220	-212	-287
Sep-10	-224	-288	-227	-241	-297	-241	-260	-234
Oct-10	-210	-298	-287	-287	-262	-226	-264	-258
Nov-10	-245	-285	-243	-277	-265	-255	-255	-269
Dec-10	-218	-212	-275	-239	-259	-209	-228	-286
Jan-11	-225	-213	-273	-280	-263	-232	-255	-248
Feb-11	-275	-218	-212	-226	-228	-239	-209	-259
Mar-11	-103	-285	-200	-246	-272	-265	-286	-238
Apr-11	-201	-203	-212	-208	-169	-206	-202	-200
May-11	-285	-252	-225	-231	-230	-229	-214	-219
Jun-11	-221	-210	-287	-161	-226	-212	-173	-224
Jul-11	-254	-126	-158	-285	-178	-298	-225	-133
Aug-11	-235	-220	-212	-287	-218	-235	-221	-210
Sep-11	-297	-241	-210	-251	-224	-188	-197	-241
Oct-11	-262	-226	-264	-298	-210	-298	-187	-207

Table 4.15. ANOVA of sediment Eh in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	1119.84	0.84
Station	6	150.19	0.11
Phase	3	2595.42	*1.94
Station * Phase	7	1208.75	0.90
Error	174	1339.22	
Total	192		
R^2 = .076			

* Variation is significant at 5% level

Table 4.16. Monthly variation in moisture content in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	47.9	42.5	40.2	35.8	39.9	37.3	42.8	45.3
Dec-09	40.3	43.2	42.8	36.8	36.9	39.5	43.2	40.1
Jan-10	38.5	36.8	37.6	41.4	47.5	37.5	45.7	35.8
Feb-10	48.2	39.6	36.6	41.4	41.9	36.5	38.8	42.
Mar-10	32.0	32.6	27.9	33.3	33.8	33.8	35.3	46.1
Apr-10	38.3	38.3	32.9	35.4	31.7	33.1	40.8	41.1
May-10	36.2	37.1	35.8	40.3	39.9	37.3	42.8	40.1
Jun-10	48.2	40.1	36.6	41.4	36.9	39.5	43.2	35.8
Jul-10	48.5	40.5	57.0	41.4	47.5	37.5	45.7	42.0
Aug-10	31.7	37.3	32.4	56.2	30.1	32.1	33.2	40.0
Sep-10	47.9	42.5	40.2	35.8	39.9	37.3	42.8	40.1
Oct-10	39.2	43.2	42.8	36.8	36.9	39.5	43.2	35.8
Nov-10	29.6	37.4	22.5	26.3	22.4	23.5	36.9	37.0
Dec-10	38.5	26.8	27.6	31.4	37.5	27.5	35.7	2.69
Jan-11	18.2	30.1	31.3	17.6	16.8	22.6	25.8	27.8
Feb-11	17.0	30.0	32.5	1.75	19.9	23.0	25.2	2.6.8
Mar-11	19.4	29.2	23.3	24.0	33.0	23.0	26.1	28.8
Apr-11	29.8	20.8	27.9	16.2	22.3	32.6	25.3	26.4
May-11	19.3	20.3	25.3	19.2	20.1	24.8	16.8	19.4
Jun-11	33.2	40.2	40.1	36.3	49.9	49.5	40.1	46.8
Jul-11	32.5	33.3	35.8	36.9	35.2	30.6	36.	60.8
Aug-11	43.1	33.2	42.9	35.6	33.6	35.4	37.4	31.5
Sep-11	48.3	36.4	34.1	30.1	40.9	39.8	47.2	62.8
Oct-11	11.3	17.1	41.3	20.3	29.5	22.6	27.9	23.3

Table 4.17. ANOVA of moisture content in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	1.26	2.84
Station	6	2.08	**4.67
Phase	3	0.42	0.95
Station * Phase	7	1.18	**2.64
Error	174	0.45	
Total	192		
R^2 = .217			

** Variation is significant at 1% level

Table 4.18. Monthly variations in organic matter in stations 1 to 8 in Maranchery Kole wetlands during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	7.26	9.76	6.86	6.12	10.15	4.71	6.86	4.60
Dec-09	12.24	7.86	6.33	9.55	4.03	6.52	13.38	11.15
Jan-10	5.52	6.53	6.40	6.84	6.72	8.79	7.40	7.17
Feb-10	3.36	6.98	6.33	4.10	6.52	6.91	7.00	13.52
Mar-10	5.09	14.65	8.64	10.52	8.07	8.31	4.71	12.77
Apr-10	5.53	6.53	8.26	15.69	5.57	5.02	10.29	6.33
May-10	5.17	6.98	6.38	6.86	3.10	2.28	7.46	8.59
Jun-10	5.00	3.10	1.84	5.93	2.64	2.34	7.12	8.26
Jul-10	3.64	1.67	5.43	6.19	1.95	4.95	2.91	4.93
Aug-10	7.46	5.38	6.59	10.48	8.26	6.67	5.69	4.41
Sep-10	7.05	6.86	6.26	7.57	8.33	5.36	8.41	6.65
Oct-10	6.47	8.53	8.64	5.62	5.72	7.86	5.28	4.81
Nov-10	7.86	5.60	5.21	6.95	7.10	6.33	5.12	5.71
Dec-10	8.41	6.28	8.67	8.19	5.74	7.05	8.81	11.50
Jan-11	8.64	6.52	8.02	6.47	9.55	6.10	10.40	7.71
Feb-11	8.53	6.72	9.41	2.41	11.00	9.21	11.64	8.43
Mar-11	5.79	6.26	6.31	5.17	3.52	6.67	5.79	7.26
Apr-11	5.38	6.88	7.71	4.71	8.07	11.27	9.26	9.50
May-11	5.72	5.59	4.91	0.88	4.55	3.71	1.14	4.83
Jun-11	5.38	4.03	4.03	5.59	5.24	12.38	6.72	10.76
Jul-11	8.07	4.71	5.26	10.09	6.05	8.26	6.38	6.21
Aug-11	4.21	5.17	6.05	9.74	2.83	6.64	11.36	6.26
Sep-11	6.05	10.43	2.16	5.78	0.88	8.93	6.59	5.05
Oct-11	7.45	5.60	3.22	5.76	5.62	4.81	4.26	5.41

Table 4.19. ANOVA of organic matter in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	3.15	1.50
Station	6	1.15	0.55
Phase	3	1.67	0.79
Station * Phase	7	4.59	**2.19
Error	174	2.10	
Total	192		
R^2 = .128			

** Variation is significant at 1% level

Table 4.20. Monthly variation in available phosphorus in stations 1 to 8 in Maranchery Kole wetlands.

Months	station 1	station 2	station 3	station 4	station 5	station 6	station 7	station 8
Nov-09	0.219	0.846	1.536	0.289	1.564	0.01	0.647	0.513
Dec-09	1.121	0.877	0.768	0.651	1.259	1.3	1.107	0.677
Jan-10	1.053	0.641	1.142	0.574	0.634	1.512	1.114	0.843
Feb-10	0.417	0.511	0.747	0.657	0.745	0.974	0.15	0.414
Mar-10	0.264	0.314	0.141	0.347	0.552	0.476	0.411	0.316
Apr-10	0.316	0.311	0.332	0.454	0.413	0.51	0.224	0.425
May-10	0.378	0.417	0.679	0.12	3.325	0.289	0.247	0.355
Jun-10	1.864	0.984	1.648	1.254	1.284	0.998	2.963	2.1
Jul-10	1.987	0.984	1.648	2.729	2.684	2.815	1.963	3.476
Aug-10	0.941	0.764	1.852	1.687	2.612	1.983	2.331	1.647
Sep-10	0.871	0.933	0.687	0.511	1.441	1.006	0.984	1.121
Oct-10	0.54	0.954	0.846	0.417	0.254	0.988	0.761	0.206
Nov-10	0.031	0.147	0.847	0.62	0.743	0.847	0.651	1.287
Dec-10	2.164	1.237	0.251	0.364	0.469	1.475	2.549	0.927
Jan-11	0.321	0.372	0.124	0.21	0.397	0.487	0.022	0.954
Feb-11	0.145	0.324	0.146	0.471	0.478	0.384	0.158	0.164
Mar-11	0.312	0.512	0.256	0.312	0.169	0.247	0.149	0.558
Apr-11	0.497	0.641	0.238	0.33	0.197	0.546	0.473	0.046
May-11	0.547	0.455	0.1	0.344	0.447	0.398	0.33	0.489
Jun-11	2.694	1.652	1.47	0.987	1.853	1.21	1.244	1.688
Jul-11	0.878	0.784	0.312	1.649	0.68	0.984	1.255	1.124
Aug-11	1.546	2.947	1.982	1.495	1.828	0.948	1.265	2.091
Sep-11	2.978	1.642	0.623	0.946	1.694	2.664	1.784	3.546
Oct-11	1.345	0.964	1.654	0.561	0.547	0.62	0.845	0.214

Table 4.21. ANOVA of available phosphorus in Maranchery Kole during the study period.

Source	df	Mean Square	F
Corrected Model	17	0.96	1.79
Station	6	0.27	0.50
Phase	3	4.21	**7.87
Station * Phase	7	0.17	0.32
Error	174	0.53	
Total	192		
R^2 = .149			

** Variation is significant at 1% level

Table 4.22. Monthly variation in available nitrogen in stations 1 to 8 in Maranchery Kole during the study period.

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Nov-09	0.018	0.018	0.020	0.030	0.019	0.018	0.028	0.019
Dec-09	0.019	0.021	0.021	0.018	0.023	0.018	0.026	0.023
Jan-10	0.016	0.002	0.022	0.029	0.022	0.017	0.007	0.020
Feb-10	0.012	0.006	0.019	0.016	0.018	0.025	0.020	0.025
Mar-10	0.021	0.023	0.020	0.022	0.023	0.025	0.021	0.019
Apr-10	0.021	0.025	0.025	0.027	0.026	0.018	0.026	0.023
May-10	0.004	0.022	0.014	0.021	0.019	0.009	0.002	0.001
Jun-10	0.020	0.029	0.013	0.015	0.015	0.006	0.006	0.014
Jul-10	0.025	0.023	0.025	0.024	0.019	0.023	0.023	0.023
Aug-10	0.013	0.016	0.019	0.017	0.011	0.015	0.011	0.014
Sep-10	0.021	0.028	0.021	0.034	0.028	0.023	0.015	0.025
Oct-10	0.020	0.020	0.022	0.018	0.016	0.019	0.023	0.025
Nov-10	0.021	0.005	0.011	0.011	0.006	0.018	0.011	0.008
Dec-10	0.019	0.021	0.018	0.019	0.029	0.018	0.034	0.027
Jan-11	0.006	0.017	0.014	0.023	0.014	0.014	0.015	0.007
Feb-11	0.016	0.020	0.020	0.013	0.022	0.016	0.003	0.016
Mar-11	0.015	0.018	0.011	0.016	0.013	0.022	0.009	0.017
Apr-11	0.015	0.025	0.015	0.010	0.015	0.011	0.010	0.015
May-11	0.011	0.015	0.020	0.009	0.002	0.015	0.011	0.016
Jun-11	0.024	0.021	0.017	0.024	0.005	0.025	0.015	0.021
Jul-11	0.021	0.014	0.020	0.021	0.022	0.013	0.017	0.021
Aug-11	0.036	0.032	0.033	0.048	0.008	0.035	0.052	0.038
Sep-11	0.022	0.032	0.028	0.021	0.044	0.030	0.026	0.027
Oct-11	0.011	0.007	0.023	0.017	0.027	0.015	0.018	0.019

Table 4.23. ANOVA of available nitrogen in Maranchery Kole wetlands during during the study period.

Source	df	Mean Square	F
Corrected Model	17	6.5E-05	1.1
Station	6	1.3E-04	2.1
Station * Phase	7	2.8E-05	0.5
Phase	3	9.6E-05	1.6
Error	174	6.1E-05	
Total	192		
R2 = .094			

Table 4.24. ANOVA of clay in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	31.12	1.45
Station	6	56.59	**2.63
Phase	3	12.55	0.58
Station * Phase	7	28.01	1.30
Error	174	21.48	
Total	192		
R^2= .124			

** Variation is significant at 1% level

Table 4.25. ANOVA of silt in Maranchery Kole wetlands during the study period.

Source	df	Mean Square	F
Corrected Model	17	229.32	2.89
Station	6	510.23	**6.44
Phase	3	60.86	0.77
Station * Phase	7	141.72	*1.79
Error	174	79.23	
Total	192		
R^2 = .220			

** Variation is significant at 1% level
* Variation is significant at 5% level

Table 4.26. ANOVA of sand in Maranchery Kole wetlands during during the study period.

Source	df	Mean Square	F
Corrected Model	17	312.07	2.55
Station	6	736.38	**6.01
Phase	3	118.36	0.97
Station * Phase	7	214.52	*1.75
Error	174	122.59	
Total	192		
R^2 = .199			

** Variation is significant at 1% level
* Variation is significant at 5% level

Table.4.27. Correlations between environmental parameters in Maranchery Kole wetlands during the study period.

Parameters	Rainfall	Sediment temperature	Depth	Moisture content	Organic matter	Eh	Sediment pH	Available nitrogen	Available phosphorus	Clay	Silt	Sand	Dissolved oxygen	Water pH	Water temperature
Rainfall	1														
Sediment temperature	0.307**	1													
Depth	0.227**	-0.126	1												
Moisture content	-0.148*	-0.047	0.079	1											
Organic matter	-0.235**	-0.127	0.022	0.173*	1										
Eh	0.032	0.180	-0.201**	-0.054	0.041	1									
Sediment pH	0.059	-0.121	0.142*	0.212**	0.004	-0.132	1								
Available nitrogen	0.014	0.070	-0.017	0.056	0.134	-0.017	0.027	1							
Available phosphorus	0.535**	0.023	0.291**	-0.070	-0.142*	-0.029	-0.061	0.065	1						
Clay	0.103	-0.064	0.060	0.070	0.015	-0.003	0.176*	-0.039	0.045	1					
Silt	0.041	0.007	0.034	0.029	0.016	-0.044	0.106	0.157*	0.051	0.267	1				
Sand	-0.075	0.020	-0.052	-0.052	-0.019	0.038	-0.157*	-0.112	-0.060	-0.618**	-0.923**	1			
Dissolved oxygen	0.048	-0.044	0.042	-0.024	0.111	-0.010	0.089	-0.077	-0.081	-0.136	0.012	0.047	1		
Water pH	0.048	-0.324**	0.334	0.138	0.160*	-0.189*	0.107	0.096	0.081	0.080	-0.014	-0.021	-0.021	1	
Water temperature	0.489**	0.484**	0.179**	-0.017	-0.128	0.145	0.009	-0.068	0.244**	0.003	0.024	-0.020	0.096	-0.244**	1

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4.28. Results of Principal Component Analysis (PCA) of environmental parameters in Maranchery Kole wetlands during the study period.

Variable	PC1	PC2	PC3	PC4
Log (water pH)	-0.345	0.224	-0.042	-0.009
depth	-0.266	0.313	0.147	-0.317
Log (sediment temperature)	0.388	0.076	0.002	0.037
Eh	0.245	-0.363	-0.006	-0.218
Log (moisture content)	-0.346	-0.038	0.249	0.339
organic matter	-0.197	-0.378	-0.206	0.114
DO	-0.227	-0.132	-0.475	-0.118
Log (available nitrogen)	-0.317	-0.163	0.27	0.294
available phosphorous	-0.31	0.109	0.347	-0.158
sediment pH	-0.332	0.069	-0.318	0.049
clay	-0.124	0.121	-0.569	-0.027
silt	0.208	0.303	-0.123	0.74
sand	0.013	-0.467	0.108	0.017
water temperature	0.153	0.43	0.035	-0.213

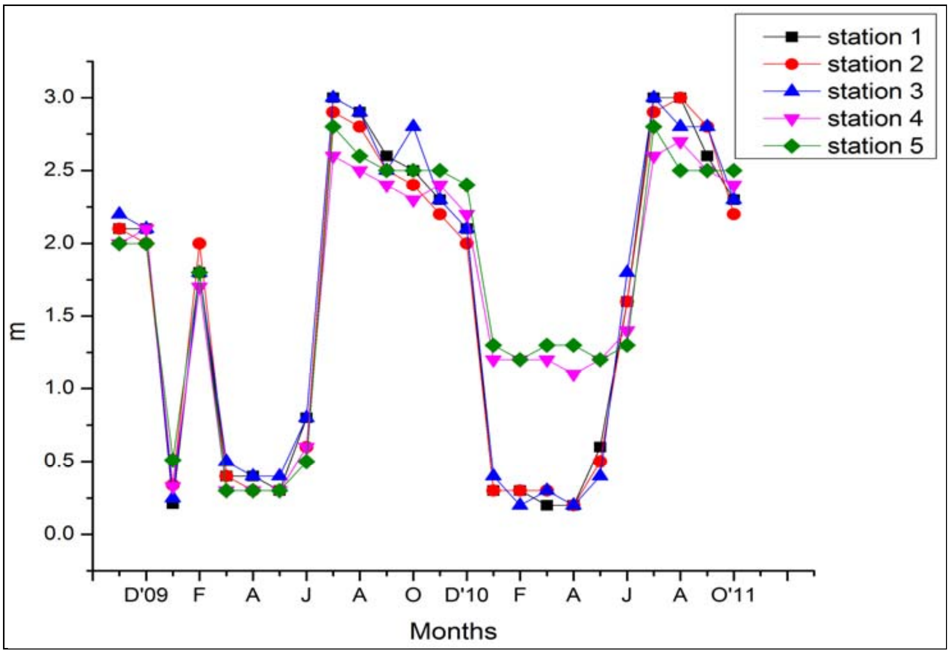


Fig. 4.1. Monthly variation in depth in stations 1 to 5 in Maranchery Kole wetlands during the study period.

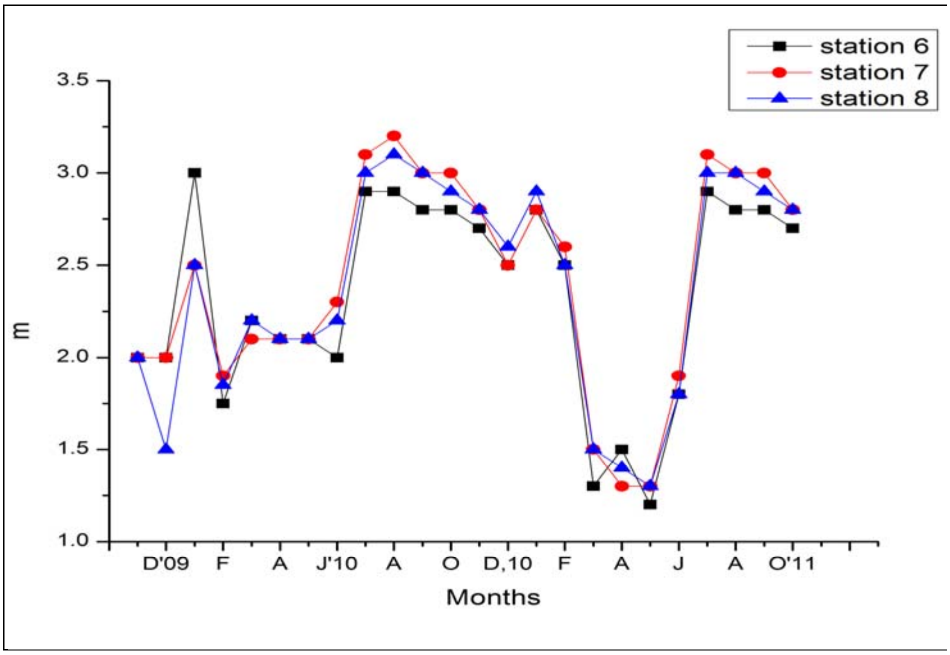


Fig. 4.2. Monthly variation in depth in stations 6 to 8 in Maranchery Kole wetlands during the study period.

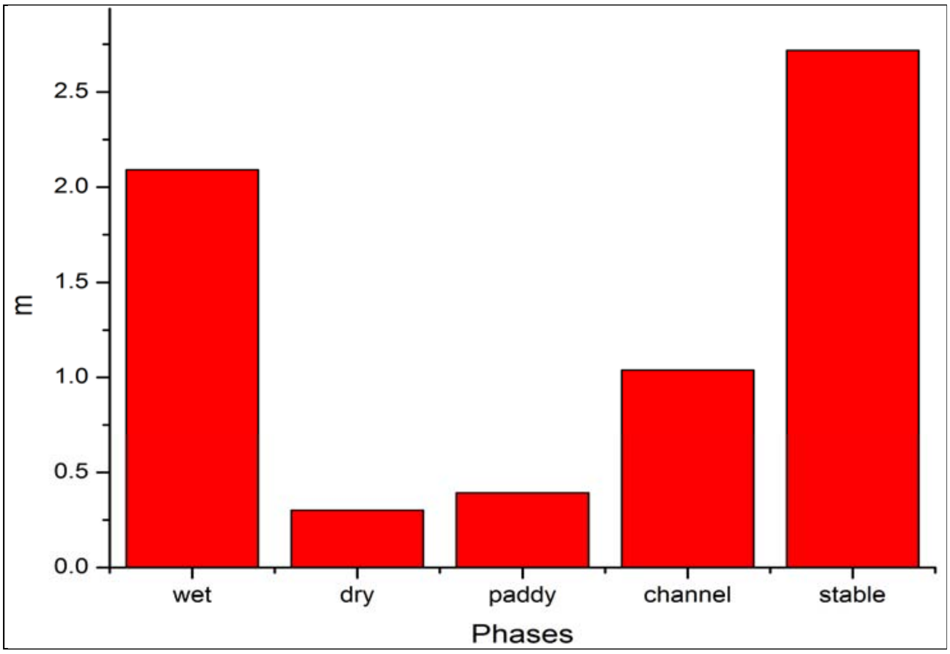


Fig. 4.3. Mean variation in depth in various phases in Maranchery Kole wetlands.

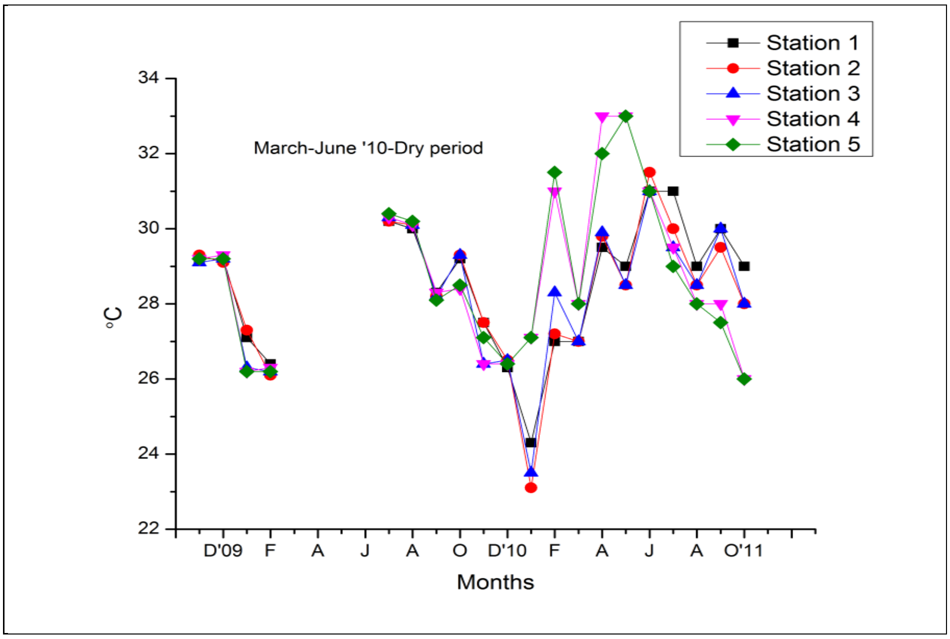


Fig. 4.4. Monthly variation in water temperature in stations 1 to 5 in Maranchery Kole wetlands during the study period.

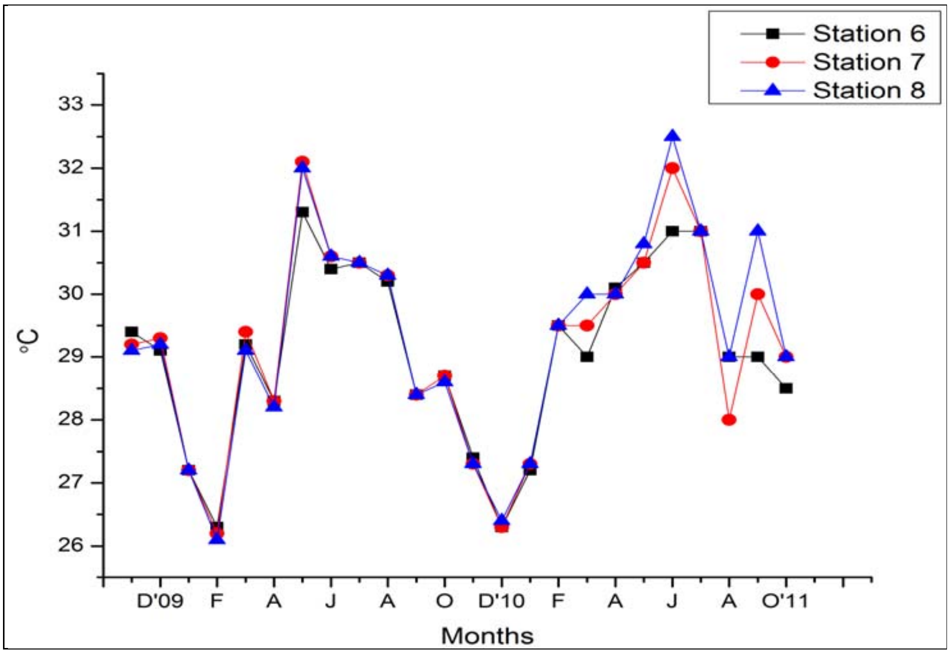


Fig. 4.5. Monthly variation in water temperature in stations 6 to 8 in Maranchery Kole wetlands during the study period.

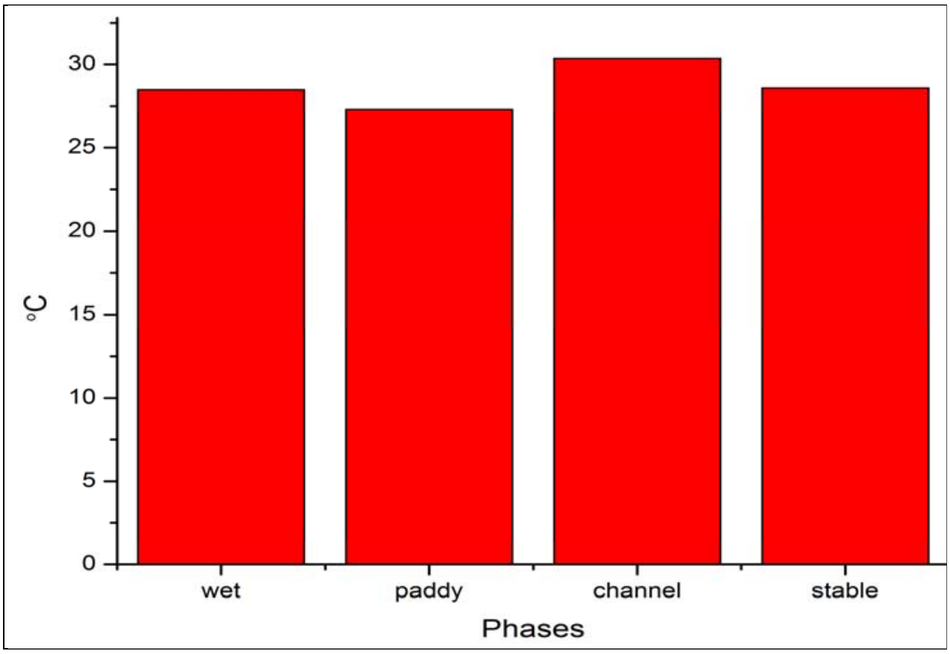


Fig. 4.6. Mean variation in water temperature in various phases in Maranchery Kole wetlands.

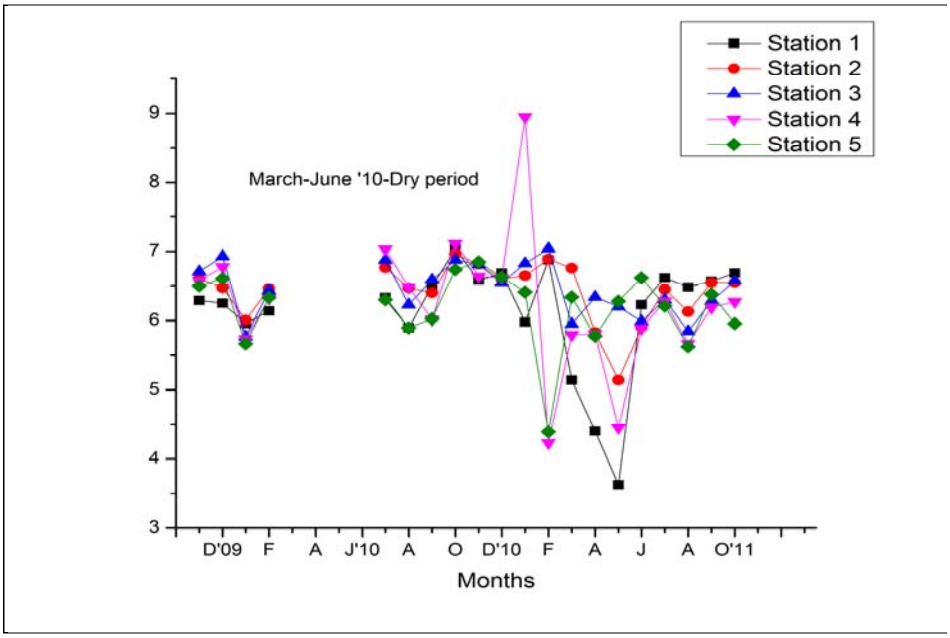


Fig. 4.7. Monthly variation in pH of water in stations 1 to 5 in Maranchery Kole wetlands during the study period.

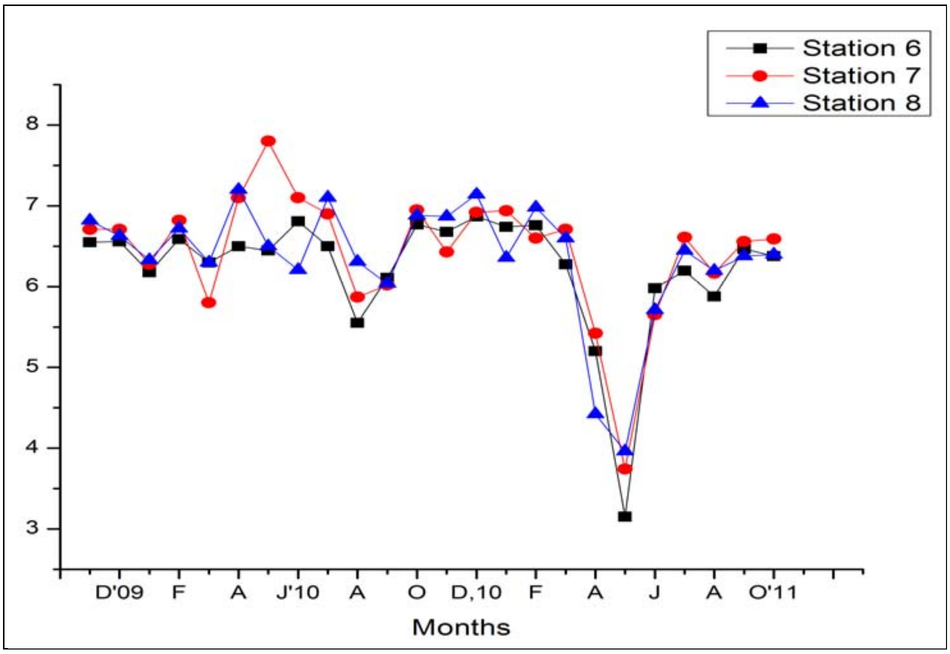


Fig. 4.8. Monthly variation in pH of water in stations 6 to 8 in Maranchery Kole wetlands during the study period.

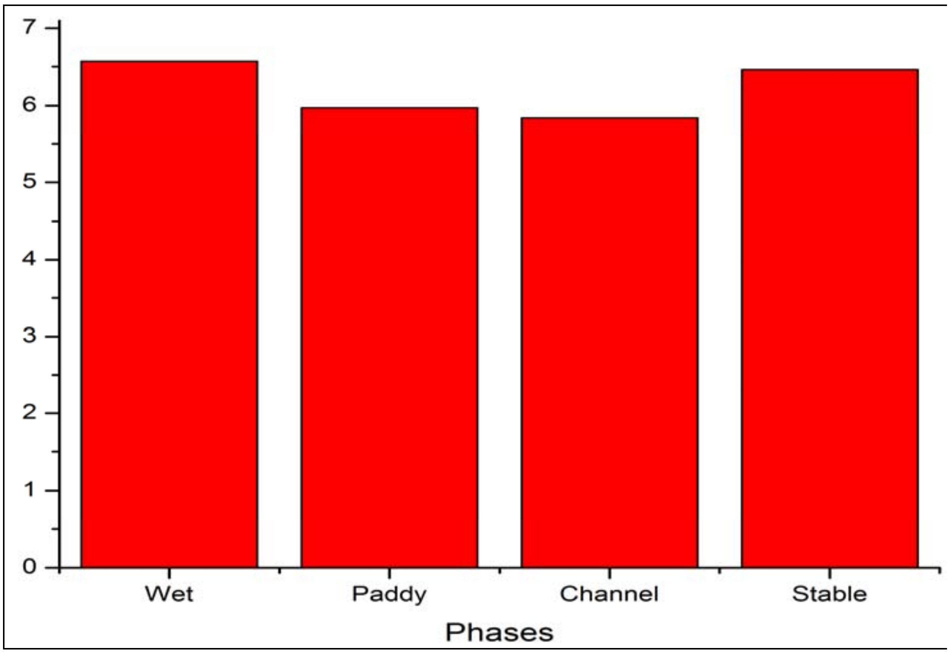


Fig. 4.9. Mean variation in pH of water in various phases in Maranchery Kole wetlands.

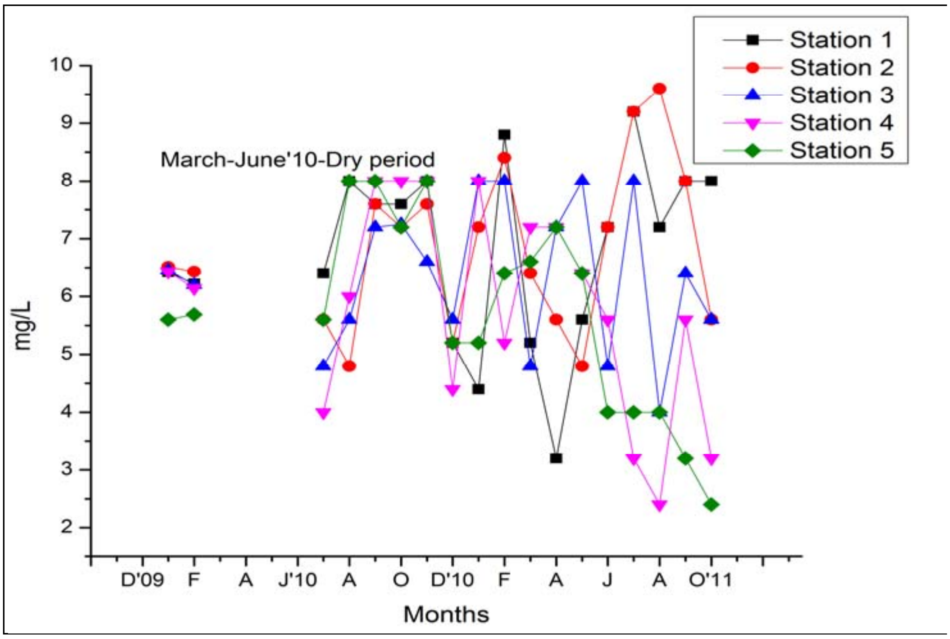


Fig. 4.10. Monthly variation in dissolved oxygen in stations 1 to 5 in Maranchery Kole wetlands during the study period.

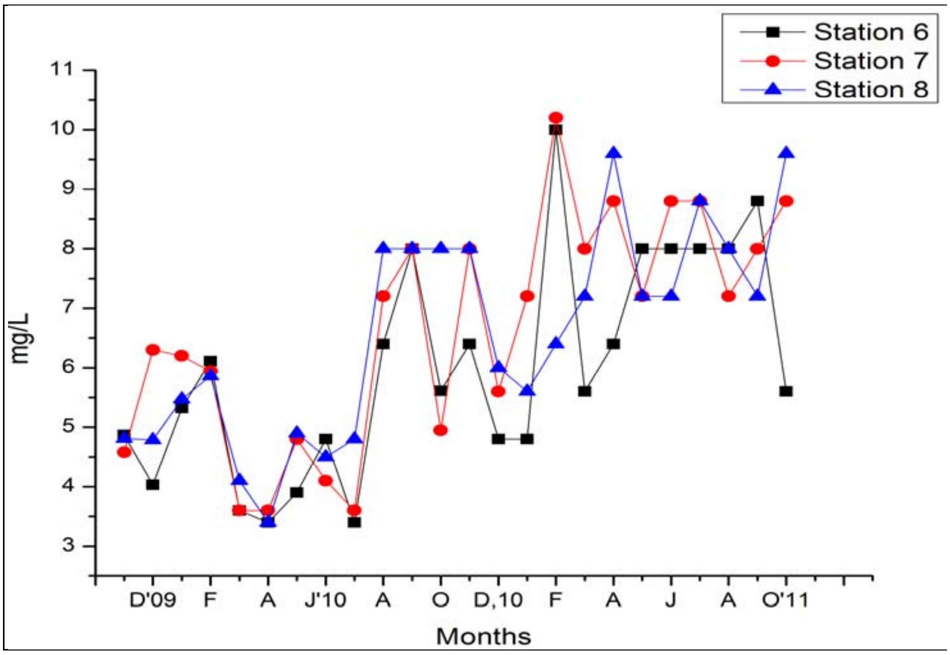


Fig. 4.11. Monthly variation in dissolved oxygen in stations 6 to 8 in Maranchery Kole wetlands during the study period.

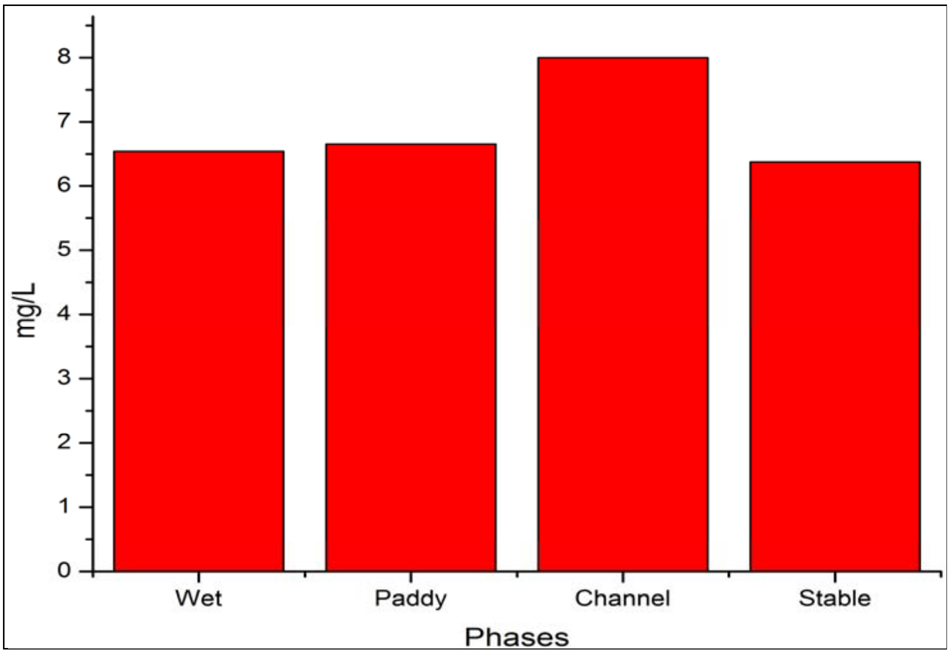


Fig. 4.12. Mean variation in dissolved oxygen in various phases in Maranchery Kole wetland

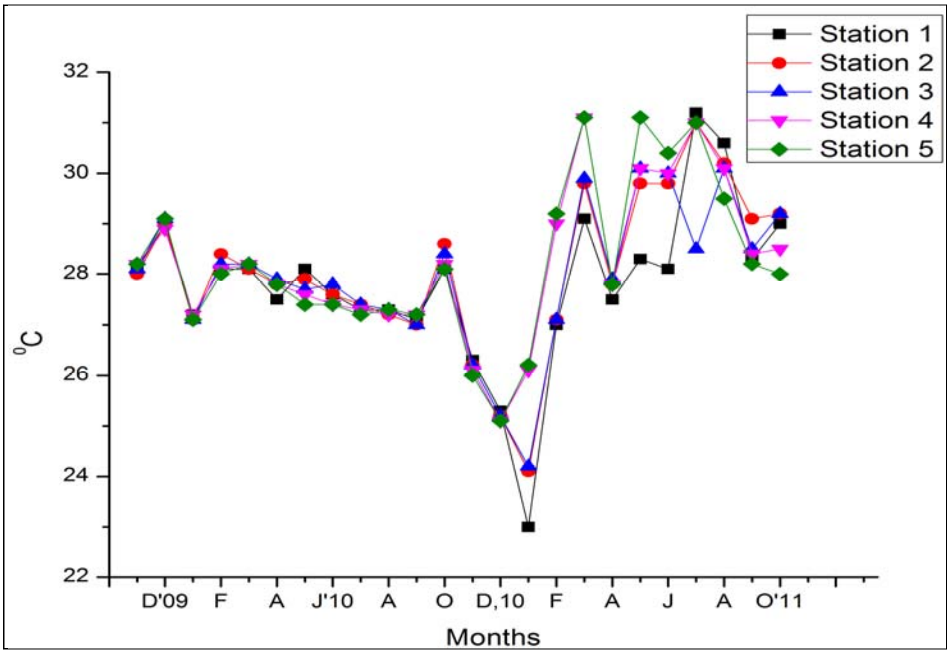


Fig. 4.13. Monthly variation in sediment temperature in stations 1 to 5 in Maranchery Kole wetlands during the study period.

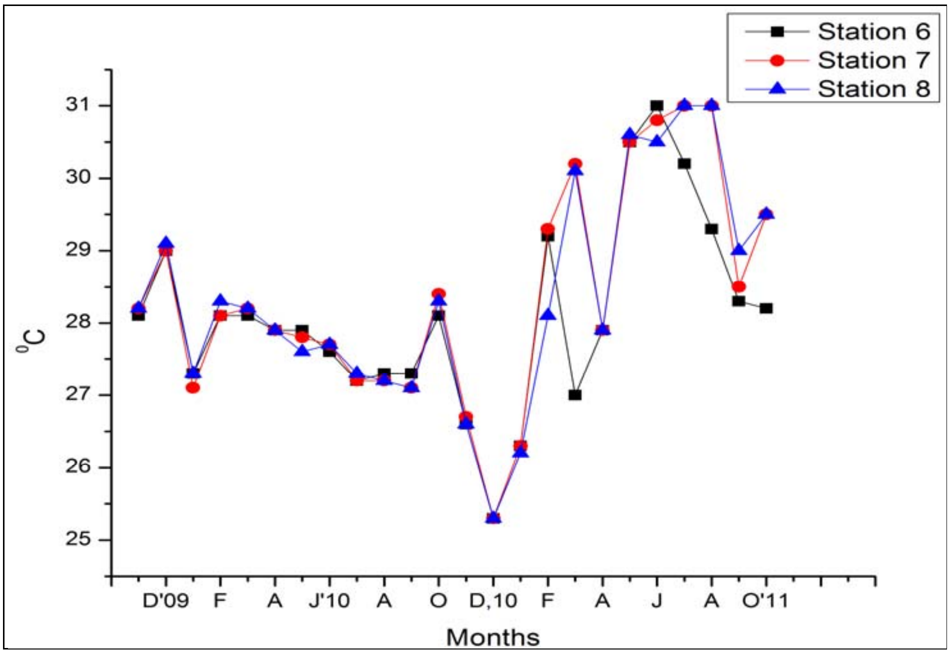


Fig.4.14. Monthly variation in sediment temperature in stations 6 to 8 in Maranchery Kole wetlands during the study period.

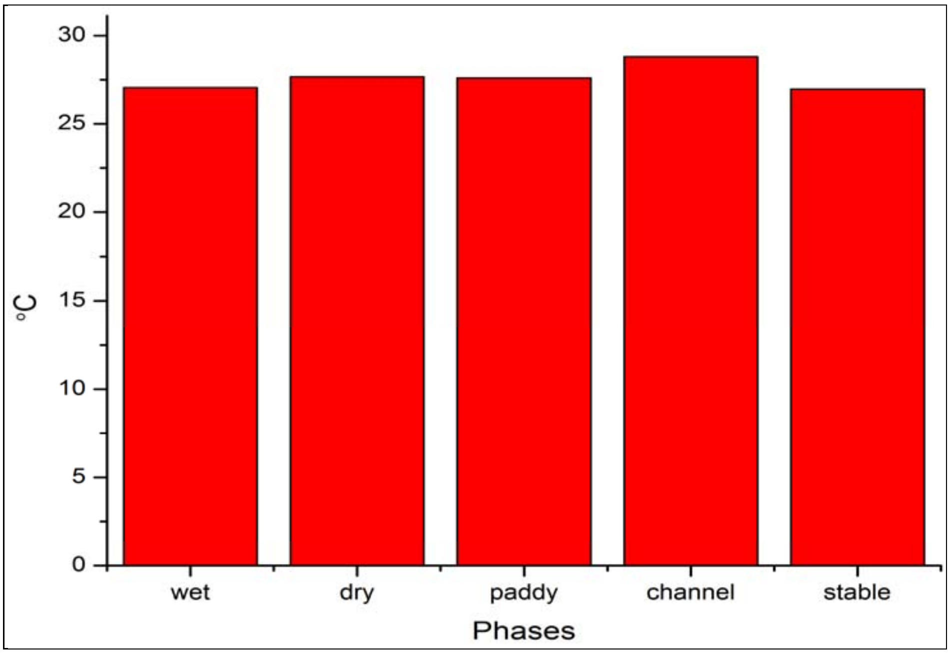


Fig. 4.15. Mean variation in sediment temperature in various phases in Maranchery Kole wetlands.

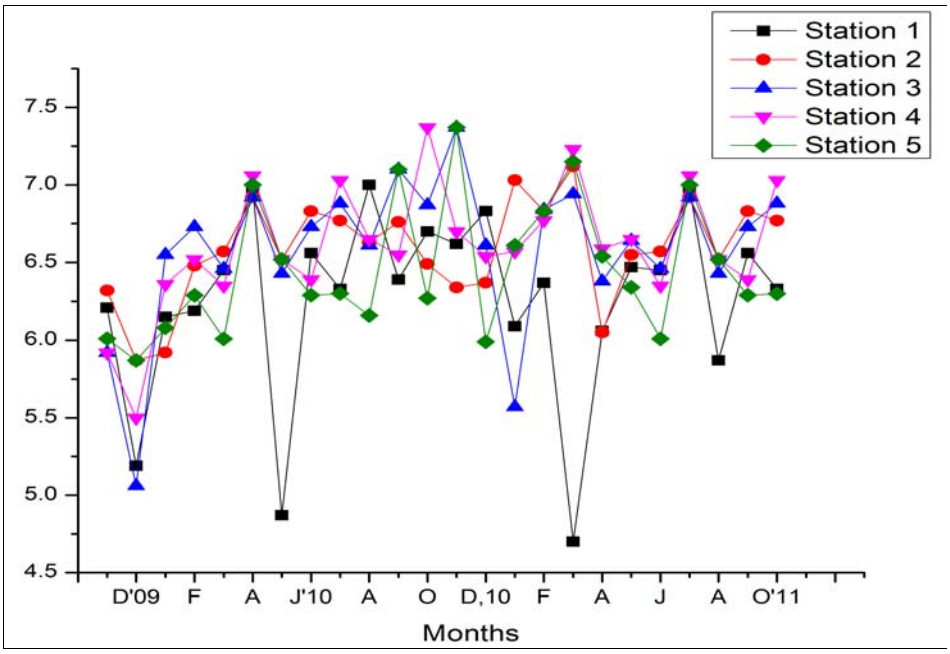


Fig. 4.16. Monthly variation in sediment pH in stations 1 to 5 in Maranchery Kole wetlands during the study period.

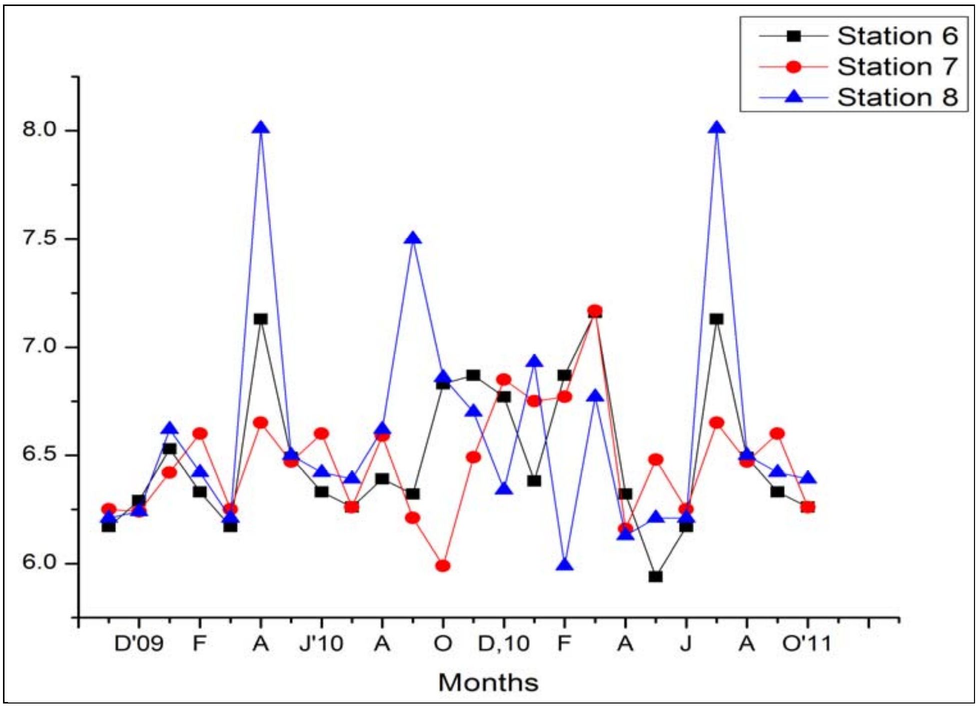


Fig. 4.17. Monthly variation in sediment pH in stations 6 to 8 in Maranchery Kole wetlands during the study period.

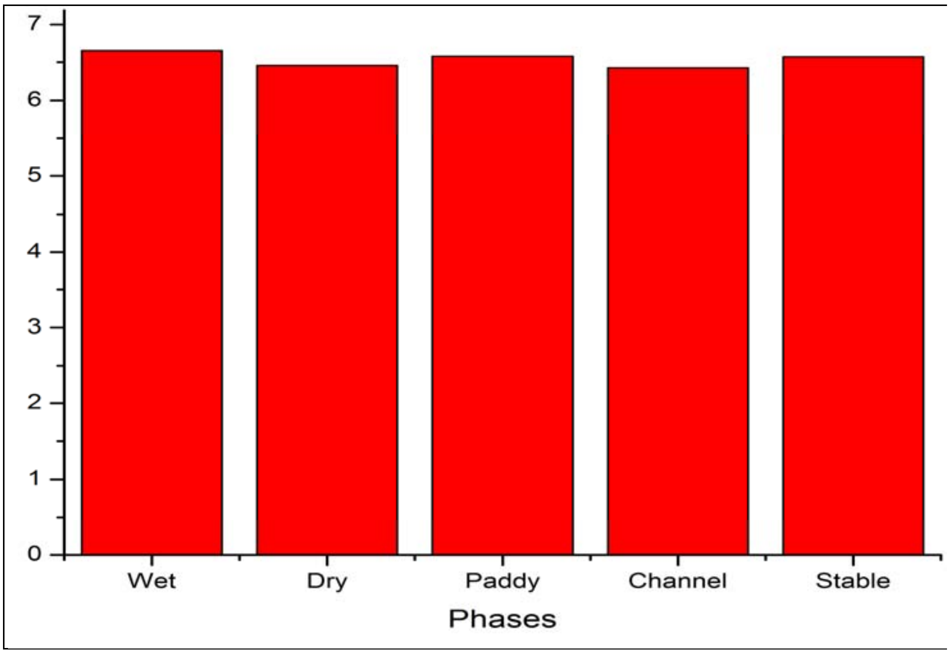


Fig. 4.18. Mean variation in sediment pH in various phases in Maranchery Kole wetlands.

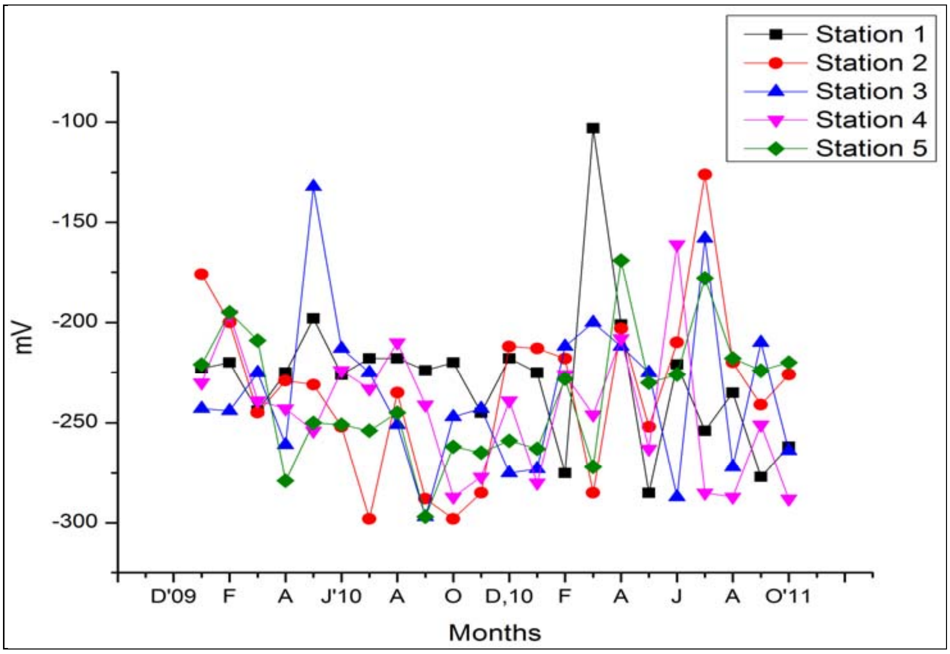


Fig. 4.19. Monthly variation in sediment Eh in stations 1 to 5 in Maranchery Kole wetlands during the study period.

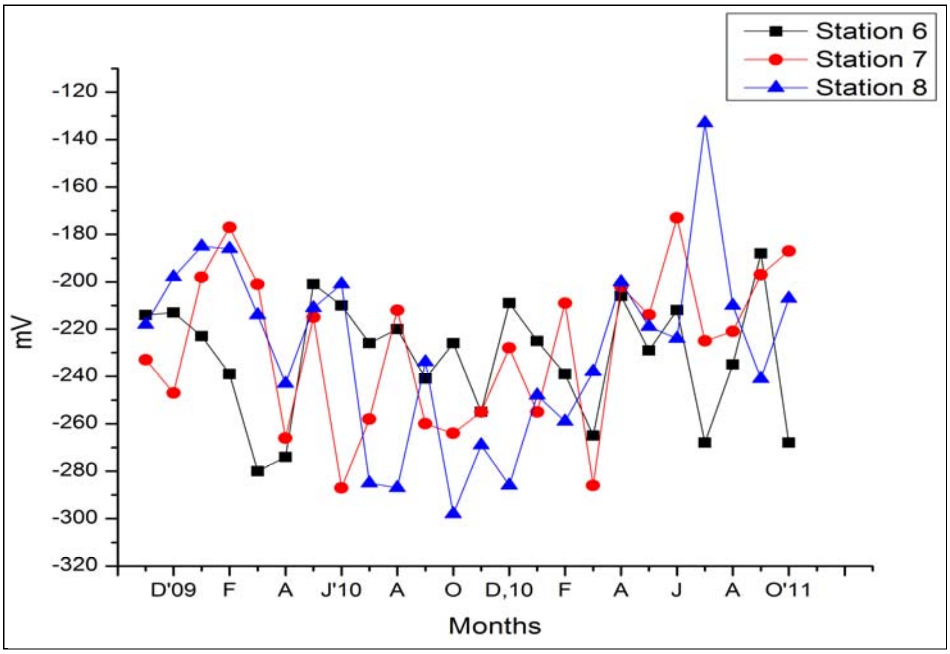


Fig. 4.20. Monthly variation in sediment Eh in stations 6 to 8 in Maranchery Kole wetlands during the study period.

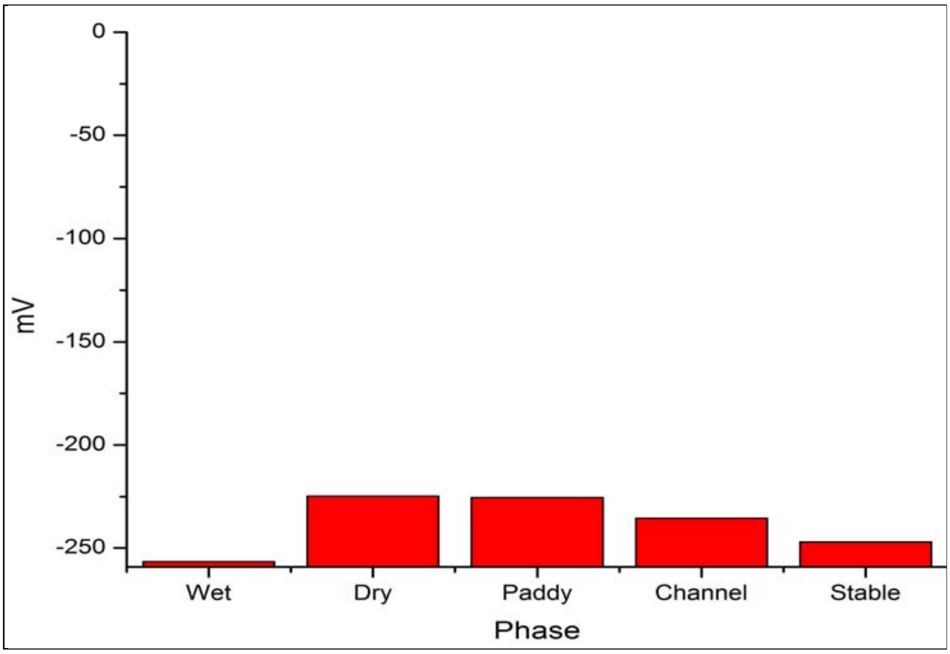


Fig. 4.21. Mean variation in sediment Eh in various phases in Maranchery Kole wetlands.

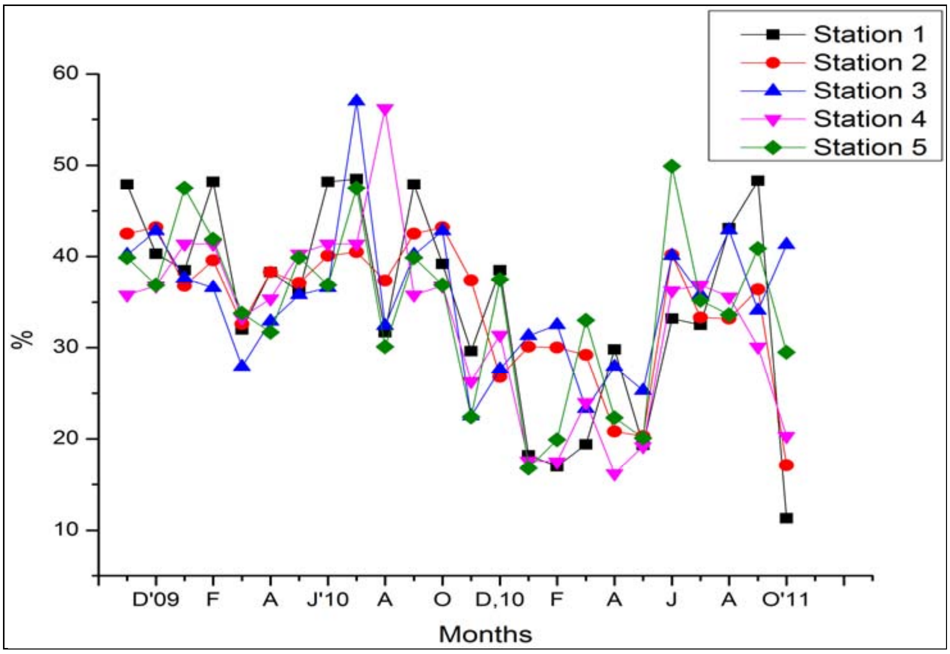


Fig. 4.22. Monthly variation in moisture content in stations 1 to 5 in Maranchery Kole wetlands during the study period.

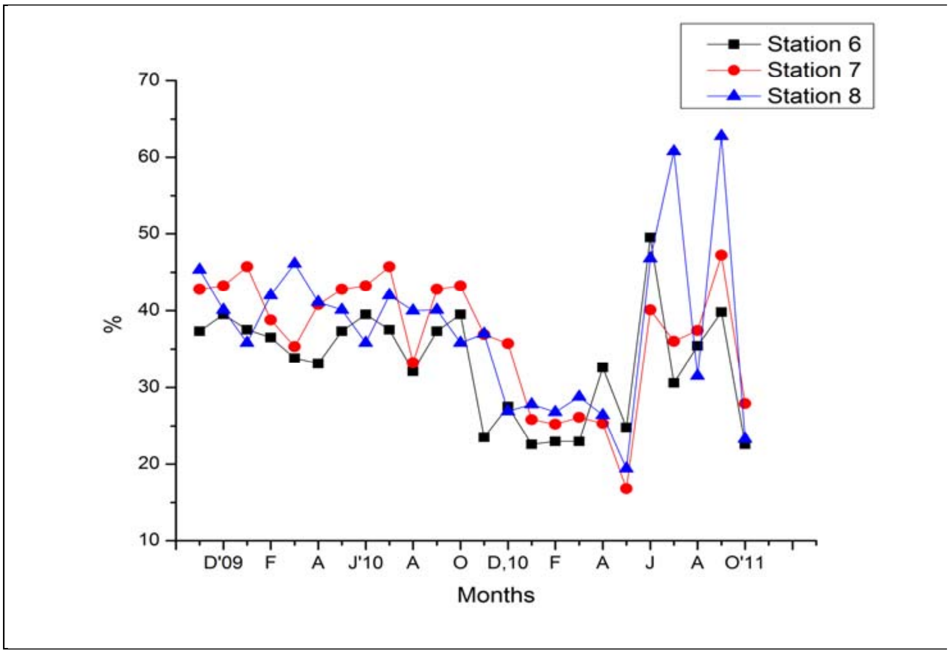


Fig. 4.23. Monthly variation in moisture content in stations 6 to 8 in Maranchery Kole wetlands during the study period.

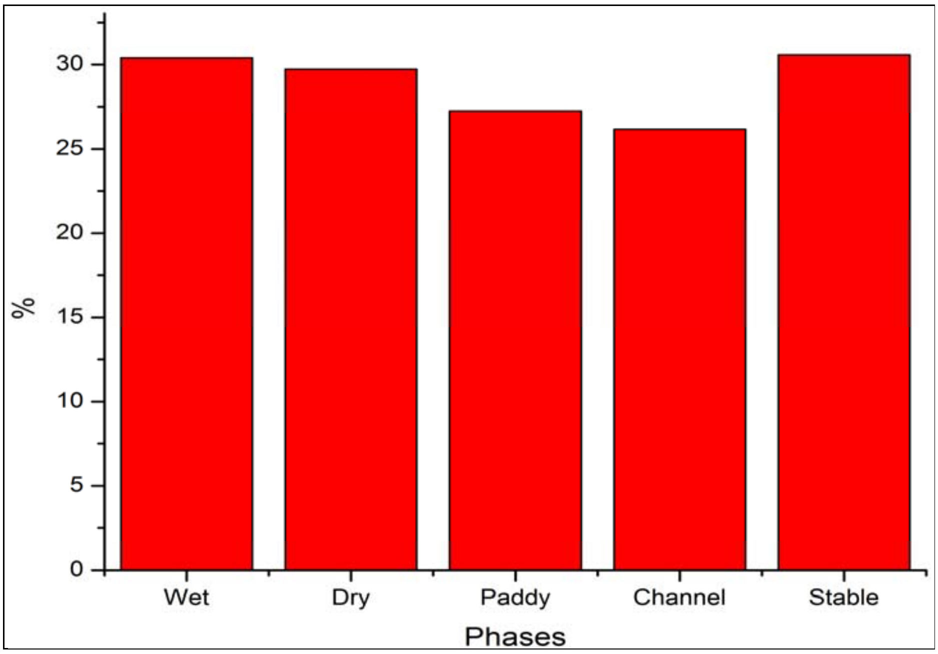


Fig. 4.24. Mean variation in moisture content in various phases in Maranchery Kole wetlands.

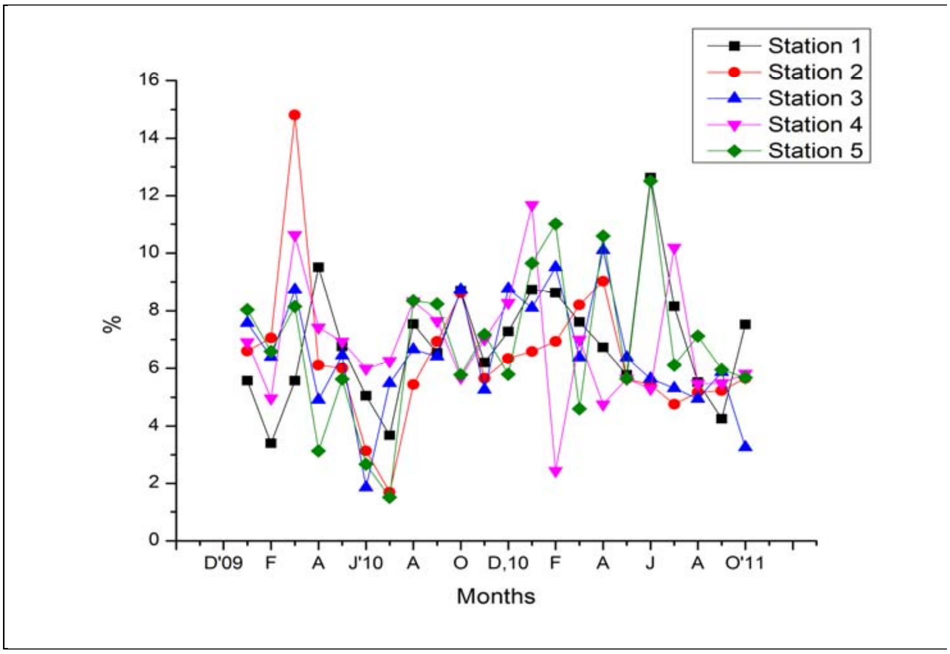


Fig. 4.25. Monthly variation in organic matter in stations 1 to 5 in Maranchery Kole wetlands during the study period.

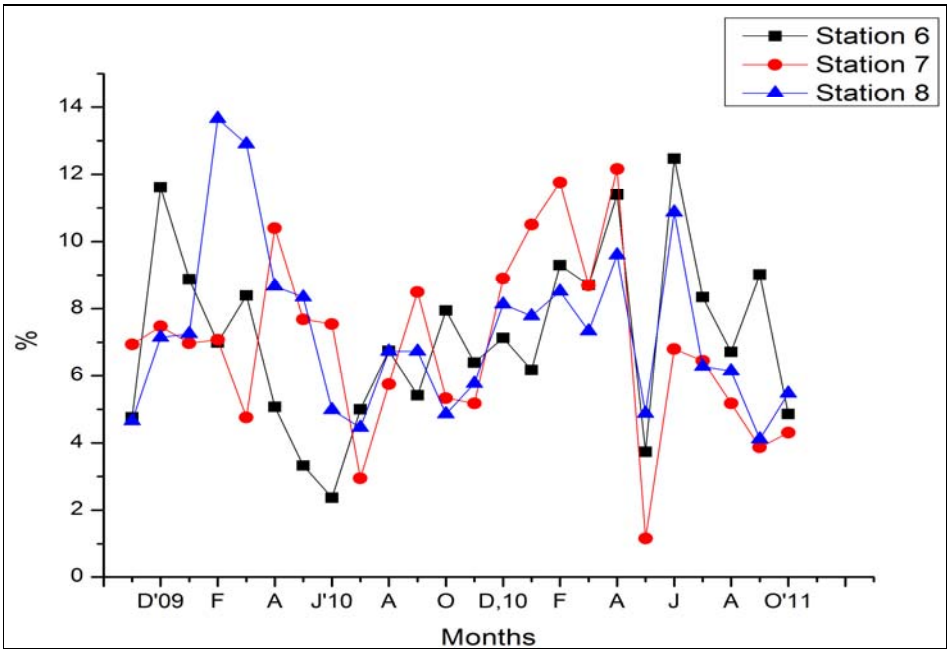


Fig. 4.26. Monthly variation in organic matter in stations 6 to 8 in Maranchery Kole wetlands during the study period.

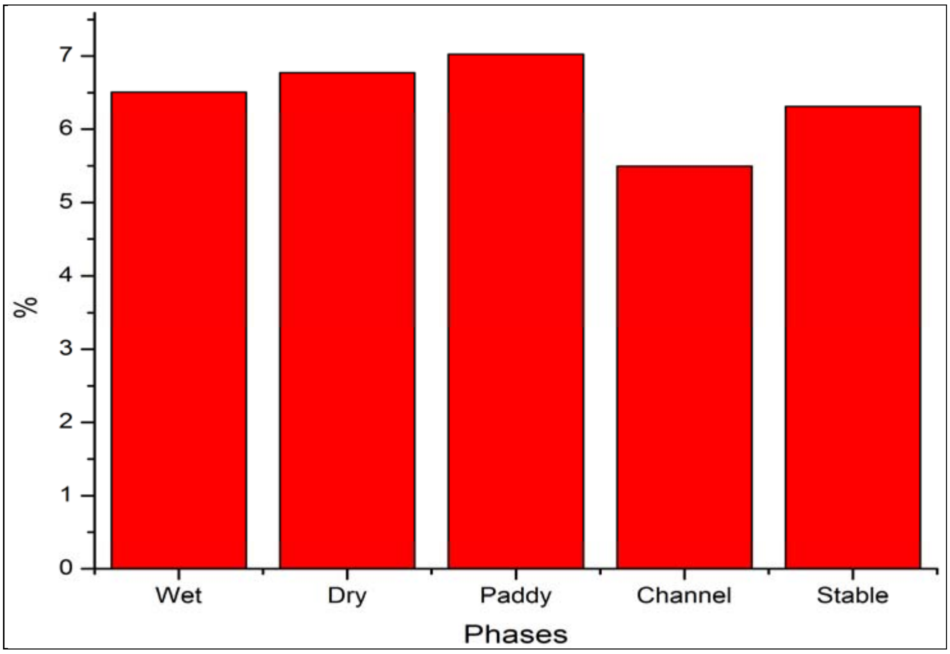


Fig. 4.27. Mean variation in organic matter in various phases in Maranchery Kole wetlands.

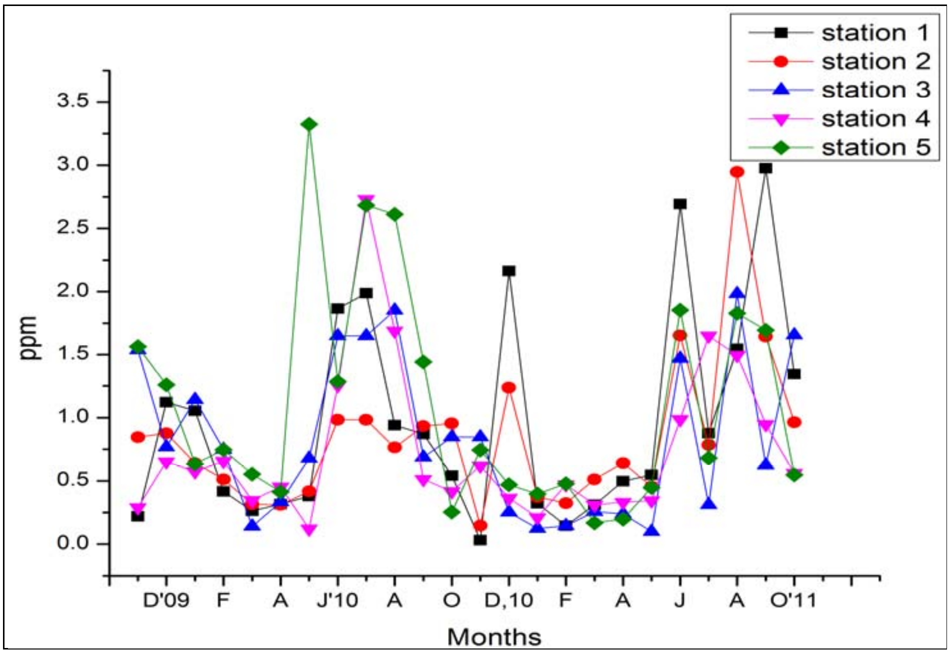


Fig. 4.28. Monthly variation in available phosphorus in stations 1 to 5 in Maranchery Kole wetlands during the study period.

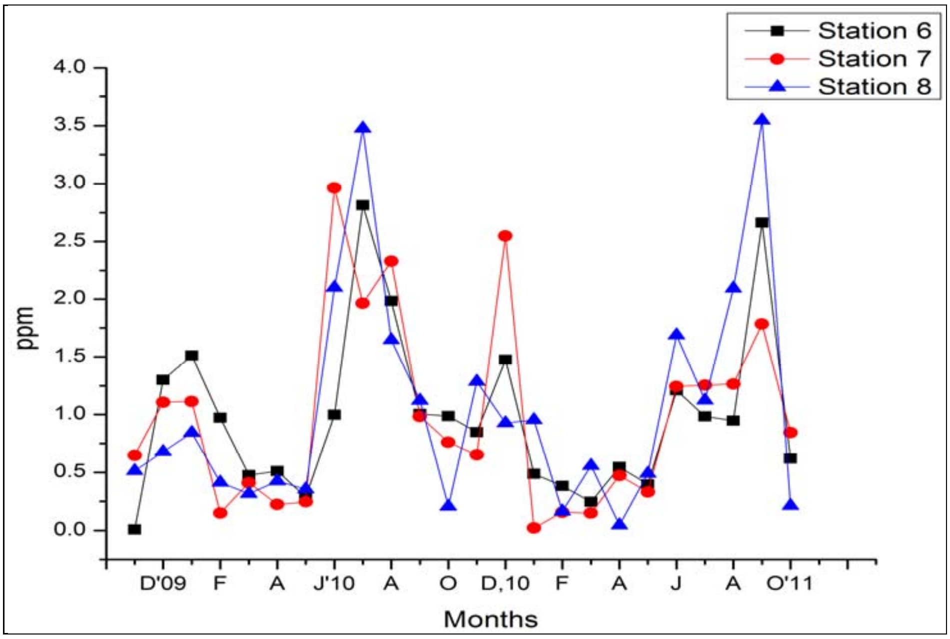


Fig. 4.29. Monthly variation in available phosphorus in stations 6 to 8 in Maranchery Kole wetlands during the study period.

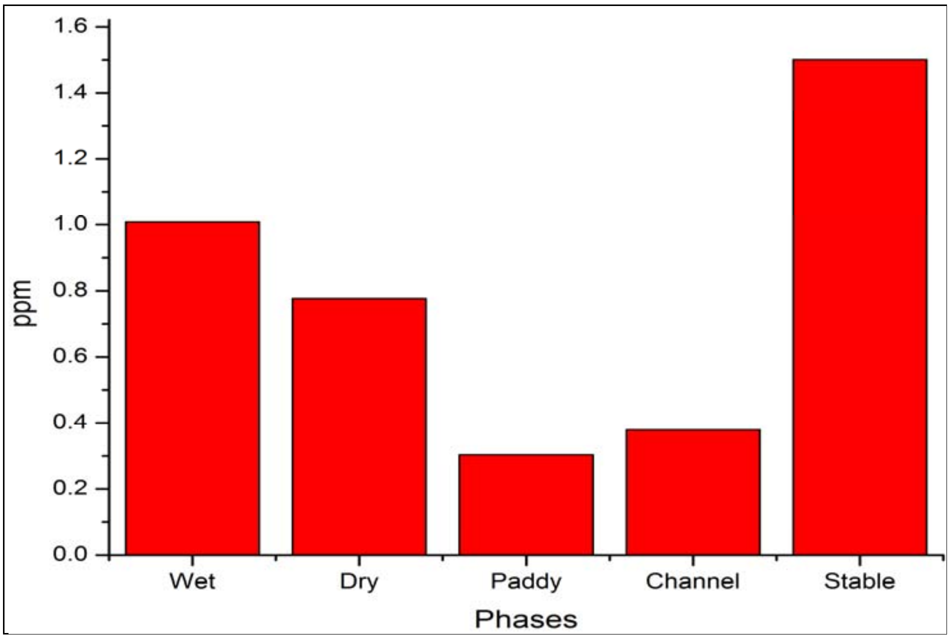


Fig. 4.30. Mean variation in available phosphorus in various phases in Maranchery Kole wetlands.

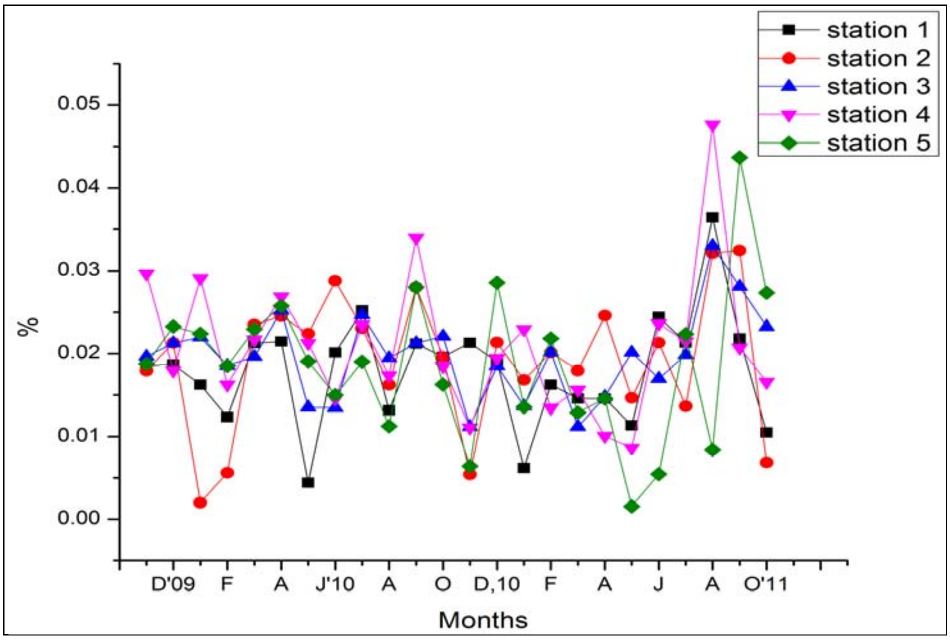


Fig. 4.31. Monthly variation in available nitrogen in stations 1 to 5 in Maranchery Kole wetlands during the study period.

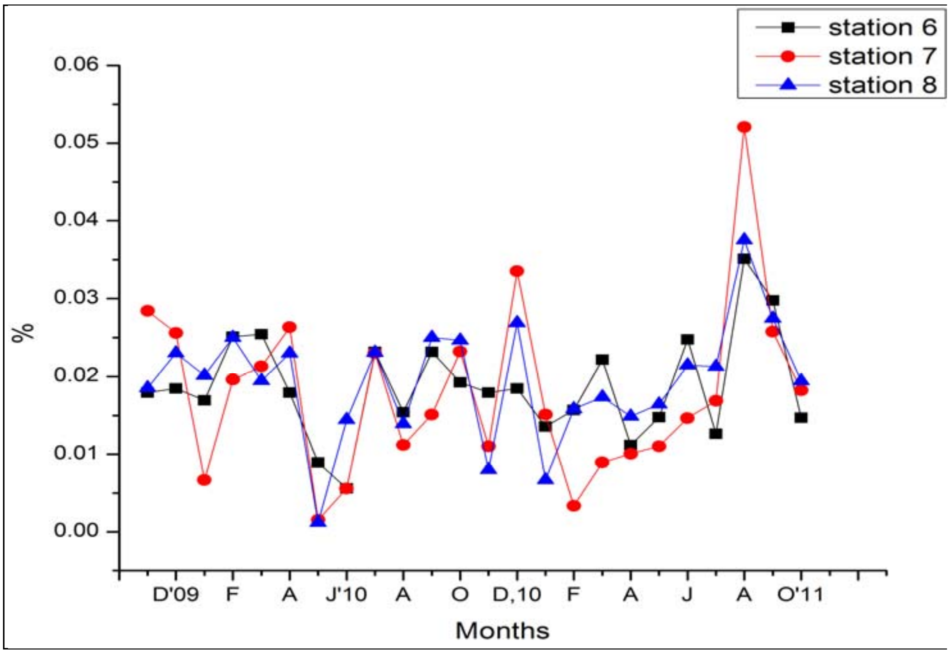


Fig. 4.32. Monthly variation in available nitrogen in stations 6 to 8 in Maranchery Kole wetlands during the study period.

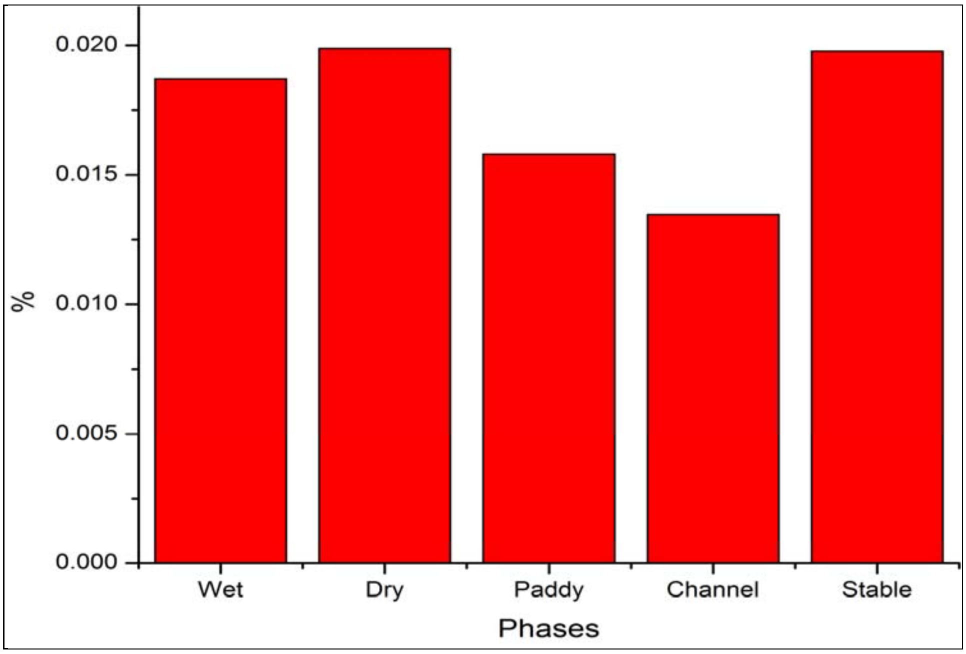


Fig. 4.33. Mean variation in available nitrogen in various phases in Maranchery Kole wetlands.

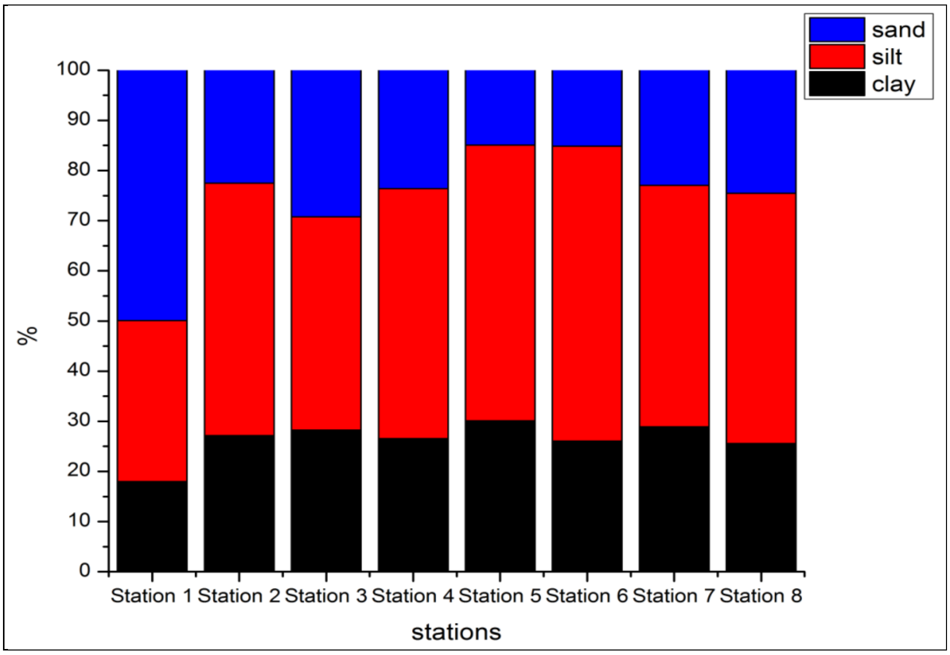


Fig. 4.34. Sediment texture in various stations in Maranchery Kole wetlands

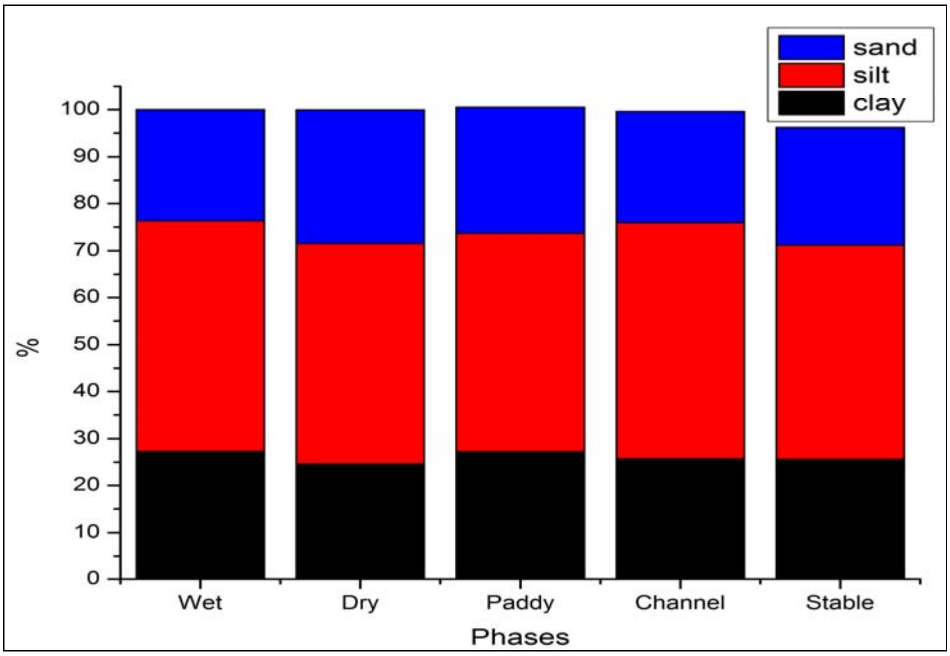


Fig. 4.35. Sediment texture in various phases in Maranchery Kole wetlands.

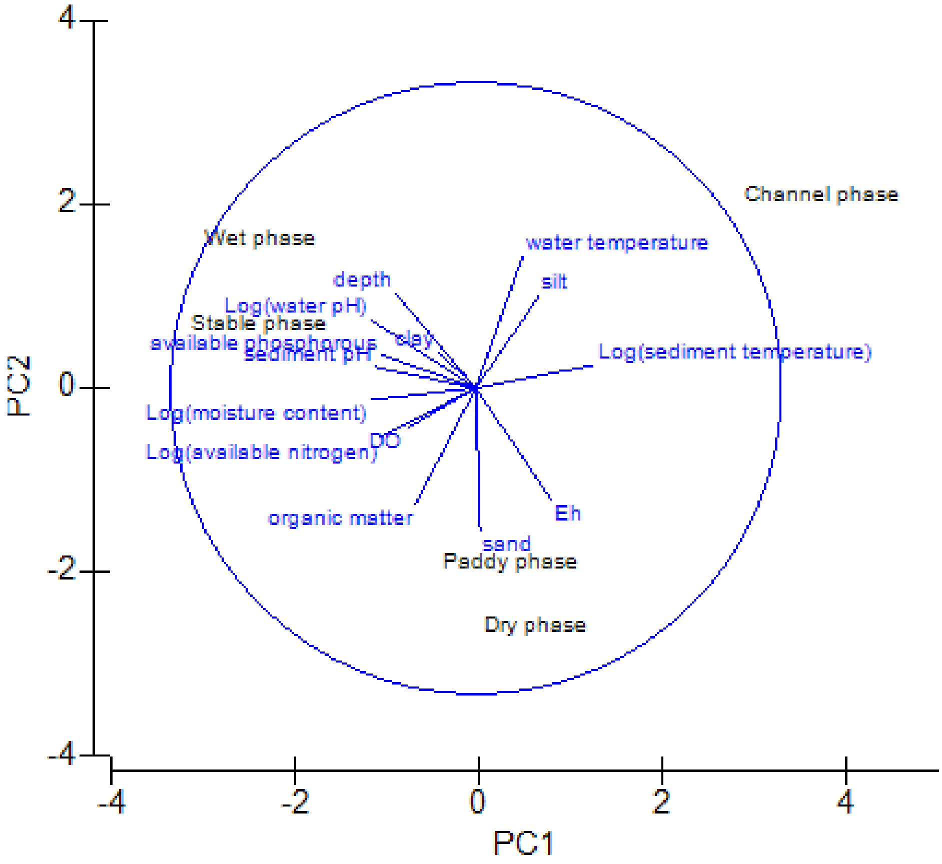


Fig. 4.36. Principal Component Analysis (PCA) ordination of environmental variables in different phases in Maranchery Kole wetland.

Chapter - 5

STANDING STOCK OF MACROBENTHOS

5.1 Introduction

According to Odum (1971), benthos are mainly detritivorous among decomposers, breaking down organic matter and substances, releasing compounds and elements back into the environment and carrying energy to the next trophic level. Benthic macro invertebrates are key components of aquatic food webs that link organic matter and nutrient resources present in the sediments with higher trophic levels (Wallace and Webster 1996). Its role as a link between primary producers, decomposers and higher trophic levels in the ecosystem is well known (Pandit et al. 1991).

The quantitative study on shallow water began by Peterson (1915) though Hensen introduced this aspect in ocean studies during the 1880s. The abundance and biomass of benthic organisms depend on a variety of factors such as depth, the nature of the substratum, presence of macrophytes, seasons and biological interactions such as competition, predation etc. The study on the bottom fauna in a tropical freshwater fish pond showed that the peak period in the abundance of most of the organisms was between the months of January and April (Michael 1964). The benthic study from Sacramento river showed a higher abundance of benthos in the upstream channel and was lowest at the downstream end also the total standing crop showed the highest value in June and lowest in November (Siegfried 1980). In Spain, benthos inhabiting in two areas different in habitat characteristics and aquaculture management revealed that several epibenthic species showed a higher abundance in the polyculture lagoon but were low in abundance or absent in monoculture ponds, whereas the infaunal species, were more abundant in the monoculture ponds (Drake and Arias 1997). Mwabvu1 and Sasa (2009) observed that the benthic macro-invertebrates in Fletcher Reservoir, Zimbabwe were unevenly distributed in space and time. The abundance of infaunal benthos showed the highest numbers in coarse-sand and gravel sediments, and lowest in fine, well-sorted, sand in Port Curtis estuary, north-eastern Australia (Currie and Small 2006). In a Portuguese estuary the highest and lowest densities of benthos were observed in the oligohaline and mesohaline habitats respectively (Chainho 2007). In wetlands in Maryland, the invertebrates densities differed with difference in percent of submergent and emergent vegetation, the highest densities associated with the highest percent vegetation and vice versa (Culler et al. 2013). Recently the seasonal variations of macrobenthic fauna in Lake Nasser khors, Egypt showed the highest abundance during spring, decreased during winter and summer (Gawad and Mola 2015).

The effect of hydrological fluctuations on the abundance and biomass of benthic organisms was studied by many authors such as in temporary and permanent streams by Miller and Golladay (1996), in intermittent streams by Shivoga (2001), in vernal ponds of USA by Brooks (2000), in Emporda salt marshes by Gascon et al (2007), in St. Lucia Estuary by Pillay and Perissinotto (2008), in a coastal lagoon in Nigeria by Uwadiae (2012) and in ephemeral wetlands of Southern Appalachia by Howard (2014). Further the ecology of macroinvertebrates in aquatic systems experiencing non-seasonal and unpredictable drying was documented by Ladle and Bass (1981), Wood and Petts (1999), Boulton (2003) and (Batzer 2013).

Vembanad Kole wetlands support a broad-spectrum of prawns and fishes. Fish is widely consumed in Asia, it is considered to be the major source of animal protein for majority of people in Asia and a major source of vital micro-nutrients (Demaine and Halwart 2001, Hassan 2001). Freshwater fish, because of its relatively low price, also represents a vital source of animal protein for lower income groups (FAO 2001). Fishing is an important livelihood option available in this wetland particularly during the monsoon months as monsoon period is experienced as lean period for farmers, they consider fishery as an alternative source of income. So the estimation of benthic standing stock is important for the assessment fishery resources. 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 benthic macroinvertebrates form an important source of food for birds (Wissinger 1999, Kear 2005). The role of benthic invertebrates as food for avian fauna also emphasise the need for benthic stock assessment.

5.2 Results

5.2.1 Numerical abundance and biomass of Macrobenthos

The numerical abundance and biomass of all macrobenthic groups are given in annexure 1 and annexure 2 respectively. The average numerical abundance of the macrobenthos showed the maximum value in May 2011(18%). It showed peaks in December 2009 (5%), January 2010 (5%), May 2010 (5%), September 2010 (5%), October 2010 (6%), November 2010 (6%), January 2011 (5%) and March 2011(7%). The lowest numerical abundance was recorded in December 2010 and June 2011 (1%) (Fig. 5.1). The station wise comparison showed that, station 4 had the maximum mean numerical abundance (25%) while station 1 has the lowest (7%) (Fig. 5.2). When the mean numerical abundance was compared among the wet, dry, paddy, channel and the stable phases, the dry phase showed the minimum numerical abundance (6%) and channel phase showed the maximum numerical abundance (57%) (Fig. 5.3). 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%). ANOVA results showed that there was a significant variation in abundance at 1% level between phases in the wetland (F=3.87) (Table 5.1).

The average biomass of 8 stations (mg/m^2) varied from 0.13% in November 2009 to 28.26% in February 2011 (Fig. 5.4). The minimum benthic biomass of 1% was observed in station 8. The maximum benthic biomass of 34% was observed in station 6 (Fig. 5.5). When the biomass was compared among the wet, dry, paddy, channel and the stable phases, the maximum biomass of 91% was recorded in the channel phase. The minimum value of 0.3% was observed in the dry phase (Fig. 5.6). The variation pattern of total biomass in the wet phase was similar to its abundance pattern. The highest biomass was recorded in September 2010 (39%) and the minimum in August 2010 (3%). In the dry phase, a maximum biomass was observed in June 2010 (23%) and minimum in May 2010 (5%). The total biomass in the paddy phase showed the maximum value of 84% in January 2011 and the minimum biomass was recorded in February 2011 (3%). In the channel phase, the total biomass of benthic fauna in the channel phase was characterized with an increase in biomass in February 2010 (22%), and May 2010 (74%) which was corresponding to the presence of molluscs in the sample. The highest peak in May 2010 corresponding to the highest biomass (74%) was also due to the highest benthic abundance in May 2011. April 2011 showed the lowest benthic biomass of 1%. ANOVA results showed a significant variation at 5% level in the biomass between phases (F=1.49) (Table 5.2).

5.2.2 Numerical abundance and biomass of Oligochaetes

The mean monthly variation in numerical abundance of oligochaetes ranged from 1% in June 2011 to 16% in May 2011 with an average value of 243 ind./ m^2. The numerical abundance showed peaks in December 2009 (7%), May 2010 (6%), September 2010 (7%) and October 2010 (8%). The depressions in the abundance graph were observed in March 2010 (1%), February 2010 (2%) and April 2011 (2%) (Fig. 5.7). When the average numerical abundance of oligochaetes was compared between the stations, the maximum numerical abundance was observed in station 4 (76%) and minimum in station 1 (1%) with an average of 225 ind./ m^2 (Fig. 5.8). The average numerical abundance between the five phases was compared. The minimum numerical abundance of oligochaetes was recorded in the dry phase (3%). The channel phase showed the maximum abundance (56%) (Fig. 5.9). In wet phase, oligochaetes showed the maximum abundance (29%) in September 2010 and minimum (7%) in December 2010. In dry phase, oligochaetes showed a slight decline in abundance from 38% in January 2010 to 5% in June 2010, with an exceptional increase of 33% in April 2010. Oligochaetes also showed the similar trend as that of total abundance in paddy phase, decreasing from 51% in January 2011 to 3% in February then increased in March and April, again decreased in May 2011. In channel phase, oligochaete abundance decreased from 12% in January 2011 to 2% in March 2011 then increased showing an unusually high abundance of 78% in May 2011. In stable phase, oligochaetes showed no clear trend in abundance. A maximum abundance of 32% was observed in October 2010 and minimum of 7% in December 2010. ANOVA results showed that there was a significant variation at 1% level between phases (F=3.97) when numerical abundance of oligochaetes was considered (Table 5.3).

Oligochaetes showed maximum biomass in May 2011 (41.9%) due to the exceptional abundance during May 2011. The minimum biomass was noted in April 2011 (0.19%). The monthly variation in biomass showed the maximum value in May 2011 (42%) and minimum of 0.2% in November 2009 (Fig. 5.10). Station 5 showed the highest biomass of oligochaetes (40.28%) and Station 1 the minimum value of 2.01% (Fig. 5.11). When the biomass of oligochaetes was compared between the wet, dry, paddy, channel and the stable phases, maximum biomass was noticed in the channel phase (86%) and minimum in paddy phase (1%) (Fig. 5.12). The biomass of oligochaetes in the wet phase showed no particular pattern. The maximum value was observed in September 2010 (61%) and minimum in December 2010 (1%). In the dry phase, the maximum biomass was recorded in January (46%). Paddy phase showed the highest biomass in January 2011 (48%) and lowest biomass in February 2011 (1%). Maximum and minimum biomass in channel phase was recorded in May (70%) and April 2011 (2%) respectively whereas in stable phase September 2009 (49%) was characterized by the highest biomass. ANOVA results showed a significant variation in the biomass at 1% level between phases (F=5.28) and stations within phases (F=2.29) (Table 5.4).

5.2.3 Numerical abundance and biomass of Insects

The monthly variation in insect abundance showed the maximum value in May 2011 (22%), with peaks in January 2010 (8%), September 2011 (8%), January 2011 (7%), February 2011(8%), March 2011 (11%) and April 2011 (8%). The minimum numerical abundance was observed in the month of September 2011 (0.54%). Comparatively lower abundance were observed in November 2009 (0.56%), October 2010 (1.02%) and June 2011 (0.65%) (Fig. 5.13). Station 4 showed the maximum numerical abundance of insect fauna (30%) while the minimum values were observed in station 8 (5%). Though station 1 showed the minimum numerical abundance when the total group and oligochaetes were considered, when insect fauna was considered, station 1 was the second numerically abundant station (14%) (Fig.5.14). The maximum numerical abundance of insect fauna among the wet, dry, paddy, channel and the stable phase was compared, the minimum and maximum abundance was observed in stable phase (3%) channel phase (57%) respectively (Fig. 5.15). In wet phase, insect abundance also showed a similar pattern as that of total benthic abundance and oligochaete abundance. The maximum abundance (50%) was seen in September 2010 and minimum (5%) in December 2010. In dry phase, the abundance pattern of insects was similar to the total abundance deceasing from 49% in January 2010 to 8% in June 2010 except a peak in April 2010 (16%). Paddy phase showed a declining pattern from 33% in January 2011 with the lowest abundance of 15% in March 2011 and April 2011 and then showed an increase in insect abundance. In channel phase, insect abundance increased from January 2011 (5%) to March 2011 (21%) then declined in April (5%) followed by unusual abundance of 65% in May 2011. Stable phase was characterized by the lowest insect abundance. The abundance showed the same mean values in January, February and March 2010 (24%) then declined to nil values in December 2010. There existed a significant variation in insect abundance at 1% level between phases (F=3.31) in ANOVA results (Table 5.5).

When the monthly mean variation in insect's biomass of was analyzed, the maximum biomass of 31.27% was recorded in May 2011. November 2009 showed the minimum biomass of 0.36% (Fig. 5.16). Station 4 showed the maximum biomass of 40% and station 6 showed the minimum biomass of 3% (Fig. 5.17). The minimum biomass was observed in stable phase (2%) and maximum in paddy phase 67%. In the wet phase, the biomass of insects was highest in September 2010 (28%) and lowest in December 2010 (7%). In dry phase, insect's biomass showed the minimum value of 14% in January 2010 to the maximum value of 23% in June 2010. The biomass of insects showed the highest value (46%) in January 2011 and minimum (9%) in April 2011 in the paddy phase. In channel phase, the highest biomass of insects was observed in May 2011 (70%), corresponding to the highest abundance in May 2011, also the lowest biomass was in April 2011 (2%). The highest biomass of insects in the stable phase was noted in September 2010 (43%) during stable phase. December 2010 was characterized by the absence of insects in stable phase (Fig. 5.18). ANOVA results showed a significant variation at 5% level between phases in insect biomass (Table 5.6).

5.2.4 Numerical abundance and biomass of Molluscs

Molluscs were represented in some of the stations and contributed only 0.48% of the total numerical abundance. The maximum numerical abundance recorded was 31% in station 8 in May 2011 (Fig. 5.19). Station 5 showed the maximum biomass of molluscs (50%) and was absent in station 3 (Fig. 5.20).

5.2.5 Numerical abundance and biomass of other groups

The other groups included crustaceans, pisces and hirudinae whose contribution to the numerical abundance was 0.1%, 0.1% and 0.03% respectively. Crustacean's biomass ranged from 3.6 mg/m^2 in station 2 in February 2011 to 7.6 mg/m^2 in station 7 in January 2010. Hirudinae was represented only once in station 1 in November 2010 with the biomass 3.88 mg/m^2.

The correlation in abundance between the macrobenthic groups were given in Table 5.7. There existed a positive correlation significant at 1% level in abundance between oligochaetes and insects.

5.3 Discussion

A comparison of numerical abundance between macro invertebrates in intermittent and permanent waters gave contradictory results by various researchers. A significantly lower abundance of macroinvertebrates in intermittent streams was reported by Shivoga (2001) and Smith et al. (2003). An extremely low abundance in intermittent streams in North Africa was observed by Arab et al. (2004). On the contrary, no significant differences between macrozoobenthic abundance in temporary and permanent streams was reported by Legier and Tallinn (1973), Miller and Golladay (1996). The suspected cause of this inconsistency was the local conditions and the differences in character and extent of drying. Compared to permanent locations, severe oscillations in the benthic abundance was observed in the intermittent sites compared to permanent locations. Along with the decreasing water level, abundance tends to decrease before complete drying (Fritz and Dodds 2004, Munoz 2003). Lake Chilwa, Central Africa, which was subjected to seasonal and long-term fluctuations in water level, the invertebrate biomass showed the highest biomass during periods of high lake level when different hydrological phases were compared (Cantrell 1988). Uwadiae (2009) reported that the faunal abundance of benthic organisms was similar for wet and dry seasons, indicating no strong seasonal influence in a coastal lagoon in Nigeria. While studying the benthic macrofauna of the St. Lucia Estuary during a drought year, the macrobenthic organisms showed a higher abundance in areas where hypersaline conditions and habitat loss were less severe (Pillay and Perissinotto 2008). Gascon et al. (2007) reported a decrease in numerical abundance of the characteristic species in the Emporda salt marshes due to hydrological disturbances. Picard et al. (2003) reported a threefold increase in the total abundance of polychaetes after the first flooding event in the Rhone River. Brooks (2000) studied the effect of hydroperiod on benthic macro invertebrates in vernal ponds in USA, where the variation in benthic macroinvertebrates abundance followed no particular pattern among years and pond hydroperiod but the abundance showed a steady increase over successive surveys within years. In these ponds, oligochaetes and crustaceans were the important constituents of the benthic fauna that showed less variation according to hydro period, which was agreeing to the observation by Wiggins et al.

(1980) that the abundance of these taxa are less affected by hydroperiod length, as they were best adapted to highly ephemeral ponds. In regulated waters with more pronounced water level fluctuations and higher magnitude drawdown, a lower macroinvertebrate densities were documented (Richardson et al. 2002, Furey et al. 2006, Valdovinos et al. 2007). A recent study in two brooks in Czech Republic showed a lower abundance of macroinvertebrates at the intermittently flooded site than the permanent flooded site (Reznickova et al. 2013).

The abundance of benthos also gets affected during reduced water levels due to the vertical migration through soil by benthos as a survival strategy. Paterson and Fernando (1969) found that oligochaete species burrowed downward (>20 cm) to avoid desiccation and winter freezing. Though chironomid abundance was stable at the initial days of their study, as the dry condition progressed, the chironomid abundance was altered. Hynes (1970) observed that after a drought, benthos recolonized rapidly in dry substrates from areas that remained wet.

A glance to the studies that compare the benthic organisms in wet and dry season reveals that a strict comparison of the results of the present study to similar studies is difficult because in most of the similar works done on benthic macroinvertebrates, the sampling was done with dip nets, Surber's net, kick-net etc. giving less emphasis to the digging fauna whereas in this study, the sampling was done with Van Veen grab focussing on the benthic infauna. 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. Especially in the dry phase, the samples were taken from the water patches in the dry area, the only habitable area for the benthic organisms. All the living benthic organisms in that area would be available only in that water patch which guarantees the availability of benthos in the sample. Paddy and channel phases were also characterized by a reduced habitable area. But during wet period, the benthic organism could be present anywhere in the wetland substrata, so the chance of finding benthic organisms in our grab is less, so a strict comparison becomes difficult.

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 obviously (Sommer and Horwitz 2009). Most of the previous studies also documented an increase in benthic abundance with higher water levels (Cantrell 1988, Gascon et al. 2007). 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 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 dry phase. According to Aspbury and Juliano (1998) habitat desiccation result in decreasing the abundance of organisms as a result of greater competition and other abundance-dependent effects. 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. Another peculiarity in the dry phase 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 (2009) 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. Contrary to this, the oligochaete density was found to be higher in dry periods in the Piumhi River Brazil. The suggested reason was that during flowing periods the organisms are dragged along the bottom by strong currents, as it happens during the rains, so this instability caused a reduced abundance in wet periods and the higher abundance in dry periods due to the stability of the habitat (Suriani-Affonso 2011, Ribeiro and Uieda, 2005). Martins et al. (2008) also documented similar finding in the Sao Pedro Stream, where tubificids were recorded in higher numbers in the dry period.

There was an unusually high abundance of benthos in May 2011 in the channels. The unusually high benthic abundance was observed previously by Wishner et al. (1990), the enriched sediment resulting from reduced consumption and degradation of sinking material in the oxygen minimum zone supplying high food level, was the suggested reason. According to Brinkhurst (1972), the competition in oligochaetes is avoided by selective digestion of the bacteria with the sediment, which lead to a degree of collaboration as faeces of one species of the worm becomes the preferred food for another species. This could be a probable reason for the close clumping of oligochaetes (Kumar and Bohra 1999). Brinkhurst (1972) documented that, the unusual abundance of oligochaetes especially tubificids were clear indication of excess organic matter in an environment where oxygen deficiency and high silt loads combine to kill most of the fauna. But in this study, in May 2011, all the environmental parameters analyzed, especially oxygen, organic matter and silt content remained similar to the other samples. Though tubificids were the most abundant (61%), naidids also showed a good abundance (39%) in the particular samples. Along with oligochaetes in the benthic sample, insect larvae especially chironomids also showed an unusually high abundance comparable to that of oligochaetes. However, both Wishner et al. (1990) and Brinkhurst (1972) emphasised the significance of the abundance of food source for the unusual benthic abundance. The organic matter in the present study was higher throughout the study period, ensuring a food source for benthos. Apart from the quantity of organic matter, the nutritional quality is also important in determining benthic abundance (Neiraa 2001, Cibic et al. 2007). The abundance of good quality food would have favoured the unusual benthic abundance in May 2010 or some specific, localized condition acting on a microscale which could not be recorded in the environmental analysis would have resulted in the patchy distribution of the fauna in channels as suggested by Verdonschot et al. (2011) from his studies on agricultural ditches from Italy.

The stations 4 and 5 showed an increased numerical abundance compared to all other stations, the stations 4 and 5 were characterised by the presence of numerous and diverse aquatic macrophytes. The aquatic macrophytes would have also played a significant role as benthos are benefited from macrophytes which are known to provide food resources, refuge from predators and water flow disturbance (Xie et al. 2011).

An increase in abundance in April 2010 was noticed during this study. A medium rainfall in April 2010, after a dry spell would have made the dry area wet, thereby making the inactive dormant forms of organisms live, which would have contributed an increase in abundance in April 2010. Though there was an increase in rainfall since April 2010, a prominent increase in abundance was not obvious. The rain after the dry spell would have made the difference rather than a continuous rainfall. On the contrary, when the south west monsoon began in June, the dry areas returned back to the wet phase, but a reduced abundance in June-July was observed. The sudden heavy rains would have brought large volume of water to the area, causing a flood like disturbance to the substrate; the reduced abundance could be related to this. Though the abundance increased with the onset of flow, a reduced abundance immediately after a flood was documented (Hynes 1975). After a reduction in abundance in the initial months of monsoon, an increase in abundance was observed in this study. Sharma and Rawat (2009) also reported a similar finding from Asan wetlands, Central Himalayas. The numerical abundance of oligochaetes showed peaks in abudance in Decmber 2010, January 2010 and 2011. The maximum numerical abundance of oligochaetes was noted during cold period (December and January) by Oomachan and Belaser (1986) and Sharma (2010). Coincidentally, the highest abundance of birds in Kole wetlands was observed in December and January (Jayson 2002). The high abundance of migratory birds when the oligochaete population was high was observed in Sirpur lake in Indore (Sharma 2010). A similar study from Jharkhand, revealed that the oligochaete popoulation was higher in summer months and lower in winter. The monsoon months July-October was found to be the lean months for oligochaete production (Kumar and Bohra 1999).

In this study, the variation pattern in numerical abundance of oligochaetes and insects remained almost similar throughout the study period. The statistic results also revealed a positive correlation significant at 1% level between oligochaete abundance and insect abundance. Insects in this study was represented mostly by chironomids. Chironomids and oligochaetes are alike to some extent as they get their chief source of energy ie. bacteria 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 1999). On the other hand, there is known to be a correlation between the ecological demands and distributions of chironomidae and oligochaete 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. However a clear decrease in oligochaete abundance in the dry and paddy phases was apparent when the insects remained high in abundance in these phases. A competition for food and space in a reduced habitable area could be the reason.

The numerical abundance of insects was more in paddy phase compared to the other phases. The different growth stages of paddy might have provided sufficient food for the insects and refuge from predators which could be the reason for the increased insect abundance in paddy phase. Ali and Ahmad (1988), Che Salmah and Abu Hassan (2002) documented that the tropical rice fields support a variety of insect fauna. Dry phase also showed an increased numerical abundance of insects. In dry phase, the water patches were separated from each other resulting in severe habitat fragmentation. But as the insects are characterized by flight dispersal mode, they are less affected by habitat fragmentation. Species that have greater adult migration abilities can disperse more easily between habitats and are less likely to be effected by habitat isolation (Smith and Brumsickle 1989).

Though oligochaetes and insects were the most numerically abundant organisms, their contribution to biomass was less due to their small size. The biomass varied largely due to the presence or absence of mollusc and pisces, though their numerical abundance seems insignificant compared to oligochaetes and insects. The biomass graphs went closely in parallel to the biomass of molluscs and pisces. All the peaks in the biomass graph were corresponding to the presence of molluscs or pisces in the sample. Station 3 where a lower biomass was recorded was characterized by the presence of only oligochaetes and insects, no other groups were present in these stations. The presence of pisces and molluscs in station 6 contributed to its highest biomass. The stations 1 to 5 which were the stations characterized by the physical disturbance, showed a decreased biomass compared to the stable stations 6 to 8. The stations 1 to 5 were dominated by the presence of oligochaetes of the family Naididae. Naididae are charecterized by their small body size whereas in station 6 to 8, the dominant oligochaete forms were Tubificidae which has large body size compared to Naididae. The dry and paddy phases showed low biomass. The shallow nature of the water body made the benthos more prone to predation from birds etc. resulting in less biomass and numerical abundance. The unsuitable condition there might have limited the growth and development of a large number of oligochaetes and those few species survived were small bodied naidids which could contribute very little to the biomass. The unusually higher biomass in the channel phase was characterized by the unusual numerical abundance in May 2011 in station 4. When the insect biomass was considered, the biomass was more in paddy and dry phases compared to stable and wet phases. The food and shelter provided by the different growth stages of paddy could be the reason.

Table 5.1. ANOVA of numerical abundance of macrobenthos in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	133.13	1.48
Station	6	66.30	0.74
Phase	3	347.49	**3.87
Station * Phase	7	23.81	0.27
Error	154	89.81	
Total	192		
R2 = .263			

** Variation is significant at 1% level

Table 5.2. ANOVA of biomass of macrobenthos in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	0.106946	1.17
Station	6	0.067272	0.73
Phase	3	0.13665	*1.49
Station * Phase	7	0.029819	0.32
Error	154	0.091177	
Total	192		
R2 = .220			

* Variation is significant at 5% level

Table 5.3. ANOVA of numerical abundance of oligochaetes in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	120.95	1.19
Station	6	76.70	0.75
Phase	3	403.43	**3.97
Station * Phase	7	44.62	0.44
Error	154	101.64	
Total	192		
R2= .222			

** Variation is significant at 1% level

Table 5.4. ANOVA of biomass of oligochaetes in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	0.143	1.95
Station	6	0.107	1.46
Phase/	3	0.388	**5.28
Station * Phase	7	0.168	**2.29
Error	154	0.073	
Total	192		
R2= .319			

** Variation is significant at 1% level

Table 5.5. ANOVA of numerical abundance of insects in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	111.18	2.57
Station	6	26.68	0.62
Phase	3	143.43	**3.31
Station * Phase*	7	15.62	0.36
Error	154	43.29	
Total	192		
R2 = .382			

** Variation is significant at 1% level

Table 5.6. ANOVA of biomass of insects in Maranchery Kole wetlands.

Source	df	Mean Square	F
Corrected Model	37	0.107	1.17
Station	6	0.067	0.73
Phase	3	0.137	*1.49
Station * Phase	7	0.030	0.32
Error	154	0.091	
Total	192		
R2 = .220			

* Variation is significant at 5% level

Table 5.7. Correlation between the abundance of macro benthic groups in Maranchery Kole wetland.

	Oligochaete	**Insect**	**Mollusc**	**Crustacea**	**Others**
Oligochaete	1				
Insect	0.537**	1			
Mollusc	-0.023	0.005	1		
Crustacea	-0.053	0.019	0-.021	1	
Others	-0.029	-0.022	-0.012	-0.009	1

** Correlation is significant at 1% level

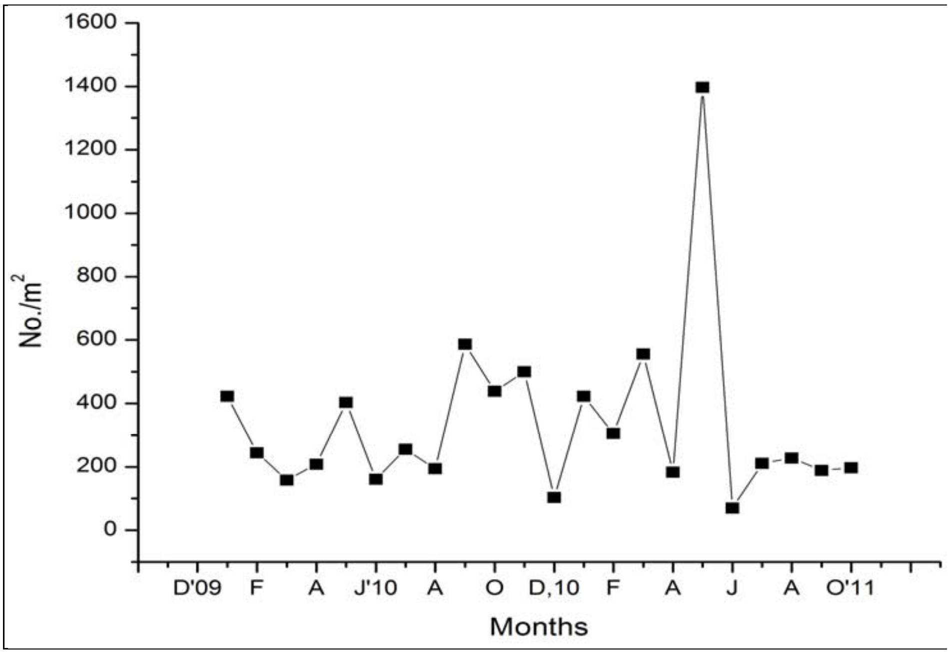


Fig.5.1. Monthly mean variation in numerical abundance of macrobenthos in Maranchery Kole wetlands during the study period.

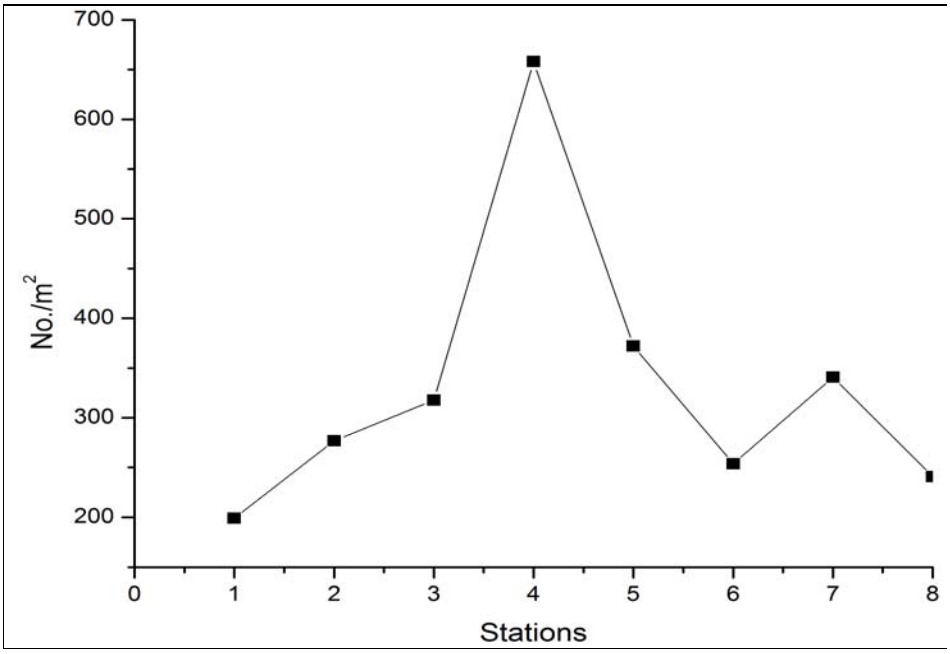


Fig.5.2. Mean variation in numerical abundance of macrobenthos in the eight stations in Maranchery Kole wetlands during the study period.

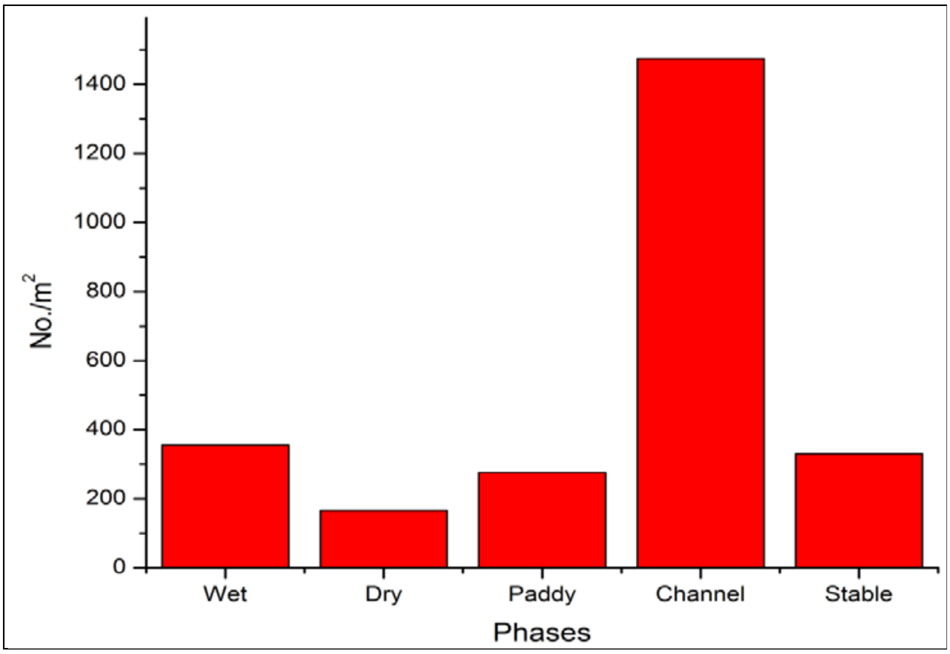


Fig.5.3. Mean variation in numerical abundance of macrobenthos in the five phases in Maranchery Kole wetlands.

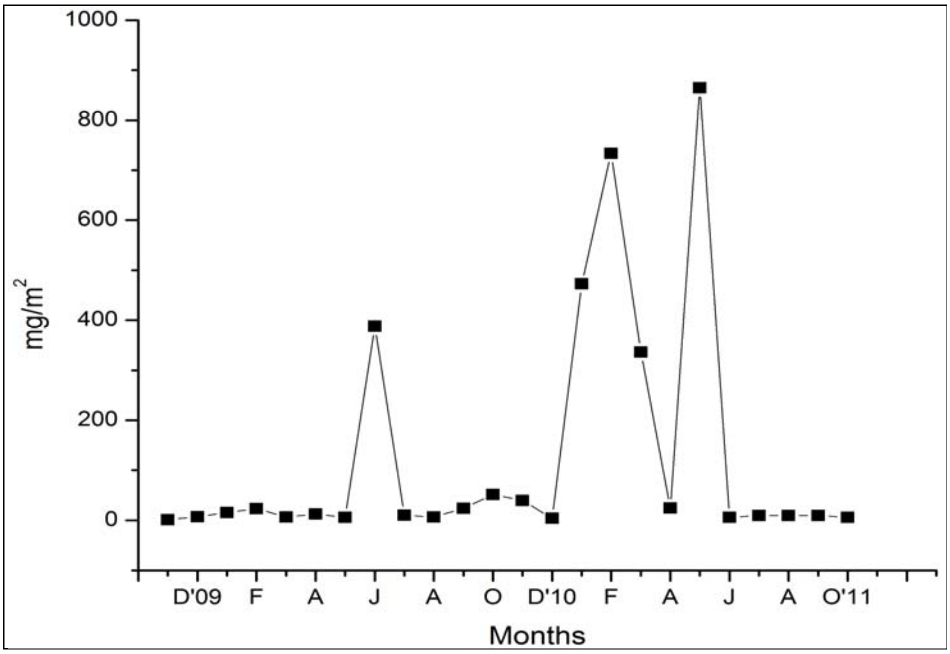


Fig.5.4. Monthly mean variation in biomass of macrobenthos in Maranchery Kole wetlands during the study period.

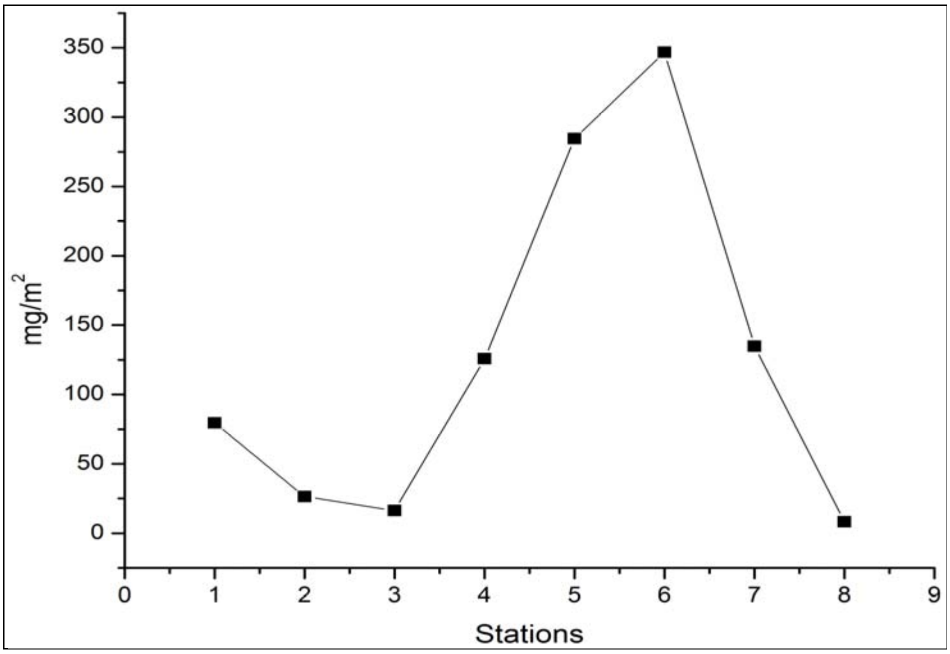


Fig.5.5. Mean variation in biomass of macrobenthos in the eight stations in Maranchery Kole wetlands during the study period.

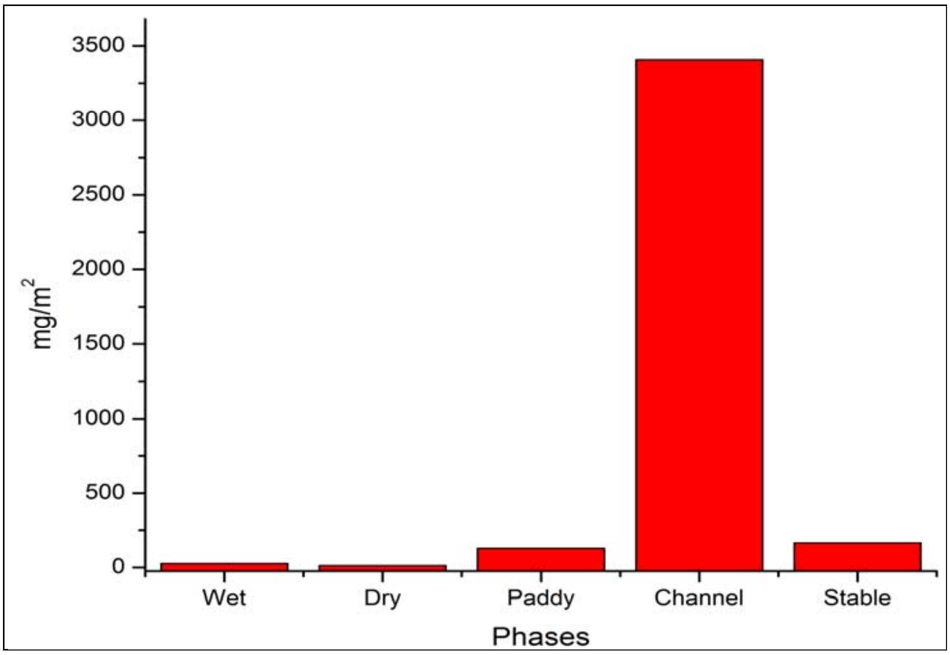


Fig.5.6. Mean variation in biomass of macrobenthos in the five phases in Maranchery Kole wetlands.

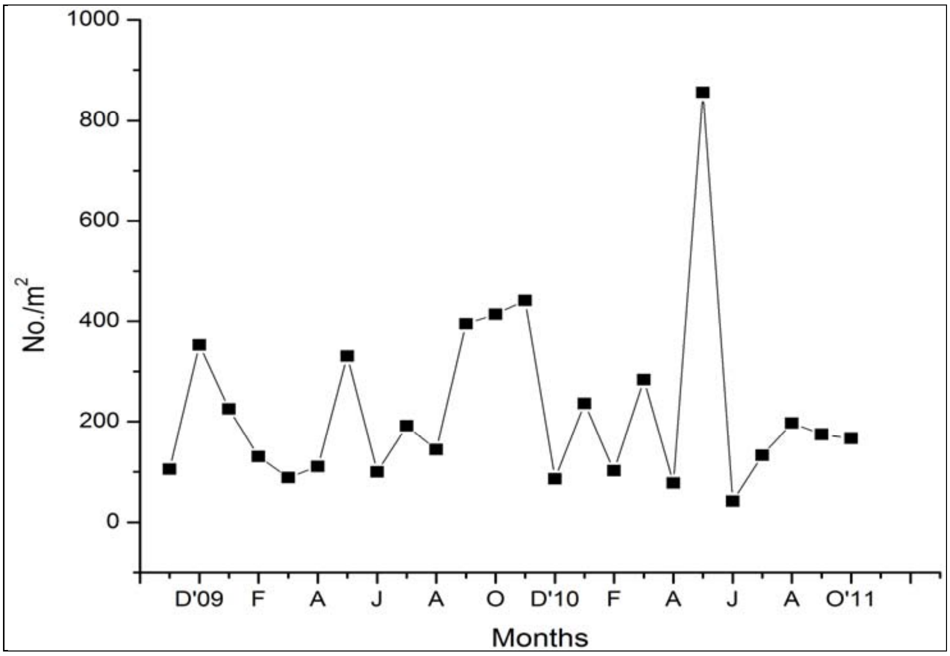


Fig.5.7. Monthly mean variation in numerical abundance of oligochaetes in Maranchery Kole wetlands during the study period.

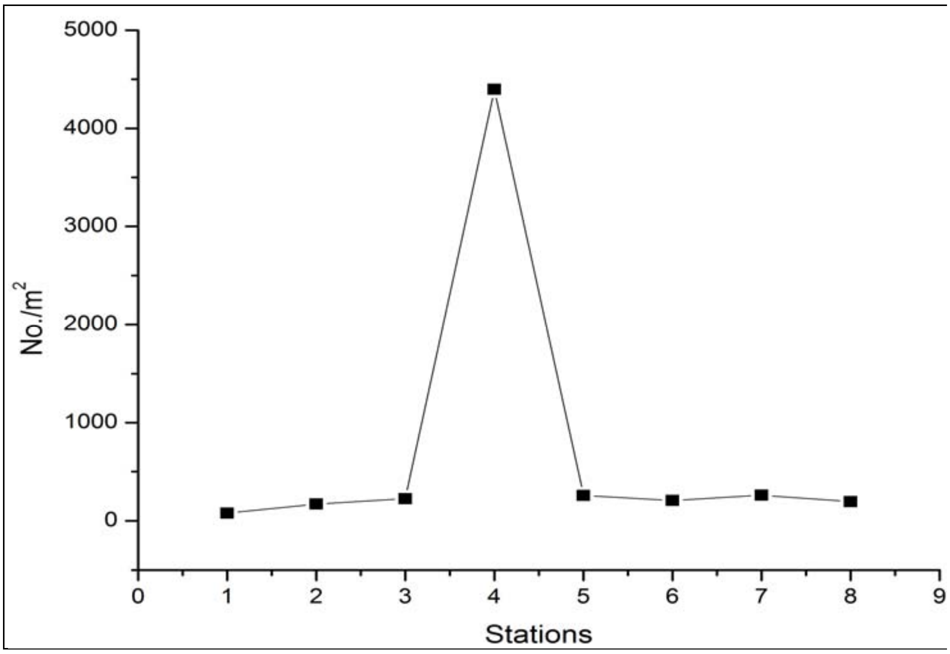


Fig.5.8. Mean variation in numerical abundance of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

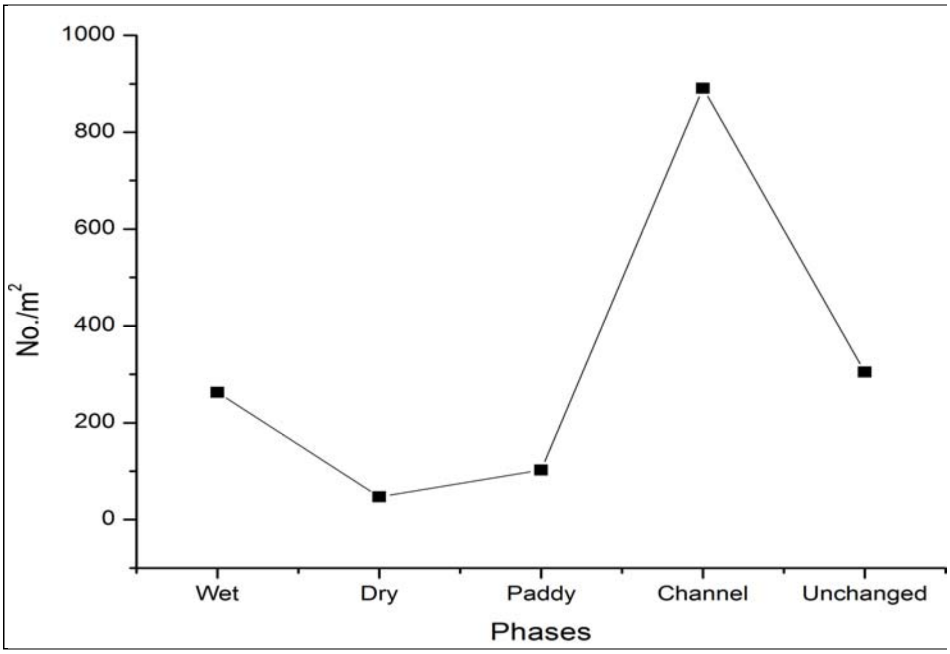


Fig.5.9. Mean variation in numerical abundance of oligochaetes in the five phases in Maranchery Kole wetlands.

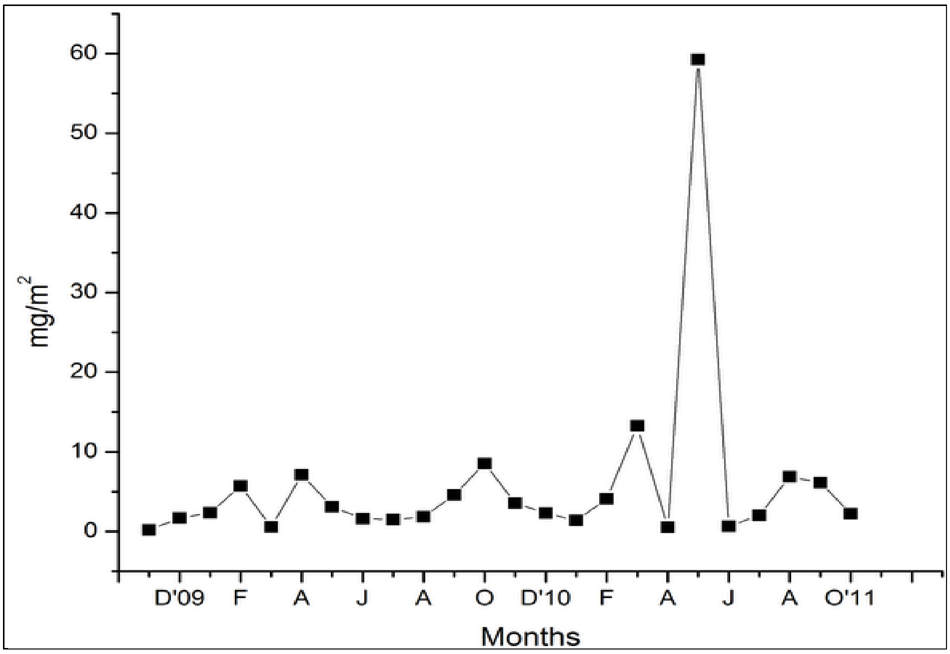


Fig.5.10. Monthly mean variation in biomass of oligochaetes in Maranchery Kole wetlands during the study period.

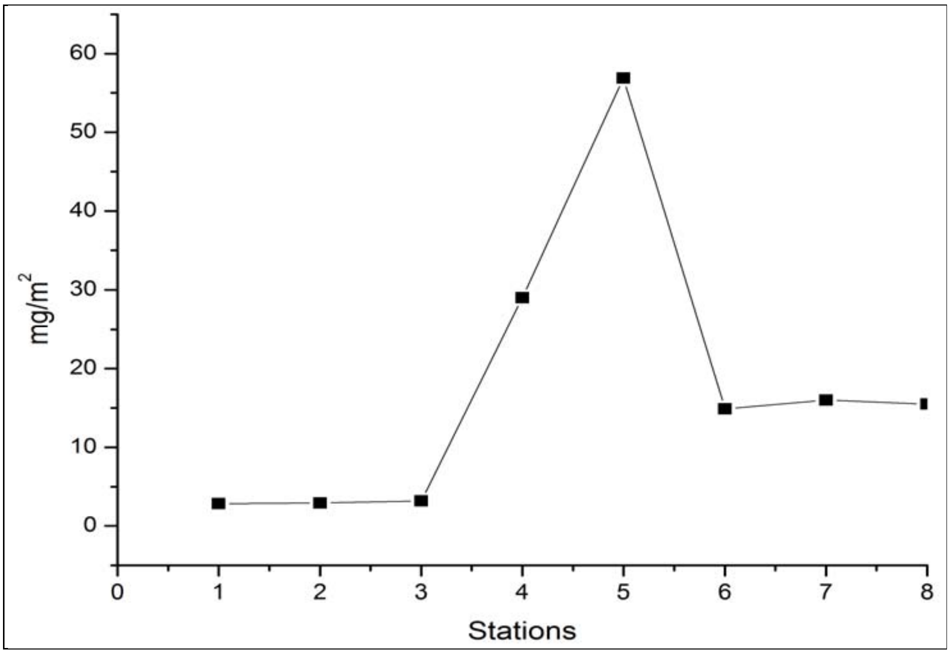


Fig.5.11. Mean variation in biomass of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

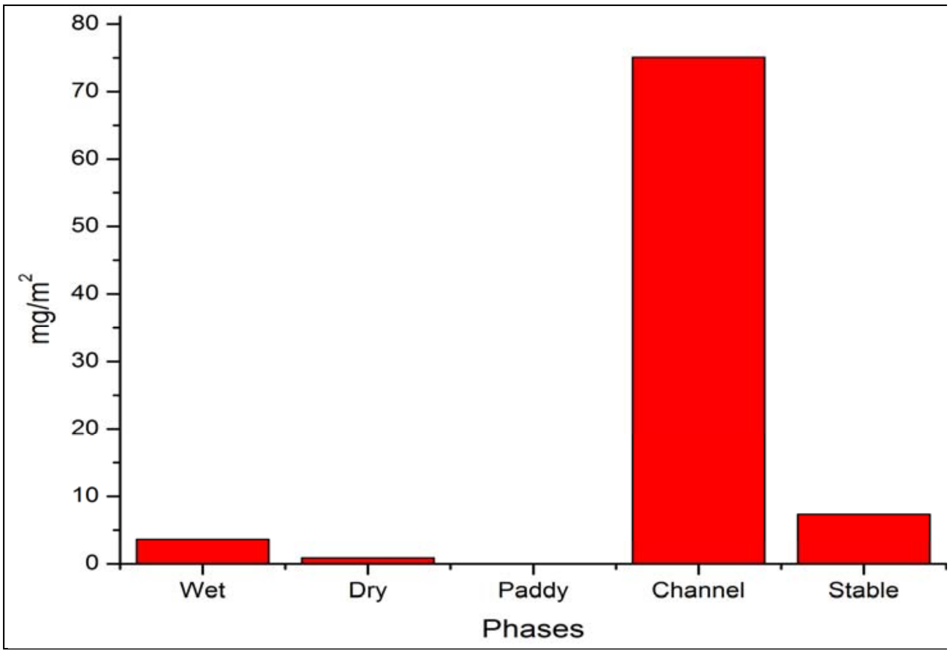


Fig.5.12. Mean variation in biomass of oligochaetes in the five phases in Maranchery Kole wetlands.

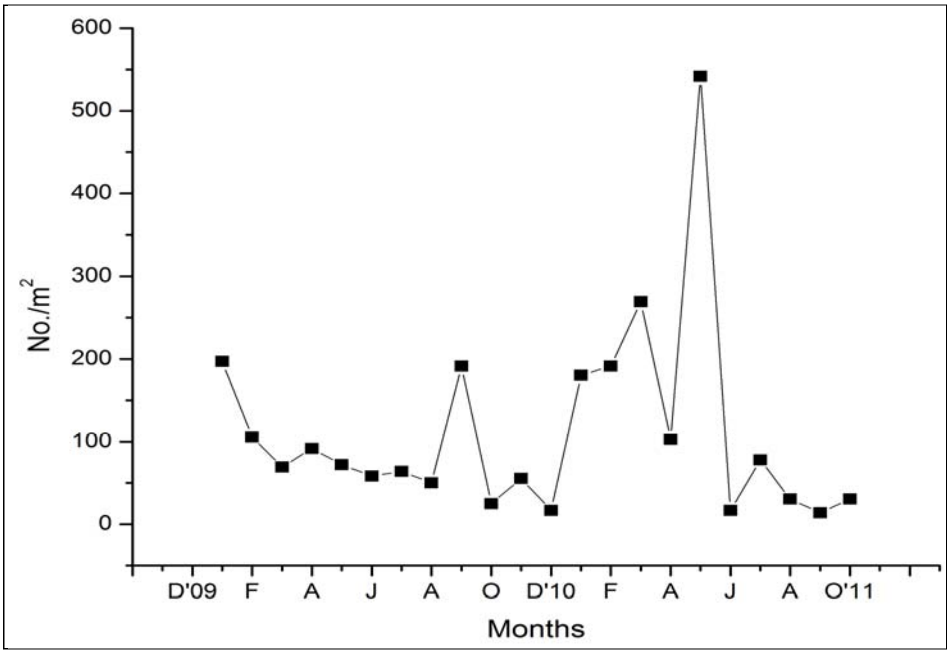


Fig.5.13. Monthly mean variation in numerical abundance of insects in Maranchery Kole wetlands during the study period.

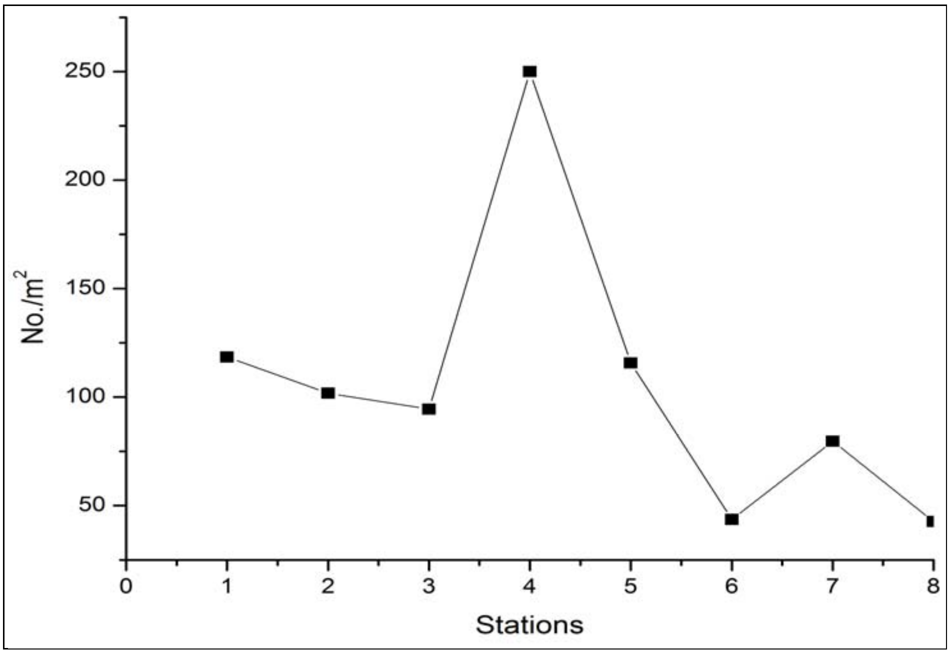


Fig.5.14. Mean variation in numerical abundance of insects in the eight stations in Maranchery Kole wetlands during the study period.

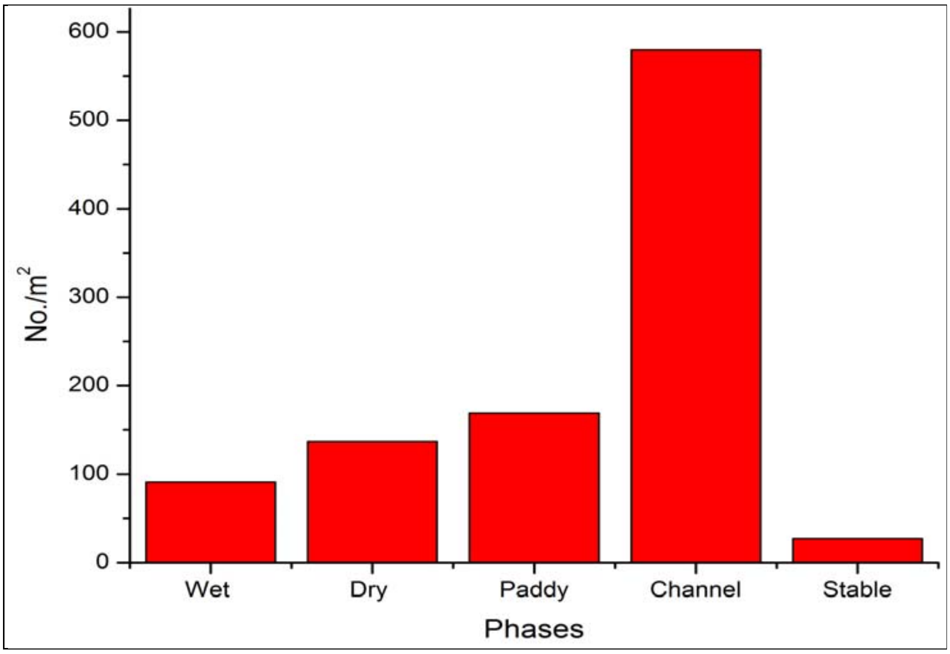


Fig.5.15. Mean variation in numerical abundance of insects in the five phases in Maranchery Kole wetlands.

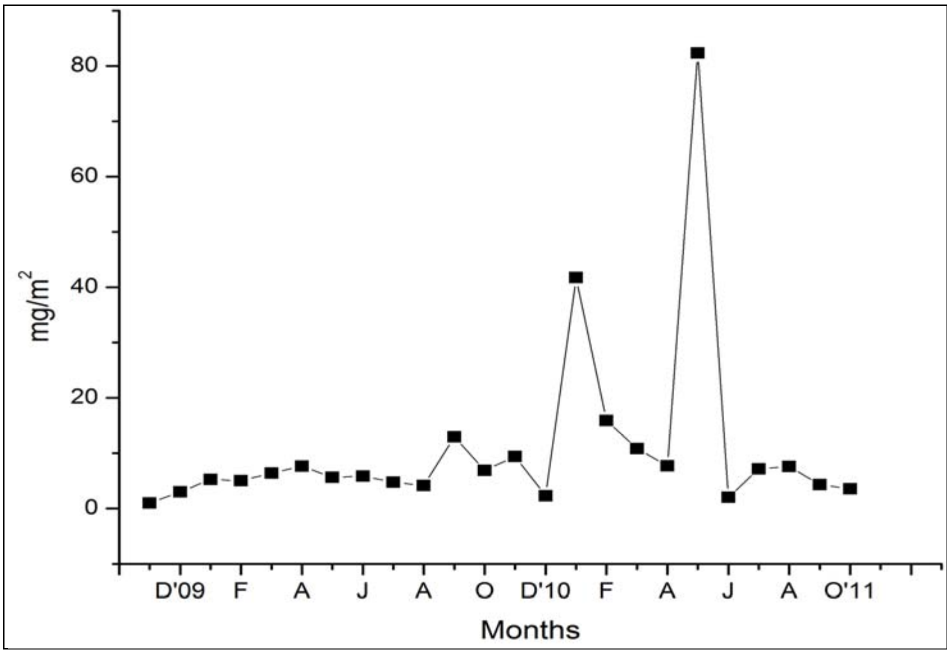


Fig.5.16. Monthly mean variation in biomass of insects in Maranchery Kole wetlands during the study period.

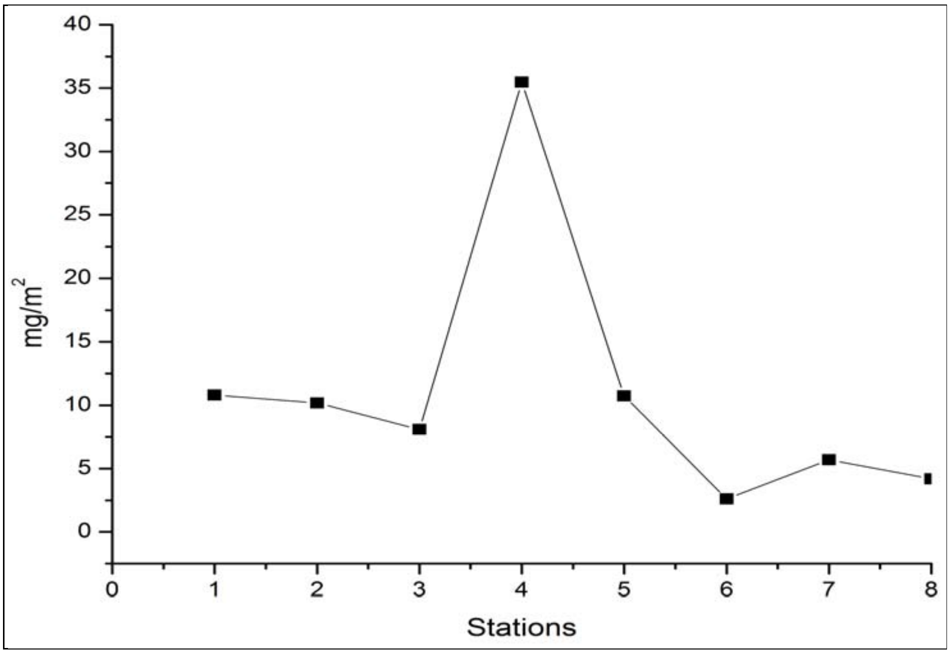


Fig.5.17. Mean variation in biomass of insects in the eight stations in Maranchery Kole wetlands during the study period.

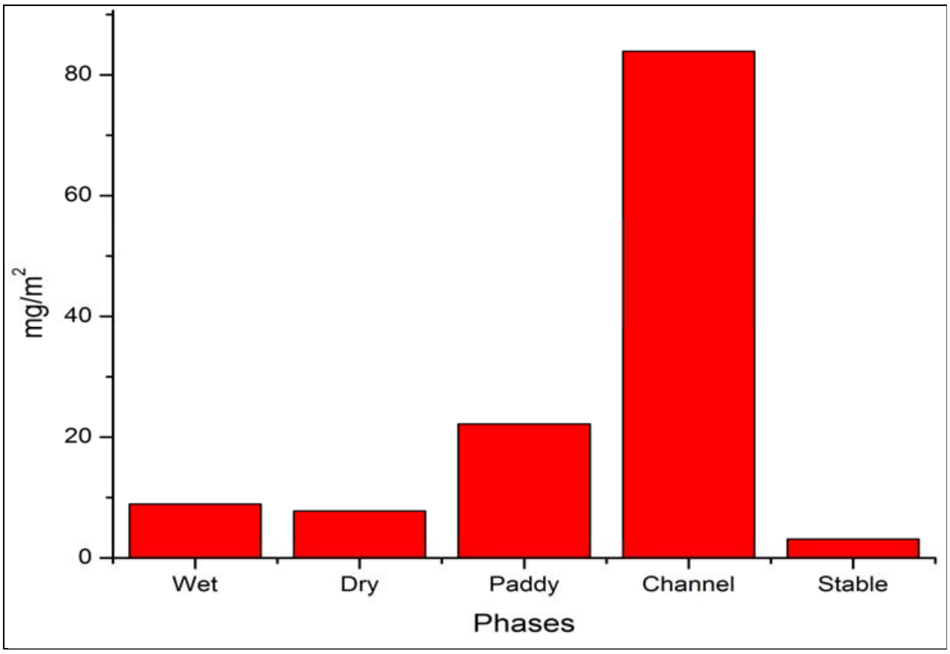


Fig.5.18. Mean variation in biomass of insects in the five phases in Maranchery Kole wetlands.

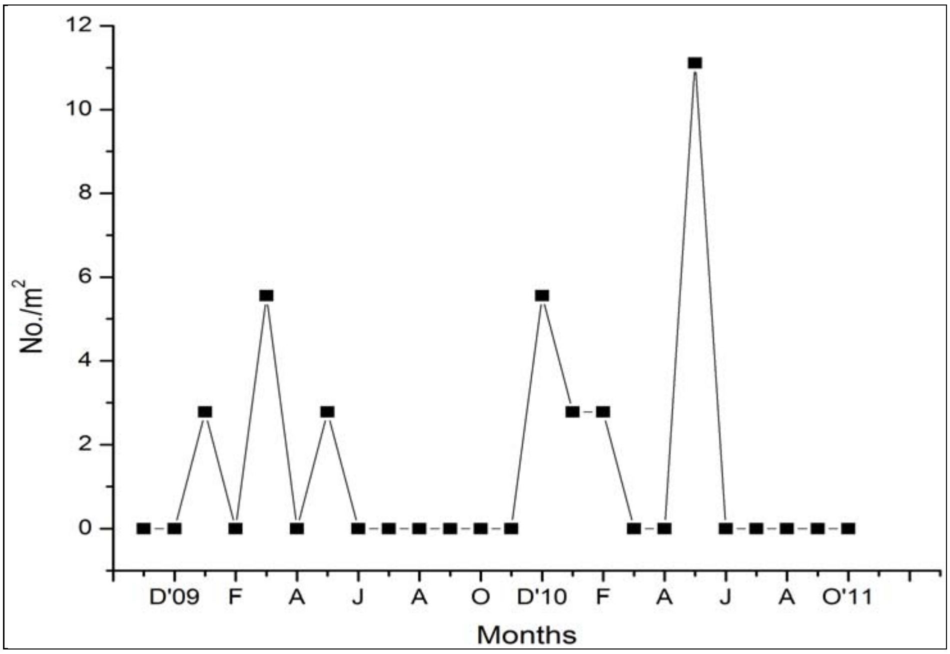


Fig.5.19. Monthly mean variation in numerical abundance of molluscs in Maranchery Kole wetlands during the study period.

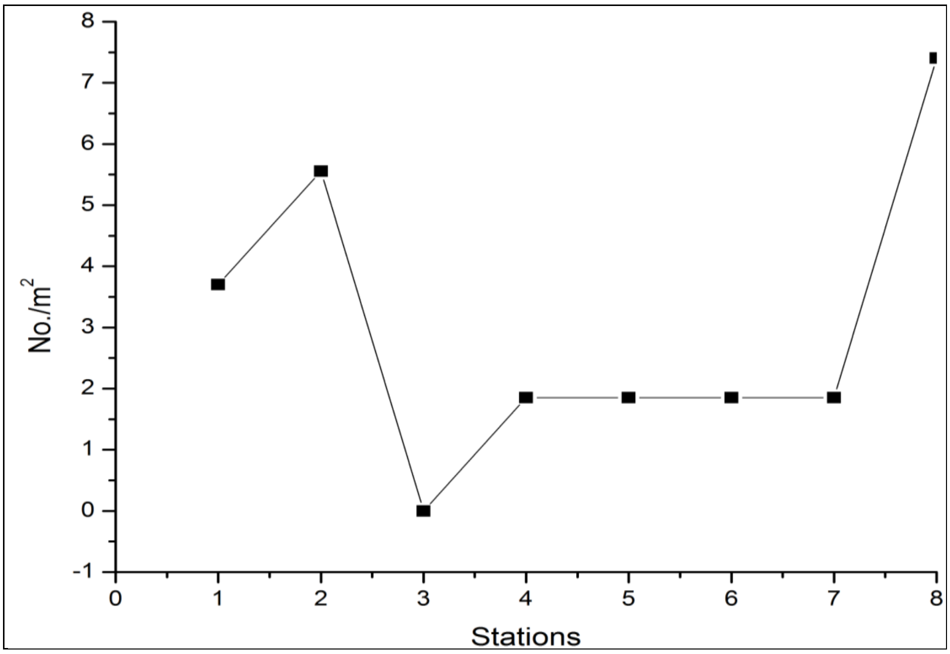


Fig.5.20. Mean variation in numerical abundance of molluscs in the eight stations in Maranchery Kole wetlands during the study period.

Chapter - 6

COMPOSITION AND COMMUNITY STRUCTURE OF MACROBENTHOS

6.1 Introduction

Benthos, the organisms that inhabits the bottom of the water body, plays an important role in aquatic community as it involves in mineralization, promotes mixing of sediments, transfers oxygen into sediments, cycles organic matter and are used to assess the quality of waters (Barnes and Hughes 1998, Idowu and Ugwumba 2005). Macro as well as micro invertebrates have their own significance in the ecosystem. Macrobenthic invertebrates form an integral part of aquatic environment and are 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 (Hutchinson 1993).

The macrobenthic community of an ecosystem, like other communities has a series of attributes that do not reside in the individual species components and has meaning only with reference to the community level of integration such as species diversity, growth form and structure, dominance, relative abundance and trophic structure (Kumar and Bohra 2005). Species are distributed individualistically based on their own genetic characteristics and populations of most of the species tend to change gradually along the environmental gradients (Kumar and Bohra 2005). The species composition especially of the benthic community in a given aquatic ecosystem often reflects the environmental conditions, which might have prevailed during its course of development. In case of adverse environmental conditions, the sensitive species might get eliminated, such changes in species composition are significant in monitoring the imprints of the adverse conditions. Thus the property of indicating such conditions make several groups of aquatic macroinvertebrates particularly the benthic organisms as good indicators (Hellawell 1986). Hence a study on the dynamics of composition and community structure of macrobenthic fauna becomes a reliable source to provide the picture of environmental status and influence of changing limnology of the concerned water body.

The literature on benthic studies is available from various parts of the world. The benthic community in Illinos River was studied by Richardson (1928). Hynes (1958) has extensively studied the benthic macroinvertebrate fauna of Welsh mountain stream. The benthic fauna of Sacramento River comprised of 30 genera, including both the epifauna and the infauna dominated by the Asiatic clam (Siegfried et al. 1980). Chironomids and oligochaetes dominated the benthic fauna in two shallow lakes Hudsons bay and Hoveton Great Broad, United Kingdom (Moss and Timms 1989). Picard et al. (2003) observed that the benthic fauna exhibited a strong year-to-year change in community structure in the Rhone river in Mediterranean. In Mondego river estuary, the polychaete, *Streblospio shrubsolii* and the amphipod *Corophium multisetosum* were the dominant species also the benthic community composition varied among different habitat types in the estuary (Chainho 2007). The study of macro-invertebrates in Fletcher Reservoir, Zimbabwe showed a total of 225 macroinvertebrates belonging to 37 species including Hemiptera, Odonata, Mollusca, Coleoptera, Diptera, Hirudinea, Ephemeroptera, Annelida, Decapoda and Trichoptera (Mwabvu1 and Sasa 2009).

Bijoy Nandan (2008) reported that amphipoda, polychaeta and gastropoda formed the dominant benthic group in the backwaters of Kerala. Latha and Thanga (2010) identified 24 families of benthic invertebrates belonging to Mollusca, Annelida and Arthropoda (crustaceans and insects) in Veli and Kadinamkulam lakes. Mytilidae of Molluscan family dominated the community there. A total of 62 macrobenthic species representing polychaetes, amphipods, bivalves and tanidaceans formed the most important benthic group from Cochin backwaters (Martin et al. 2011). Vyas et al. (2012) observed macrobenthos from 35 taxa belonging to the phylum Mollusca, Annelida and Arthropoda from River Narmada. Raju et al. (2013) documented ten benthic groups including Oligochaeta, Polychaeta, Algae, Amphipoda, Nematoda, Ostracoda, Copepoda, Insecta, Chironomous larvae and Bivalvia from Astamudi estuary, Kerala. Ishaq and Khan (2014) reported 27 genera belonging to seven orders of benthic organisms including Ephemeroptera, Diptera, Coleoptera, Hemiptera, Plecoptera, Odonata and Trichoptera from the River Yamuna at Kalsi.

Though paddy fields are called temporary wetlands, the benthic studies from paddy fields are scarce. One of the earliest researchers to document invertebrates in rice fields was Meien (1940) who recorded about 185 species belonging to four major phyla from rice fields in Uzbekistan. Heckman (1974, 1979) found insects to be the dominant aquatic invertebrates in rice fields of Laos and Thailand. Bambardaneniya (2000) recorded a total of 178 aquatic invertebrate species belonging to 96 families and 10 major phyla from an irrigated rice field in Sri Lanka. Half of the invertebrate species were arthropods (92 species) dominated by insects (62 species) followed by annelids (23 species) which was dominated by oligochaetes (21 species). In Pavia province, Italy, 4 phyla (Mollusca, Annelida, Nematomorpha, and Arthropoda) including 8 classes were the constituent benthic fauna in the rice fields (Lupi et al. 2013). The studies from the rice fields of Bako, Ethiopia revealed that the benthic fauna was composed of nematodes, oligochaetes, gastropods, chironomus larvae and other insect larvae (Desta et al. 2014). Fourteen species of invertebrate macrofauna belonging to Oligochaeta, Hirudinea, Gastropoda and Insecta have been recorded from the rice fields of Chapra, Bihar (Ojha et al. 2010). The benthic fauna recorded from paddy fields of Kashmir included 5 genera from Annelida, 1 genus each from Arthropoda and Mollusca (Bahaar and Bhat 2011).

The distribution of benthic organisms varies depending on many factors. When the microdistribution of macroinvertebrates in a temporary pond was studied, the central sediments were characterized by the presence of Oligochaeta Tubificidae, Nematoda, Chironomidae, Tanypodinae and Chironominae. Submerged macrophyte beds were characterized by Ephemeroptera, Odonata and Coleoptera species. The algal substratum was charecterized by species of Coleoptera and Hemiptera. The littoral sediments were characterized by Oligochaeta Enchytraeidae, young larvae of sympetrum and diptera Ceratopogonidae (Bazzanti et al. 2003). While studying the macrozoobenthos of Karavasta wetland Albania, Marzano (2010) revealed that polychaetes and crustaceans prevailed on soft bottoms whereas sponges, bryozoans, polychaetes, crustaceans and molluscs prevailed on hard substrates. A study on benthic macroinvertebrates in semi-natural, urban and agricultural land along the highland Ken River in central India revealed that insects dominated the fauna at semi natural (90%) and urban locations (93%) compared to agriculture sites whereas annelids also contributed a major share (32%) along with insects (48%) (Nautiyal and Mishra 2013).

Hydrological variability is a critical factor in structuring the composition and community structure of fresh water habitats. The effect of water level manipulation on the benthic invertebrates revealed that changes in macro invertebrate structure due to water level fluctuations was evident in shallow waters than deep waters (Mcewen and Butler 2009). The response of the organisms vary in the events of disturbances, species lacking the properties of resilience or resistance cannot survive the scenario compared to others (Gjerlov 1997). The studies on the response of benthos to a prolonged drought in South Africa revealed that there existed a core of taxa able to persist even under shallow depth conditions and prolonged hypersalinity. Six phyla of 46 families constitituted the taxa, annelida and arthropoda being the most abundant (MacKay 2010). Sommer and Horwitz (2009) studied the effect on the response of benthos to acidification induced by drought in wetlands on the Gnangara mound, Western Australia. Uwadiae (2009) reported the response of benthic macroinvertebrate community to salinity gradient in a lagoon in Nigeria where the faunal abundance, species richness, diversity and evenness of wet and dry seasons revealed no strong seasonal influence. The study on the impacts of hydrological disturbance on benthos, two benthic communities with different taxa composition was distinguished, one for more stable habitat type with permanent waters characterised by the dominance of *Corophium orientale* and another for more stressed habitat type with temporary waters characterised by the dominance of Chironomus *Gr. salinarius* (Gascon 2007). Castel et al. (1990) have also found that different benthic communities are characterised by the dominance of taxa adapted to their habitat characteristics. Pillay and Perissinotto (2008) observed that despite the ongoing drought conditions in St. Lucia Estuary, a strong resilience was evident on the macrofaunal community. Further the taxa recorded during normal, prolonged period of low salinities and period of marine salinities were comparable. Reznickova et al. (2013) while comparing the macroinvertebrate assemblages of an intermittent and a permanent brook in South Moravia observed that the functional structure of the assemblages, the shares of rheobionts, grazers and predators were different among them. The literature search clearly reveals a scarcity of information on the ecology and population characteristics and species structure of benthos from temporary waters in the Indian scenario. In this era, when the climate change predictions warns about increased dry spells, its impact on community pattern of aquatic organisms particularly of those residing in temporary environments is essential.

6.2 Results

6.2.1 Faunal Composition

6.2.1.1 Macrobenthic groups

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). Oligochaetes constituted 63.3% of the total organisms, followed by insects with 36%, the remaining contribution was from crustaceans, molluscs, hirudine and pisces (Fig. 6.1). Oligochaetes and insects were the groups present in all the stations whereas crustaceans, molluscs and pisces were not represented in all stations. Hirudinae was observed only once in the sample. Oligochaetes formed 38.75% of the benthic fauna in station 1 where insects contributed 59.81%, molluscs 0.46% and pisces 0.46% (Fig. 6.2); that in station 2 oligochaetes formed 62.54% of the benthic fauna, insects contributed 36.15%, molluscs 0.97% and crustaceans 0.32% (Fig. 6.3); that in station 3 oligochaetes formed 70.09% of the benthic fauna, insects contributed 29.90% (Fig. 6.4); that in station 4 oligochaetes formed 55.91% of the benthic fauna, insects contributed 44.05%, molluscs and hirudinae 0.01% each (Fig. 6.5); that in station 5 oligochaetes formed 68.73% of the benthic fauna, insects contributed 31.01% and molluscs 0.25% (Fig. 6.6); that in station 6 oligochaetes formed 81.75% of the benthic fauna, insects contributed 17.15%, molluscs 0.36%, hirudinae and pisces 0.72% (Fig. 6.7); that in station 7 oligochaetes formed 78.4% of the benthic fauna, insects contributed 20.94%, molluscs 0.43% and crustaceans 0.21% (Fig. 6.8); that in station 8 oligochaetes formed 82.03% and insects contributed 17.96% of the benthic fauna (Fig. 6.9). 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% (Fig. 6.10); that in dry phase oligochaetes formed 24.08% of the benthic fauna, insects contributed 74.87% and molluscs 1.07% (Fig. 6.11); that in paddy phase oligochaetes formed 39.31% of the benthic fauna, insects contributed 60.39% (Fig. 6.12); that in channel phase oligochaetes formed 60.39% of the benthic fauna, insects contributed 39.31% and molluscs 0.15% (Fig. 6.13); that stable phase oligochaetes formed 88.76% of the benthic fauna, insects contributed 10.86% and crustaceans 0.37% (Fig. 6.14).

6.2.1.2 Insects

The insects were the second major group observed in Maranchery Kole wetlands. Adult insects were very less in number whereas the major contributors were insect larvae. 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). The major share of insects was contributed by Diptera (78%) that was represented by Chironomidae (90.57%), Chaoboridae (2.73%), Ceratopogonidae (9.6%), Empedidae (0.24%) and Tipulidae (0.73%). Odonata formed 5.54% represented by Zygoptera (94%), Libellulidae (4%) and Coenegrionidae (2%). Trichoptera constituted 3.45% of the insects that was composed of Gyrinidae (41.93%), Hydrophilidae (45.16%), Limnephilidae (6.45%), Dryopidae (3.2%) and Dysticidae (3.2%). The contribution from Ephemeroptera was 0.22% of the insect fauna that was composed of Leptophlebidae (50%) and Baetidae (50%). Heteroptera and Megaloptera constituted 0.11% of the insects each represented by the only families Aphelecherinidae and Corydalidae respectively. A total of ten insect families were present in station 1, Chironomidae formed 57.07% of the insect fauna, Ceratopogonidae contributed 23.90%, hydrophilidae 5.85%, Libellulidae 2.44%, Leptophlebidae 2.44%, Limnephilidae 2.44%, Tipulidae 1.46%, Gyrinidae 1.46%, Chlorocyphilidae 1.46% and Aphelocheiridae 1.46%. In station 2, nine insect families were present, Chironomidae formed 61.23% of the insect fauna, Ceratopogonidae contributed 15.57%, Hydrophilidae 7.60%, Gyrinidae 4.34%, Chaoboridae 3.26%, Tipulidae 2.89%, Chlorocyphilidae 2.89%, Aphelocheiridae 1.08% and Dysticidae 1.08%. In station 3, five insect families were present, Chironomidae formed 73.30% of the insect fauna, Ceratopogonidae contributed 10.19%, Chaoboridae 6.79%, Gyrinidae 6.79% and Hydrophilidae 2.91%. In station 4, four insect families were present, Chironomidae formed 89.77% of the insect fauna, Ceratopogonidae contributed 7.96%, Empedidae 1.28% and Chaoboridae 0.26%. In station 5, 6 insect families were present, Chironomidae formed 88.66% of the insect fauna, Ceratopogonidae contributed 5.58%, Gyrinidae 3.04%, hydrophilidae 1.01%, Dryopidae 0.84% and Coenegrionidae 0.84%. In station 6, four insect families were present, Chironomidae formed 64.75% of the insect fauna, Ceratopogonidae contributed 27.20%, Tipulidae 5.74% and Chaoboridae 2.29%. In station 7, six insect families were present, Chironomidae formed 71.88% of the insect fauna, Chlorocyphilidae contributed 14.63%, Ceratopogonidae 7.45% and Chaoboridae 4.30%. In station 8, three insect families were present, Chaoboridae formed 87.99% of the insect fauna, Chironomidae contributed 11.17% and Ceratopogonidae 0.82% (Fig. 6.15). The insect fauna in wet phase consisted of Chironomidae (81.35%), Ceratopogonidae (11.86%), Chaoboridae (3.39%), Limnephilidae (1.69%) and Baetidae (1.69%); that in dry phase consisted of Chironomidae (50.28%), Ceratopogonidae (22.34%), Gyrinidae (15.64%), Empedidae (3.39%) and Aphelecherinidae (2.79%); that in paddy phase consisted of Chironomidae (51.35%), Ceratopogonidae (14.86%), Hydrophilidae (9.46%), Gyrinidae (12.6%), Aphelecherinidae (2.7%), Chaoboridae (1.35%), Tipulidae (1.35%), Empedidae (1.35%), Dryopidae (1.35%), Coenegrionidae (1.35%) Chlorocyphilidae (1.35%) and Libellulidae (1.35%); that in channel phase consisted of Chironomidae (75.09%), Empedidae (12.49%), Tipulidae (6.24%) and Aphelecherinidae (6.24%); that in stable phase consisted of Chironomidae (60.52%), Ceratopogonidae (18.41%), Chaoboridae (13.15%) and Tipulidae (7.2%) (Fig. 6.16).

6.2.1.3 Molluscs

Molluscs were the third abundant group represented by 0.42% of the benthic population. They were present in stations 1, 2 4, 5, 6 7 and 8. Among molluscs, the numerical abundance of gastropods was more compared to bivalves. Gastropods were represented by *Bithynia sp., Pyla sp.* and bivalves were represented by the families Unionidae and Lymnea.

6.2.1.4 Other groups

Crustaceans formed 0.10% of the benthic population represented by *Macrobrachium sp.* and the family paleomonidae. Crustaceans were present only in February 2010 in stations 1 and 7 and in station 2 in February 2011. Pisces and Hirudinae were the other groups present representing 0.10% and 0.03% respectively. Pisces present were *Mystus sp.* and *Tetradon sp.*

6.2.2 Community structure of macrobenthos

6.2.2.1 Univariate analyses of macrobenthic community structure

Monthly mean variation in richness of macrobenthic faunal groups in Maranchery Kole wetlands is presented in Fig. 6.17. The maximum richness was recorded in February in 2011 (d=0.69) and minimum in May 2011 (d=0.14). The mean richness was 0.27±0.14. The evenness based on benthic groups showed a mean value of 0.67±0.19 with the maximum evenness in January 2010 (j'=0.99) and minimum in October 2010 (j'=0.32) (Fig.6.18). Shannon Wiener diversity was the highest in June 2011 (H'=1.36) and lowest in October 2010 (H'=0.31) (Fig.6.19). The average diversity was 0.83±0.27. Dominance based on benthic groups ranged from 0.44 in June 2011 to 0.89 in October 2010 with an average value of 0.59±0.13 (Fig.6.20). When richness based on benthic groups was compared among the stations, the maximum richness was observed in station 1 (d=0.47) and minimum in station 5 (d=0.10) (Table 6.1) (Fig.6.21). The evenness based on benthic groups showed the maximum evenness in station 5 (j'=0.89) and station 6 showed the lowest (j'=0.37) (Table 6.1) (Fig.6.22). Station wise, the maximum diversity was in station 1 (H'=1.11) and minimum in station 6 (H'=0.75) (Table 6.1) (Fig.6.22). When the dominance based on benthic groups were compared, station 6 showed the maximum dominance (λ'=0.69) and station 1 the lowest (λ'=0.50) (Table 6.1) (Fig.6.23). When the 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) (Table 6.2) (Fig.6.24). Evenness index ranged from j'=0.33 in stable phase to j'=0.55 in dry phase when the phases were compared (Table 6.2) (Fig.6.25). 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) (Table 6.2) (Fig.6.26). 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) (Table 6.2) (Fig.6.27).

Variation in richness of insect families among the stations in Maranchery Kole wetlands is given in Fig.6.28. The maximum richness was observed in station 1 (d=1.57), closely followed by station 2 (d=1.494) and minimum in station 8 (d=0.27) (Table 6.1) (Fig.6.29). The evenness based on insect families showed the maximum evenness in station 6 (j'=0.63) and station 5 showed the lowest (j'=0.28). (Table 6.1) (Fig.6.30). The maximum diversity was in station 2 (H'=1.99) closely followed by station 2 (H'=1.94) and minimum in station 8 (H'=0.57) (Table 6.1) (Fig.6.31). When the dominance based on insect families was compared, station 5 showed the highest dominance (λ'=0.789) closely followed by station 8 (λ'=0.786) and the lowest station 1 (λ'=0.38) (Table 6.1) (Fig.6.32). When the richness was compared among different phases, the maximum richness was observed in paddy phase (d=1.25). The minimum richness was observed in the stable phase (d=0.60) (Table 6.2) (Fig.6.33). Evenness index ranged from j'=0.23 in channel phase to j'=0.70 in paddy phase when the phases were compared (Table 6.2) (Fig.6.34). The maximum diversity was in paddy phase (H'=1.97), closely followed by dry phase (H'=1.60) the lowest diversity was observed in the channel phase (H'=0.46) (Table 6.2) (Fig.6.35). The minimum dominance value was observed in the paddy phase (λ'=0.32), whereas the maximum dominance was observed in the channel phase (λ'=0.85) (Table 6.2) (Fig.6.36).

6.2.2.1 Multivariate analyses of macrobenthic community structure

Cluster analysis

Bray Curtis similarity for analyzing the similarity between the stations based on numerical abundance of total organism was done. The similarity between stations showed that station 4 was standing apart from the other stations with 30% similarity whereas the other stations were clustered with more than 80% similarity (Fig. 6.37). The similarity analysis between the phases showed that wet phase and stable phase were clustered at 96% similarity, dry and paddy phases were clustered at 83% similarity and channel phase was standing apart from the other phases with 55% similarity (Fig. 6.38).

MDS plots (Non metric multi dimensional scaling)

MDS plots were constructed to analyze the similarity between stations and phases with respect to total numerical abundance. The MDS plots showed an average of 20% similarity for all stations. Stations 1,2,3,5,6,7 and 8 were clustered together at 60% similarity but stations 4 was standing apart from the other stations. The stress value of MDS plots was 0.01 (Fig. 6.39). 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. 6.40).

6.3 Discussion

Aquatic biota, by definition, are characterised by adaptations to an existence in water. Therefore, it is predicted that artificial or natural drying could stress or even eliminate these biota from aquatic environment. The temporary fresh waters that experience a recurrent dry phase of varying length that is sometimes predictable in both its time of onset and duration occur in most regions (Williams et al. 1996). Even though regional differences prevail in their type and method of formation they have many physical, chemical and biological properties in common (Williams 1996). Fauna inhabiting such temporary waters require adaptations that promote resistance (the ability to tolerate a disturbance) and resilience (the ability to recover following a disturbance) to stream bed drying (Lake 2000). These adaptations include physiological, behavioural, morphological and life history strategies (Humphries and Baldwin 2003). Physiological adaptations to habitat drying include desiccation tolerant egg, larval or adult stages in either a dormant active state (Williams 2006). Life history adaptations common in aquatic insects, involve the synchronization of terrestrial life stages with regular streambed drying events (Salavert et al. 2008), although such strategies may not promote persistence during unpredictable hydrological disturbances (Lytle and Poff

2004). Behavioural adaptations centre on the use of physical habitat refugia that minimise exposure to adverse conditions (Lancaster and Hildrew 1993). Refugia during drying events are areas that either retain free water or maintain relatively high humidity (Boulton 1989). The following organisms which were present in Maranchery Kole wetlands 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 (Williams et al. 1987). Apart from pisces and crustaceans whose representation in Maranchery Kole wetland was nominal, all the other benthic organisms were found to have survival mechanisms against dry periods. So, such survival mechanisms maintained the benthic populations in Maranchery wetland during the different phases of the study.

When oligochaetes, the most abundant organism in Maranchery wetland was concerned, they are aquatic worms and are passive colonizers which may be introduced to a new habitat by wind, water fowl and wading birds (Chekanovskaya 1981). There are contradictory statements about the colonization ability of oligochaetes. According to Johnson (1969) and Poddubnaya (1980) oligochaetes and chironomids, were well adapted for colonizing newly established habitats whereas Bingham and Miller (1989) and Levin et al. (1996) mentioned about the slow rate of colonization of oligochaetes due to the absence of a planktonic dispersal stage. However, oligochaetes, the most abundant taxa in Marnchery Kole wetlands 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 (MacKay et al. 2010). Due to this reason, the fragmented water patches that could restrict the planktonic larval distribution does 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 Maranchery Kole wetland ensuring their presence in all the phases.

Fowler (2004) studied the recovery of benthic invertebrates in the braided Tulituki and Waipawa Rivers in New Zealand after dewatering and found out that the invertebrates rapidly colonized each denuded site and although some invertebrates were numerically dominant at different times, more than 95% of the taxa were present after 7 days. The sampling interval in our study was monthly, so the benthic fauna would have recovered from the extreme events by that time. In Maranchery, a closer sampling interval would have provided a better picture of impact on benthic fauna of the different events. Experiments on the colonisation of benthic communities revealed that the benthic invertebrates were present immediately after disturbances such as floods and channel dewatering (Williams and Hynes 1976, Sagar 1983), though pre-existing community composition may not be achieved for months (Cairns et al. 1971). In central Scotland re colonization of benthic invertebrates following before and after a drought in small streams indicated that the period of drought has had only a limited effect on the benthic communities (Morrison 1990). The appearance of oligochaetes soon after a drought has been reported from Wales, UK by Hynes (1958) and from Rhodesia, southern Africa by Harrison (1966).

Earlier studies states 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 (Lake et al. 1989, Boix et al. 2004). 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 structure.

Apart from the oligochaetes, insects were the most abundant group found in Marachery Kole wetlands. Though the number of insect families was similar in wet, dry, channel and stable phases (4-5 families), the number of insect families in paddy phase (9 families) was almost twice compared to the other phases. Lupi et al. (2013) recorded 23 insect families from Italian rice fields. The vegetative and reproducing growth stages of the rice plant such as tillering, booting and flowering stages attract a variety of phytophagous insects (Edirisinghe and Bambaradeniya 2006). The contribution of insects in benthic faunal abundance in paddy fields was mentioned in many studies (Yamazaki et al. 2013, Edirisinghe and Bambaradeniya 2006). Chironomidae was the only insect family present in all the phases.

Molluscs were present in few numbers. Previous studies show that the benthos is dominated by gastropod molluscs in littoral areas rich in aquatic vegetation whereas oligochaetes and dipterans dominate in organically rich habitats (Ahmed and Singh 1989, Vikram Reddy and Malla Rao 1989). The rich organic content in our study also supports the dominance of oligochaetes and chironomids. The contribution from other taxa was also nominal.

While considering the functional feeding groups of the benthic fauna in Maranchery Kole wetland, the predominant feeding group was collector gatherers (Naididae, Tubificidae, Lumbriculidae, Chironomide) that feed on deposited fine particulate organic material followed by predators (Ceratopogonidae, Chaoboridae, Tipulidae, Empedidae, Gyrinidae, Hydrophilidae, Dysticidae, Coenegrionidae, Chlorocyphilidae, Libellulidae, Aphelocheiridae, Hirudinae, Calopterygidae, Bagridae, Euphaeidae, Chauliode) that feed on other macroinvertebrate fauna by engulfing prey, scrapers (Dryopidae, Limnephilidae, Leptophlebidae, Baetidae, Bithynidae) that feed on aufwuchs from various substratum surfaces, collector filters (Lymnaeidae) that feed on entrained materials (detrital, microbial, algal, or animal) in the water column, Shredders (Ampullariidae) that feed or live on detrital plant tissue (coarse particulate organic material). The recognition of macroinvertebrate functional groups, their relative abundances and the ratios of various functional groups reflect environmental conditions, especially the quantity and quality of particulate organic matter inputs, periphyton growth and the nature of the organic food resources available (Cummins and Klug 1979, Wiggins and Mackay 1979). The predominance of collector gatherers in this study indicates the abundance of fine organic particulate matter (FPOM) in the system. A low ratio of shredders indicates that the coarse particulate organic matter (CPOM) is low.

Similarly a low ratio of filter-gatherers reveals that fine particulate organic matter in suspension is low compared to fine particulate organic matter in the substrate.

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 array 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. Further the input of nutrients resulting from agricultural practices can elevate primary productivity and algal concentrations, consequently altering the sources of organic matter (Wiley et al. 1990, DeLong and Brusven 1998) and the structure of macroinvertebrate communities (Sponseller et al. 2001). The shallow nature of the paddy fields also allowed more light penetration upto 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 is normally experienced in rice fields was not there. It also would have contributed to the high diversity here.

In the case of insects, richness and diversity was higher in dry and paddy phases. Unlike the wet, channel and stable phases where oligochaetes were the most numerically abundant group, in dry and paddy phases insects were the most numerically abundant group even though the abundance in dry and paddy phases was comparable to that of the other phases. The habitat fragmentation in dry and paddy phases favoured insect taxa more due to their active/flight mode of dispersal also shallow water in dry and paddy phases favours insects compared to oligochaetes. The reduced competition in these phases from oligochaetes also would have resulted in more richness and diversity. Moreover the availability of a more protected habitat niche by paddy plants to the insect to thrive could be the reason. Previous studies on temporary environments across the world also reported that the aquatic insects were the major component of the fauna in these habitats (Lake et al. 1989, Bazzanti et al. 1996, Boix et al. 2001)

The MDS cluster groupings between stations grouped station 4 significantly different from the other stations. The unusually highest abundance of oligochaetes and insects in May 2011 along with the presence of hirudinae made station 4 different from the other groups. 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 charecterized 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 (Clark 1993).

Table 6.1. Mean diversity indices of macro benthic faunal groups in the eight stations in Maranchery Kole wetlands during the study period.

	Richness (d)	Evenness (J')	Diversity (H')	Dominance (λ')
Station 1	0.4722	0.4782	1.11	0.5035
Station 2	0.341	0.5285	1.057	0.5159
Station 3	0.112	0.8702	0.8702	0.5872
Station 4	0.3103	0.4933	0.9866	0.5254
Station 5	0.1099	0.8943	0.8943	0.5714
Station 6	0.3443	0.3776	0.7552	0.6978
Station 7	0.333	0.4182	0.8364	0.6335
Station 8	0.2309	0.4944	0.7836	0.6839

Table 6.2. Mean diversity indices of macro benthic faunal groups in the five phases in Maranchery Kole wetlands.

	Richness (d)	Evenness (J')	Diversity (H')	Dominance (λ')
Wet phase	0.3406	0.5316	0.8426	0.6141
Dry phase	0.3911	0.5535	0.8772	0.6162
Paddy phase	0.5339	0.5372	1.074	0.5116
Channel phase	0.4111	0.4986	0.9972	0.5189
Stable phase	0.345	0.3348	0.5307	0.7991

Table 6.3. Mean diversity indices of insect families in the eight stations in Maranchery Kole wetlands during the study period.

	Richness (d)	Evenness (J')	Diversity (H')	Dominance (λ’)
Station 1	1.575	0.5851	1.944	0.3869
Station 2	1.494	0.6004	1.994	0.3998
Station 3	0.6529	0.5771	1.34	0.5568
Station 4	0.5758	0.4416	1.025	0.6489
Station 5	0.8223	0.2799	0.7235	0.7899
Station 6	0.5699	0.6394	1.279	0.4945
Station 7	0.9583	0.5091	1.429	0.5296
Station 8	0.2709	0.3615	0.5729	0.7867

Table 6.4. Mean diversity indices of insect families in the five phases in Maranchery Kole wetlands.

	Richness (d)	Evenness (J')	Diversity (H')	Dominance (λ’)
Wet Phase	0.8672	0.3054	0.7091	0.7614
Dry Phase	0.9761	0.6928	1.609	0.4384
Paddy Phase	1.25	0.7046	1.978	0.3298
Channel Phase	0.4945	0.2312	0.4624	0.8551
Stable Phase	0.6086	0.607	1.214	0.541

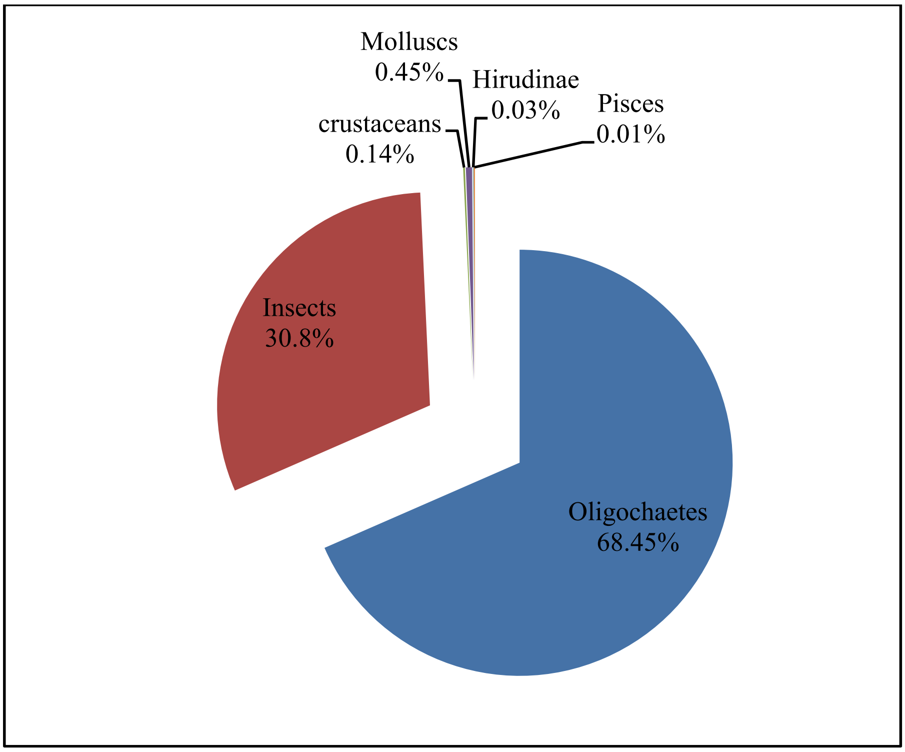


Fig.6.1. Mean percentage composition of macro benthic groups in Maranchery Kole wetland during the study period.

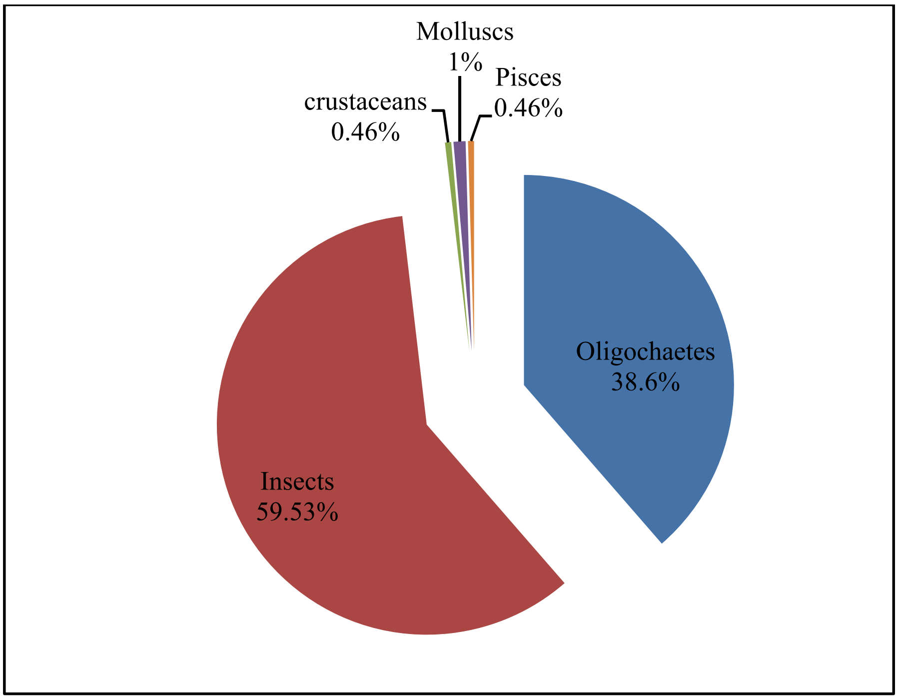


Fig.6.2. Mean percentage composition of macrobenthic faunal groups in station 1 in Maranchery Kole wetland during the study period.

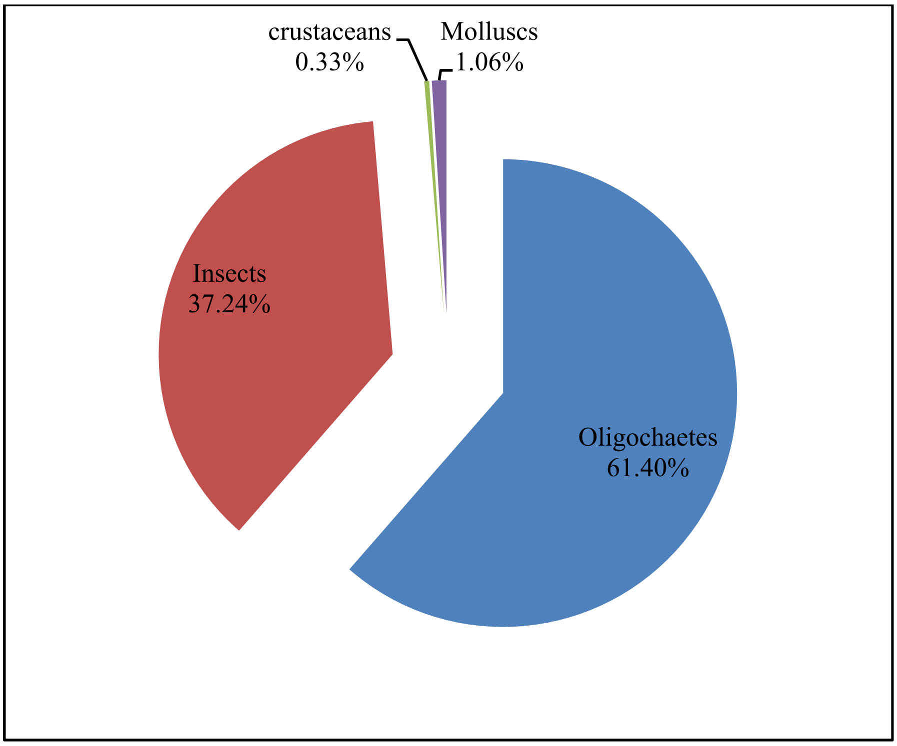


Fig.6.3. Mean percentage composition of macrobenthic faunal groups in station 2 in Maranchery Kole wetland during the study period.

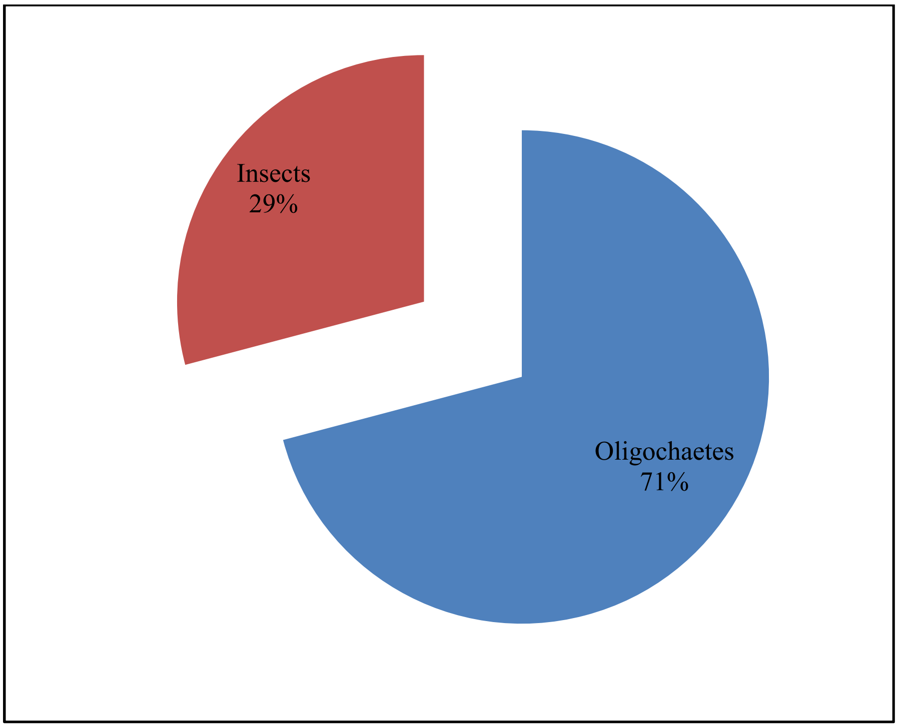


Fig.6.4. Mean percentage composition of macrobenthic faunal groups in station 3 in Maranchery Kole wetland during the study period.

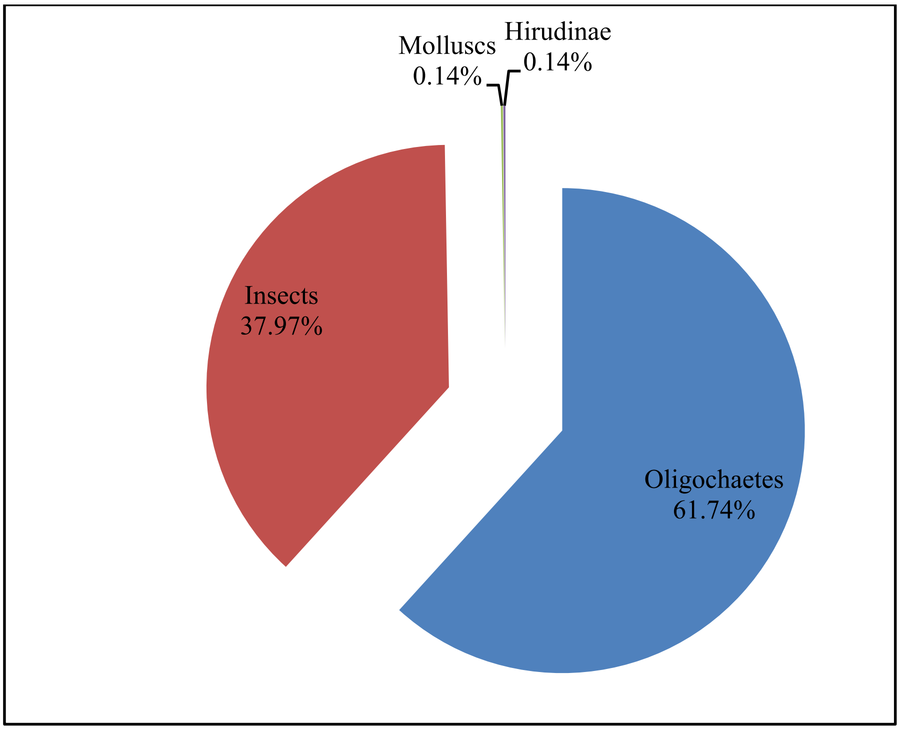


Fig.6.5. Mean percentage composition of macrobenthic faunal groups in station 4 in Maranchery Kole wetland during the study period.

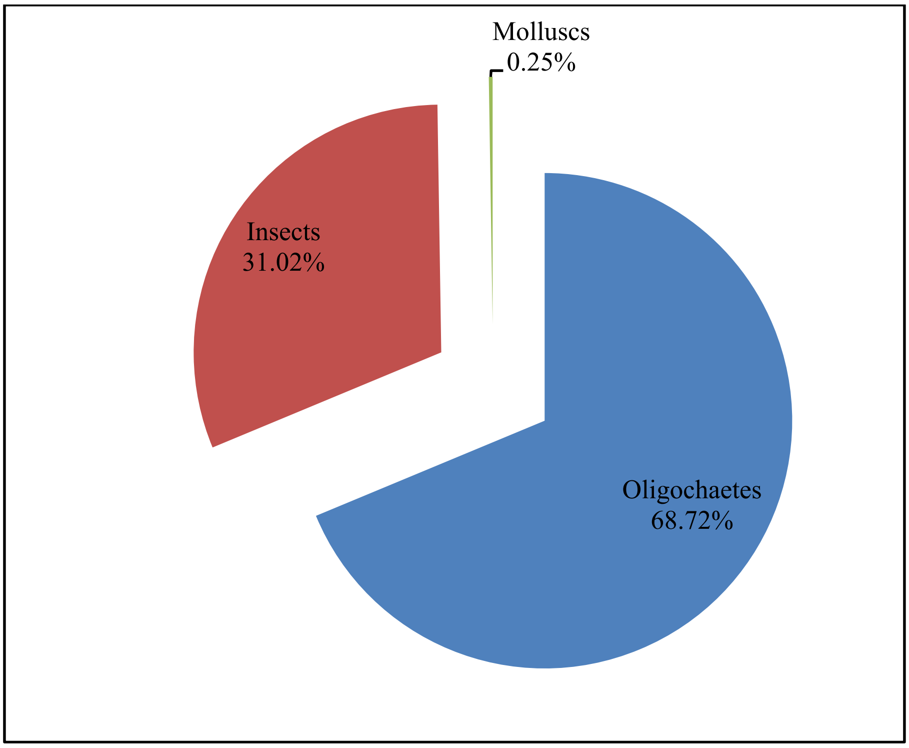


Fig.6.6. Mean percentage composition of macrobenthic faunal groups in station 5 in Maranchery Kole wetland during the study period.

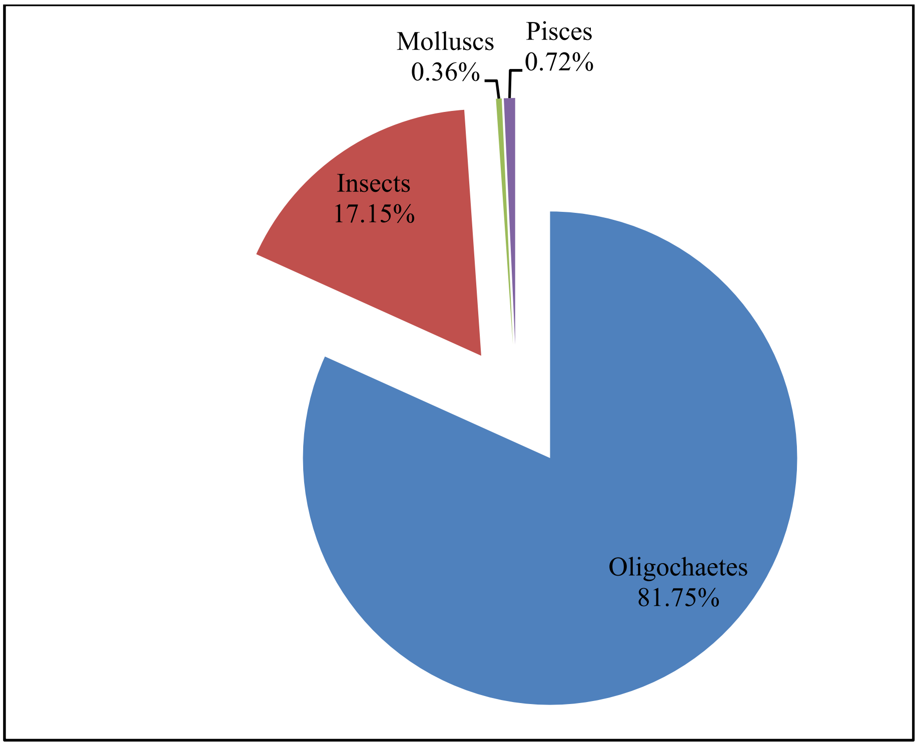


Fig.6.7. Mean percentage composition of macrobenthic faunal groups in station 6 in Maranchery Kole wetland during the study period.

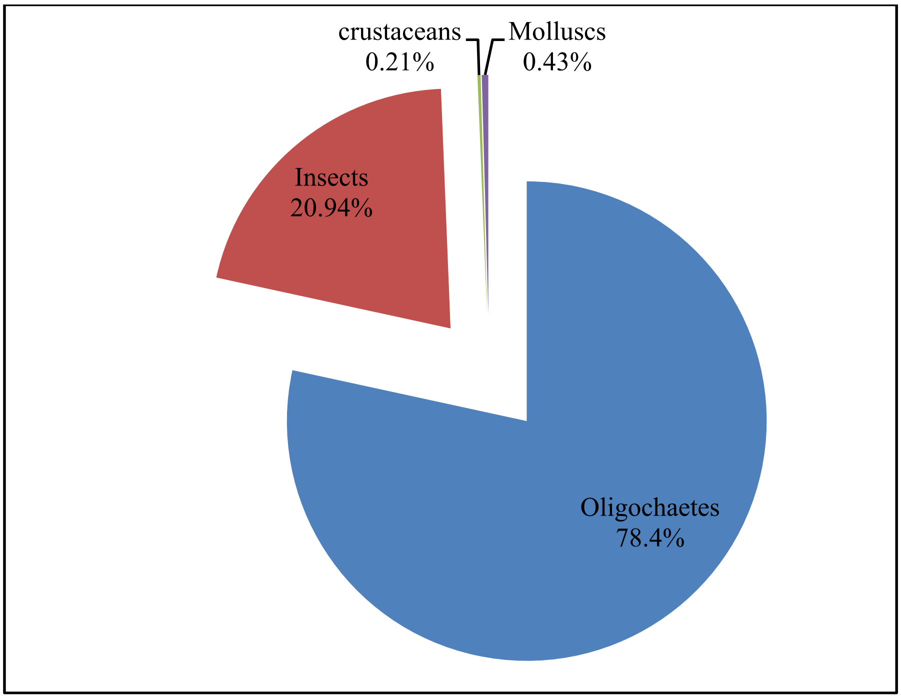


Fig.6.8. Mean percentage composition of macrobenthic faunal groups in station 7 in Maranchery Kole wetland during the study period.

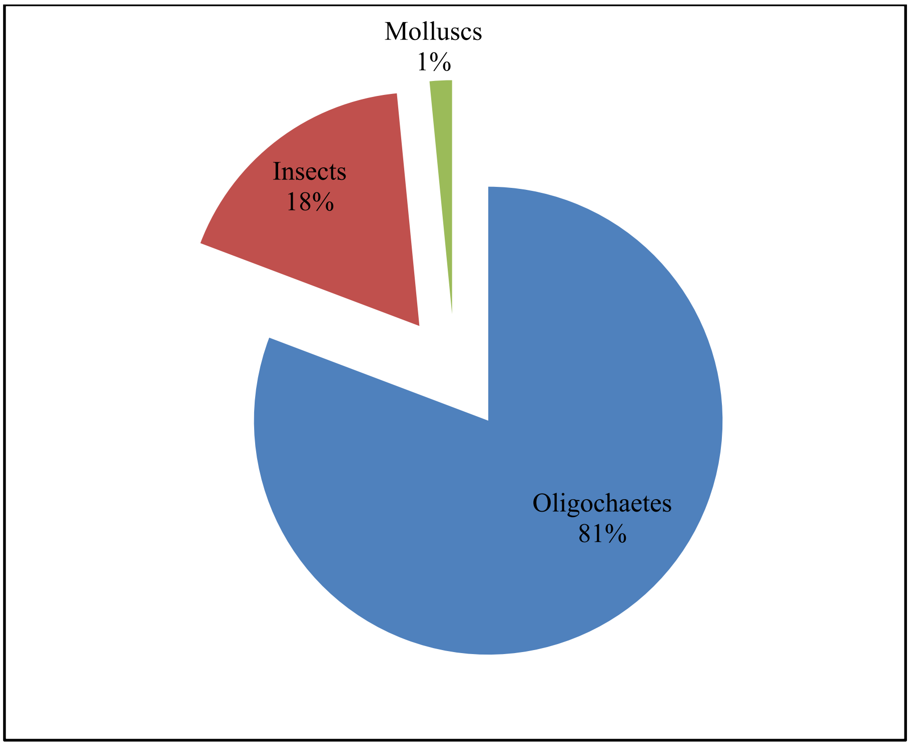


Fig.6.9. Mean percentage composition of macrobenthic faunal groups in station 8 in Maranchery Kole wetland during the study period.

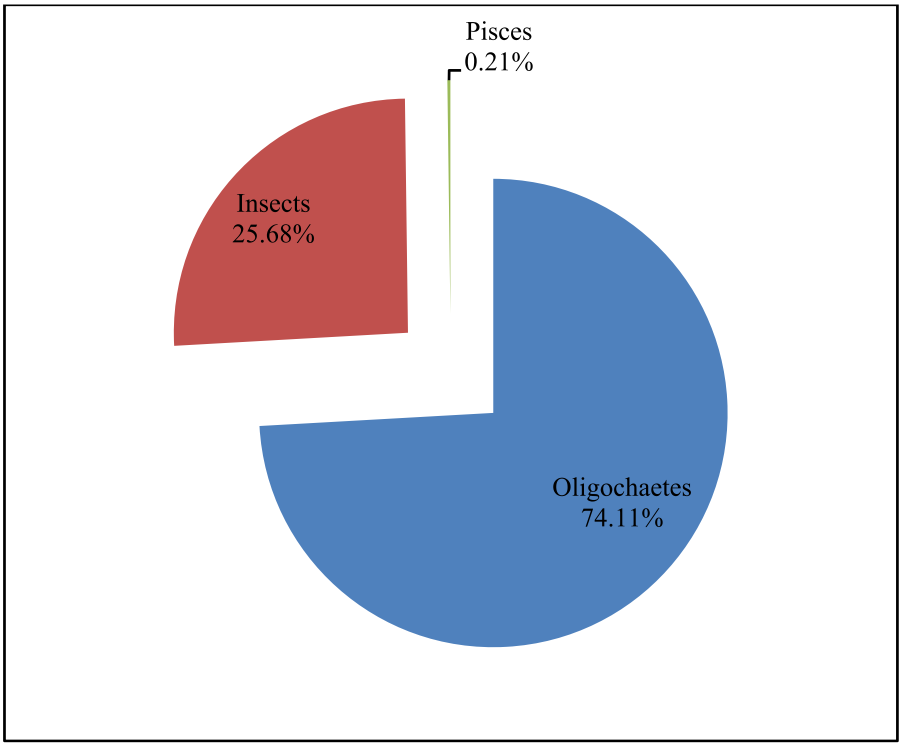


Fig.6.10. Mean percentage composition of macrobenthic faunal groups in wet phase.

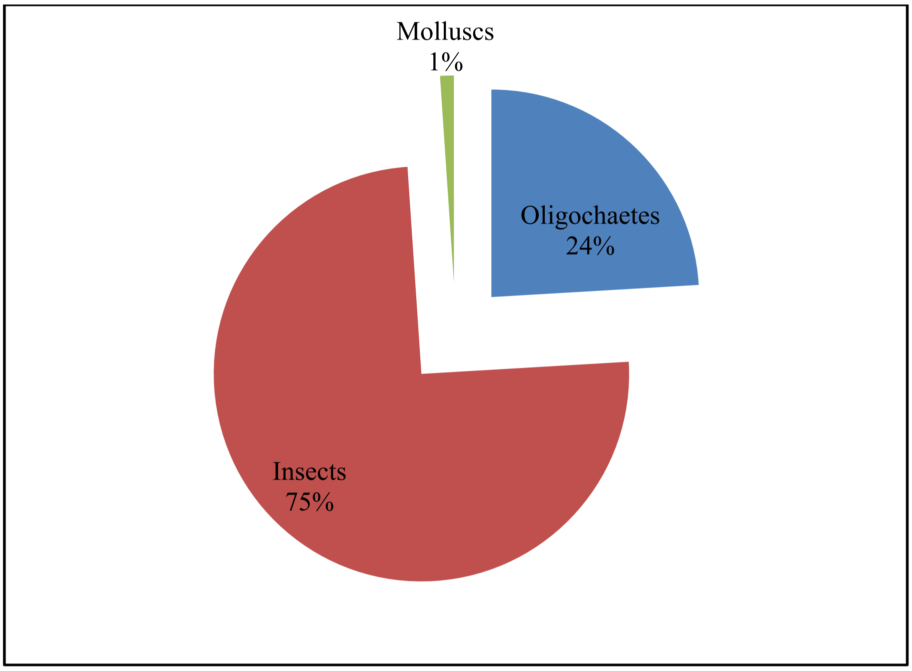


Fig.6.11. Mean percentage composition of macrobenthic faunal groups in dry phase.

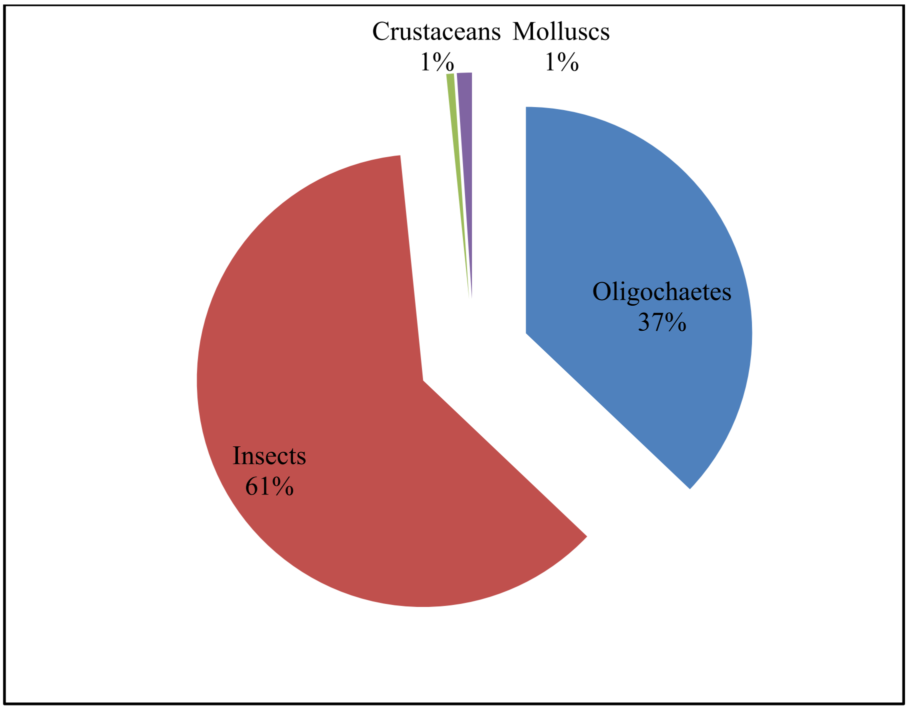


Fig.6.12. Mean percentage composition of macrobenthic faunal groups in paddy phase.

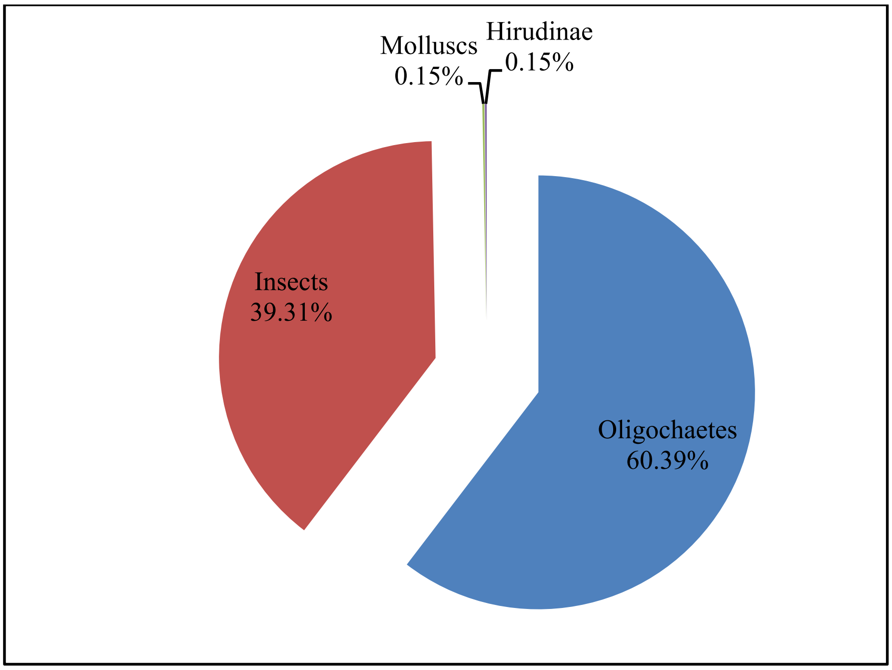


Fig.6.13. Mean percentage composition of macrobenthic faunal groups in channel phase.

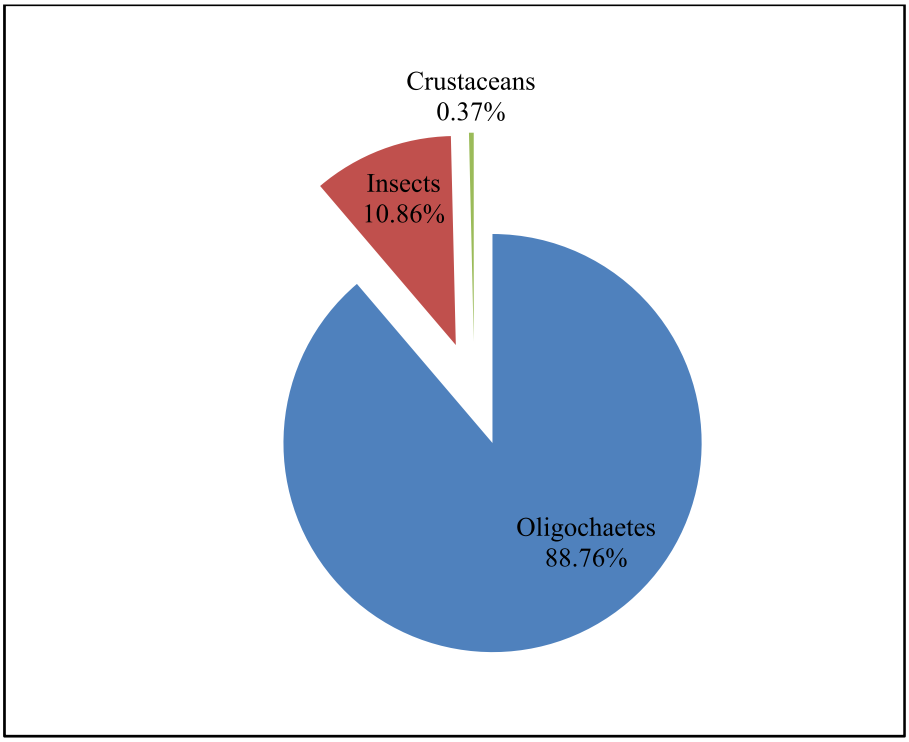


Fig.6.14. Mean percentage composition of macrobenthic faunal groups in stable phase.

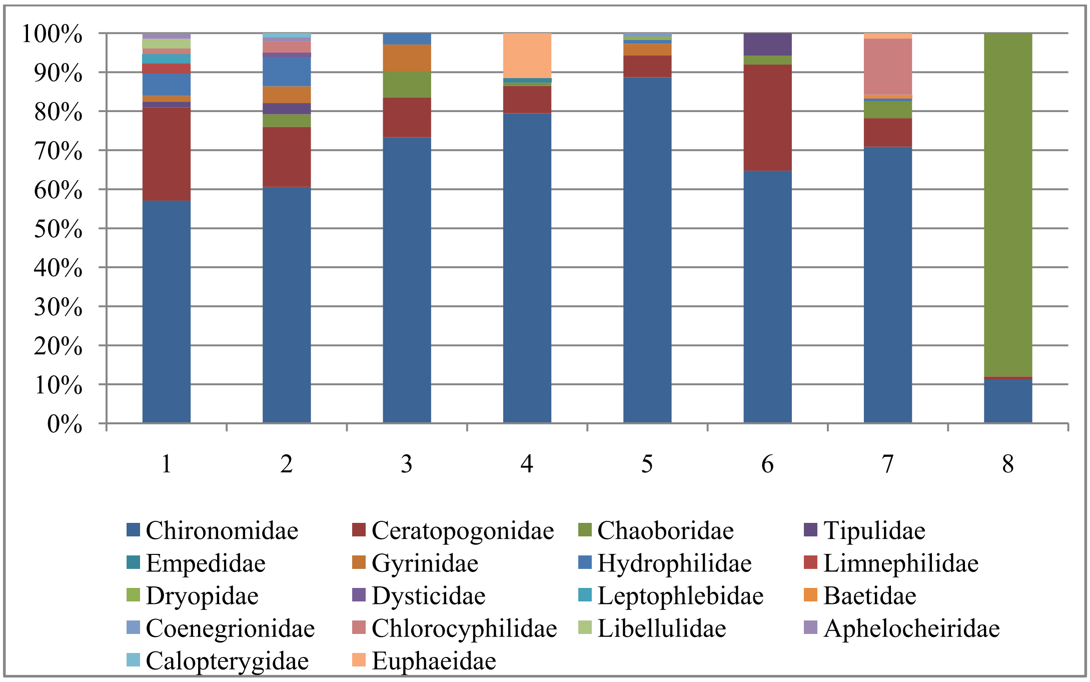


Fig.6.15. Mean percentage composition of insect families in the eight stations in Maranchery Kole wetland during the study period.

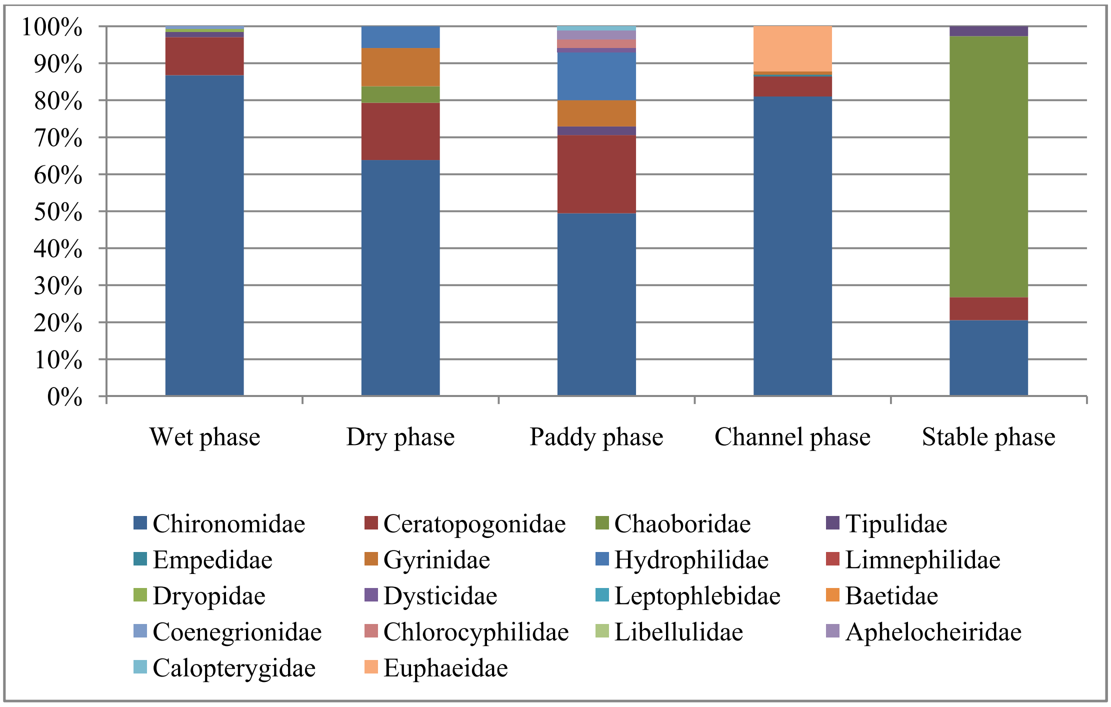


Fig.6.16. Mean percentage composition of insect families in the five phases in Maranchery Kole wetland during the study period.

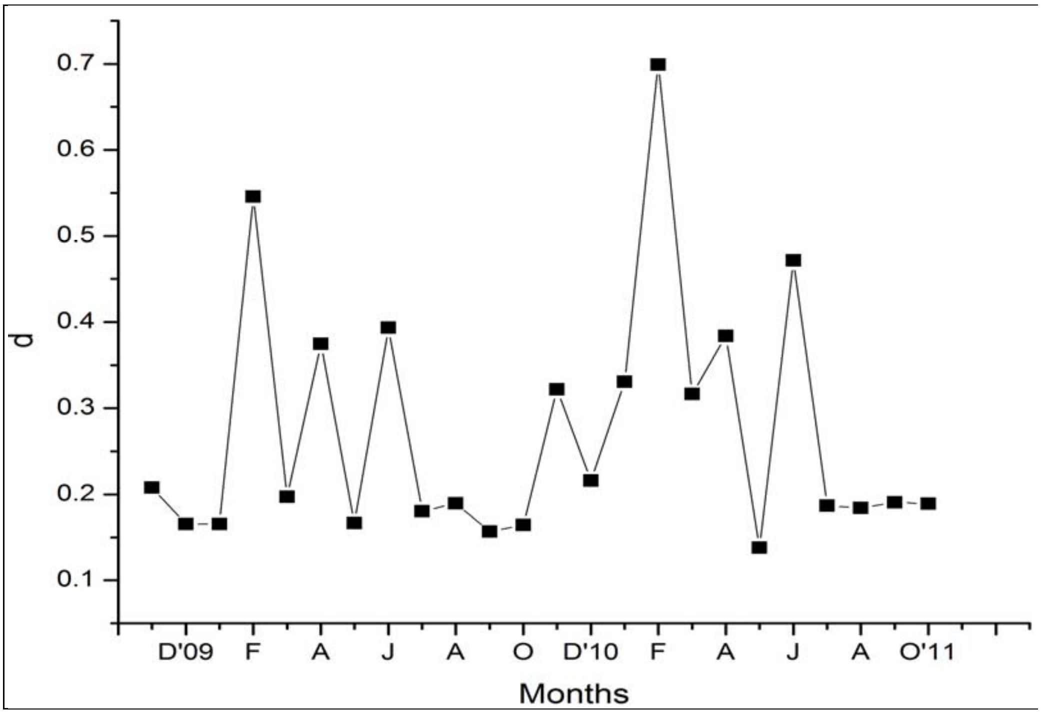


Fig.6.17. Monthly mean variation in richness of macro benthic faunal groups in Maranchery Kole wetlands.

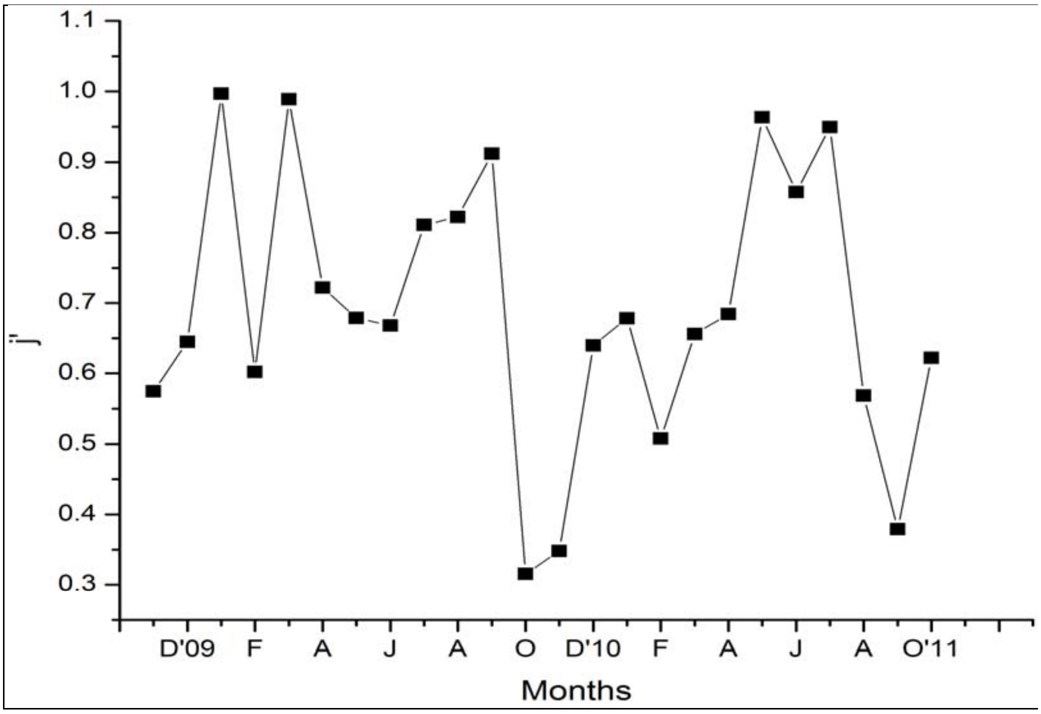


Fig.6.18 Monthly mean variation in evenness of macro benthic faunal groups in Maranchery Kole wetlands during the study period.

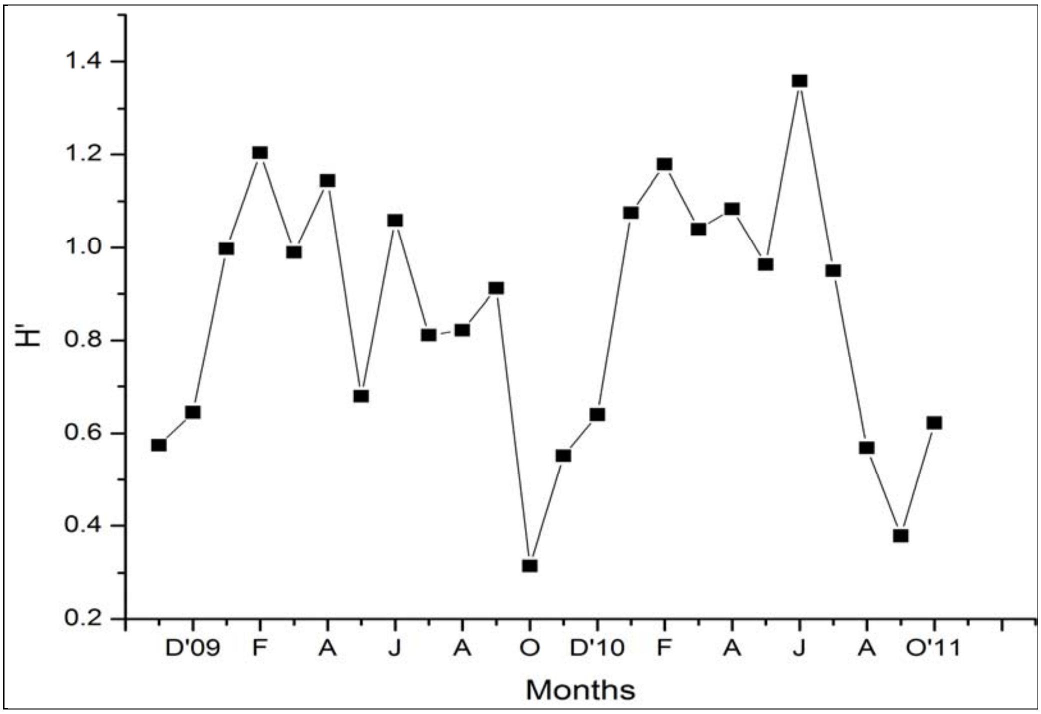


Fig.6.19. Monthly mean variation in diversity of macro benthic faunal groups in Maranchery Kole wetlands during the study period.

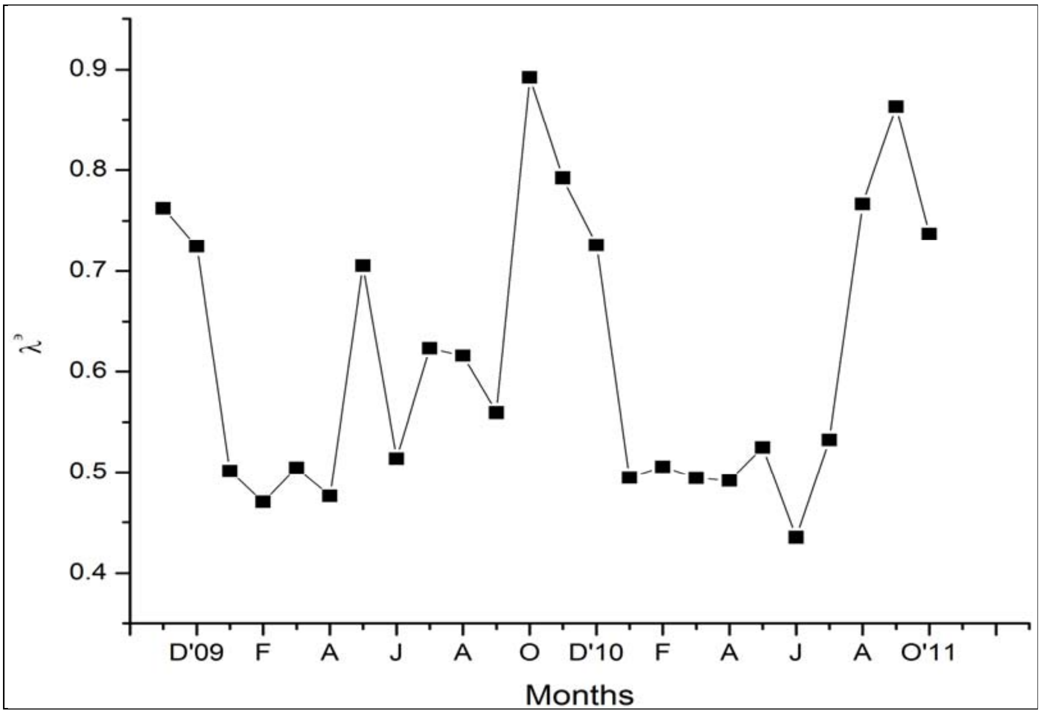


Fig.6.20. Monthly mean variation in dominance of macro benthic faunal groups in Maranchery Kole wetlands during the study period.

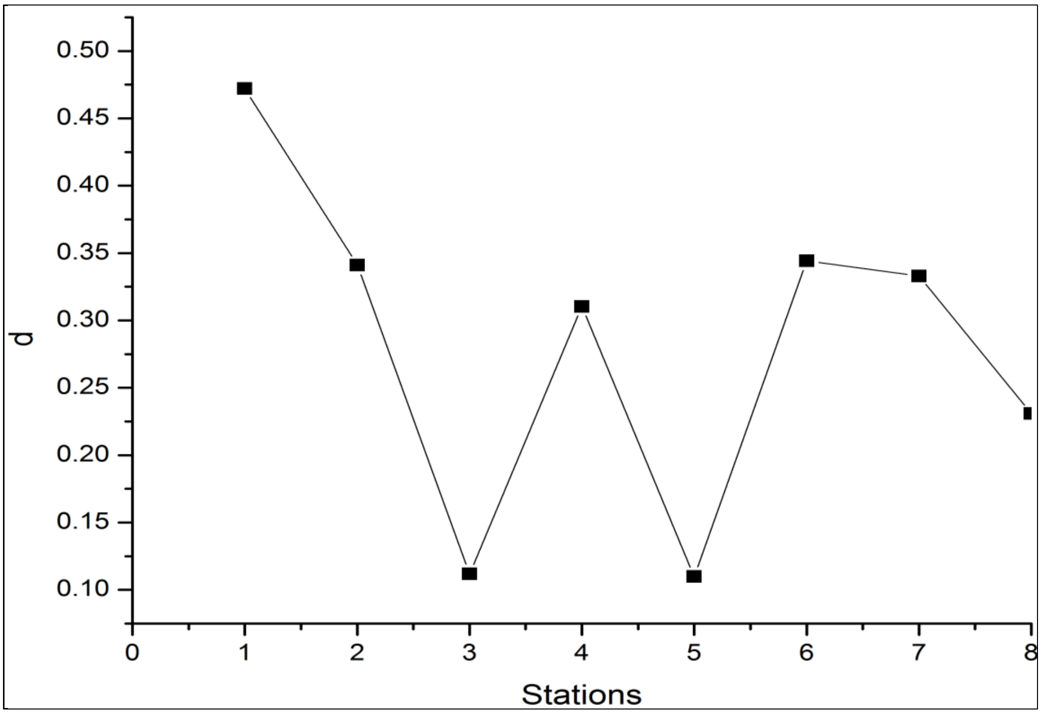


Fig.6.21. Mean variation richness of macro benthic faunal groups in the eight stations in Maranchery Kole wetlands during the study period.

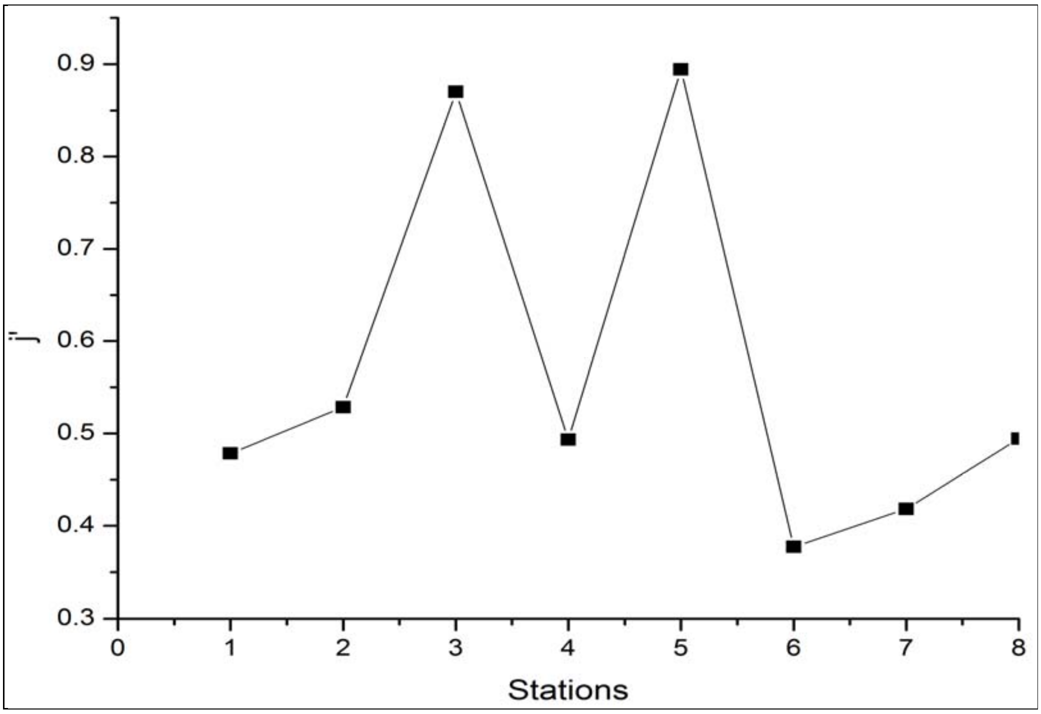


Fig.6.22. Mean variation evenness of macro benthic faunal groups in the eight stations in Maranchery Kole wetlands during the study period.

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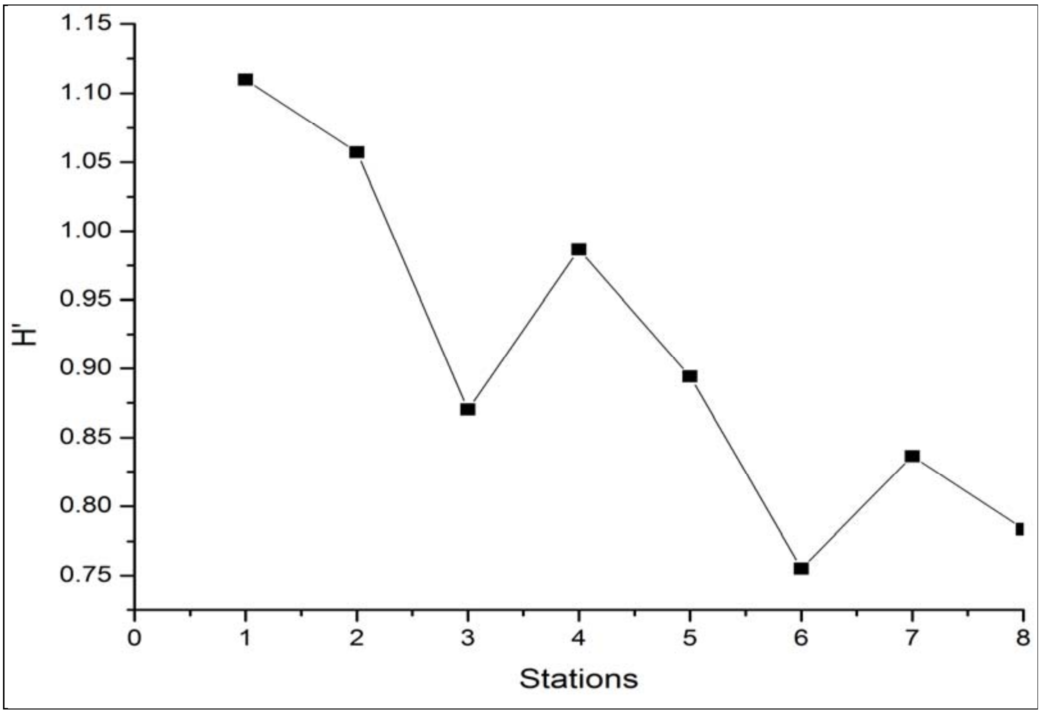

Fig.6.23. Mean variation in diversity of macro benthic faunal groups in the the eight stations in Maranchery Kole wetlands during the study period.

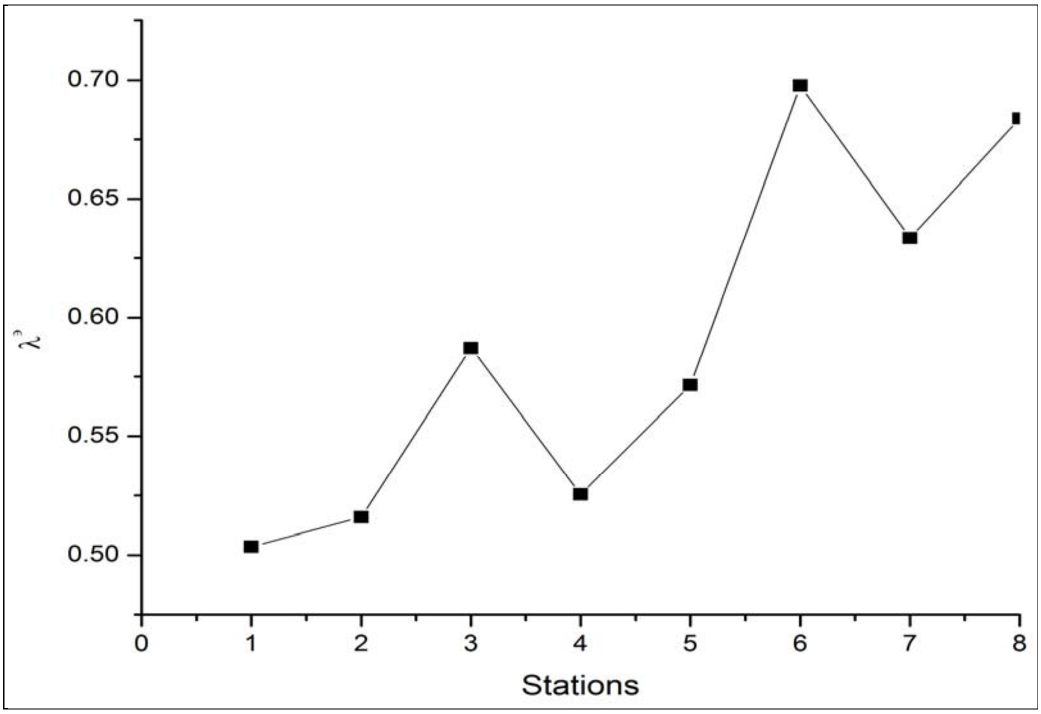

Fig.6.24. Monthly mean variation in dominance of macro benthic faunal groups in the eight stations in Maranchery Kole wetlands during the study period.

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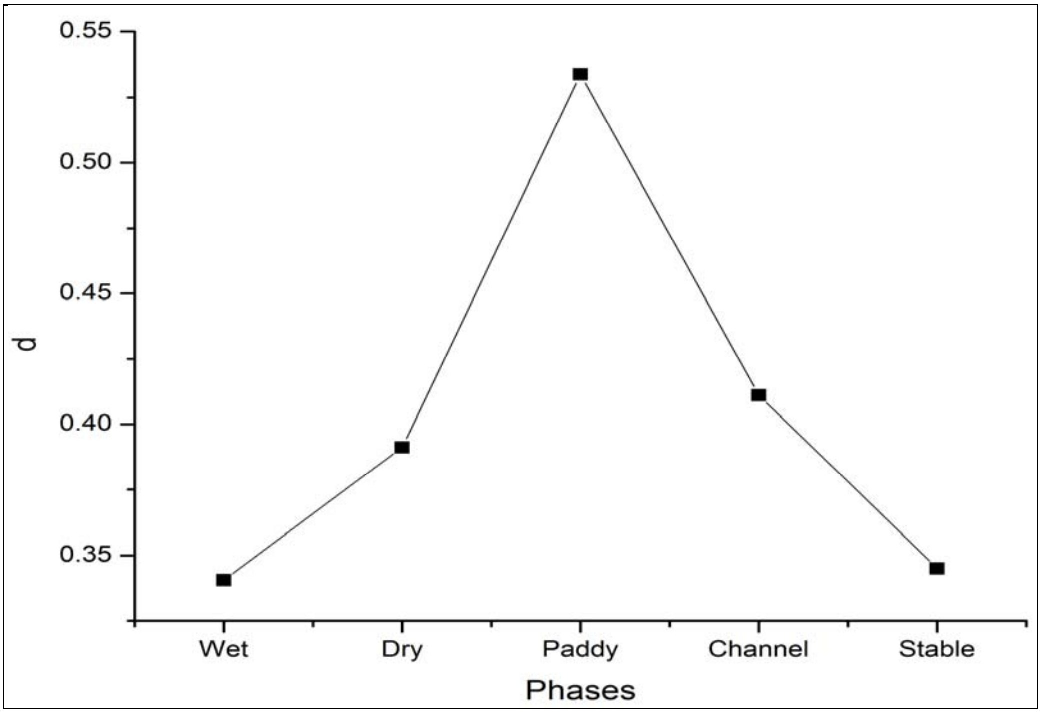

Fig.6.25. Mean variation in richness of macro benthic faunal groups in the five phases in Maranchery Kole wetlands.

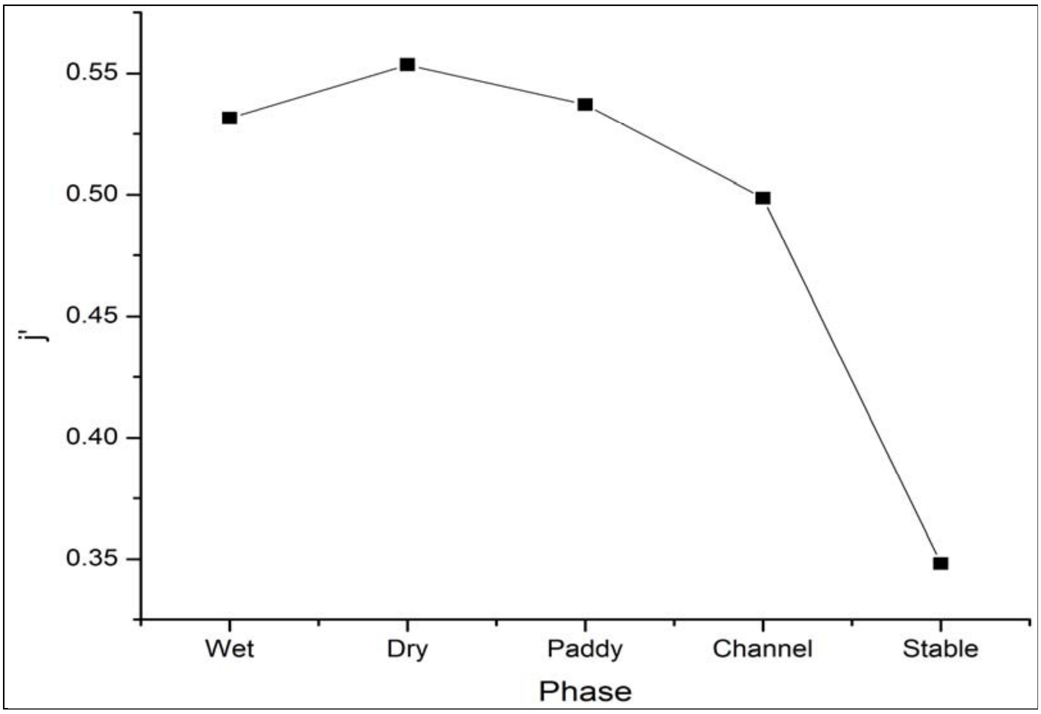

Fig.6.26. Mean variation in evenness of macro benthic faunal groups in the five phases in Maranchery Kole wetlands.

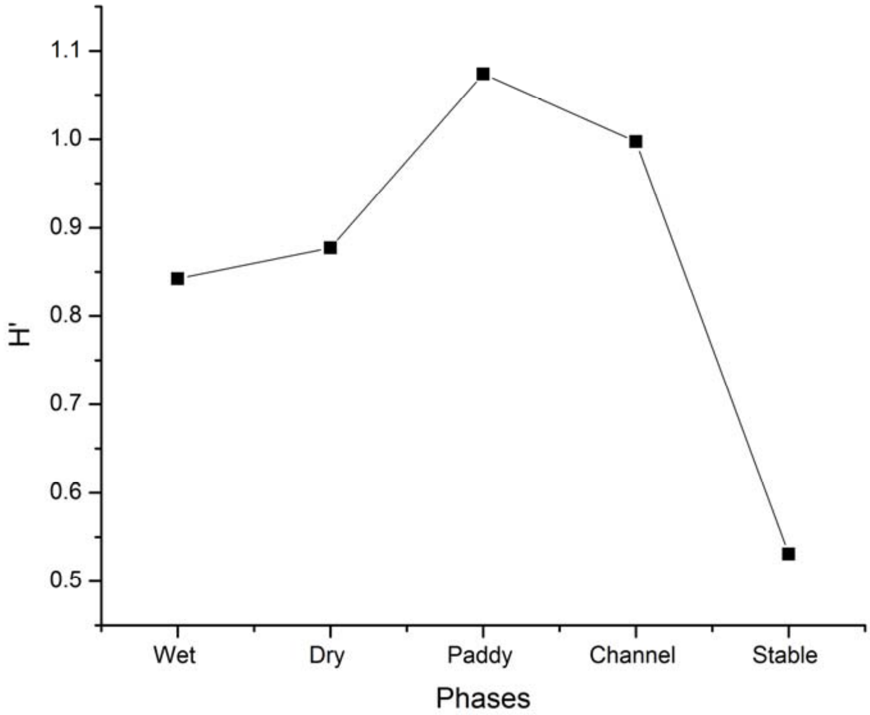

Fig.6.27. Mean variation in diversity of macro benthic faunal groups in the five phases in Maranchery Kole wetlands.

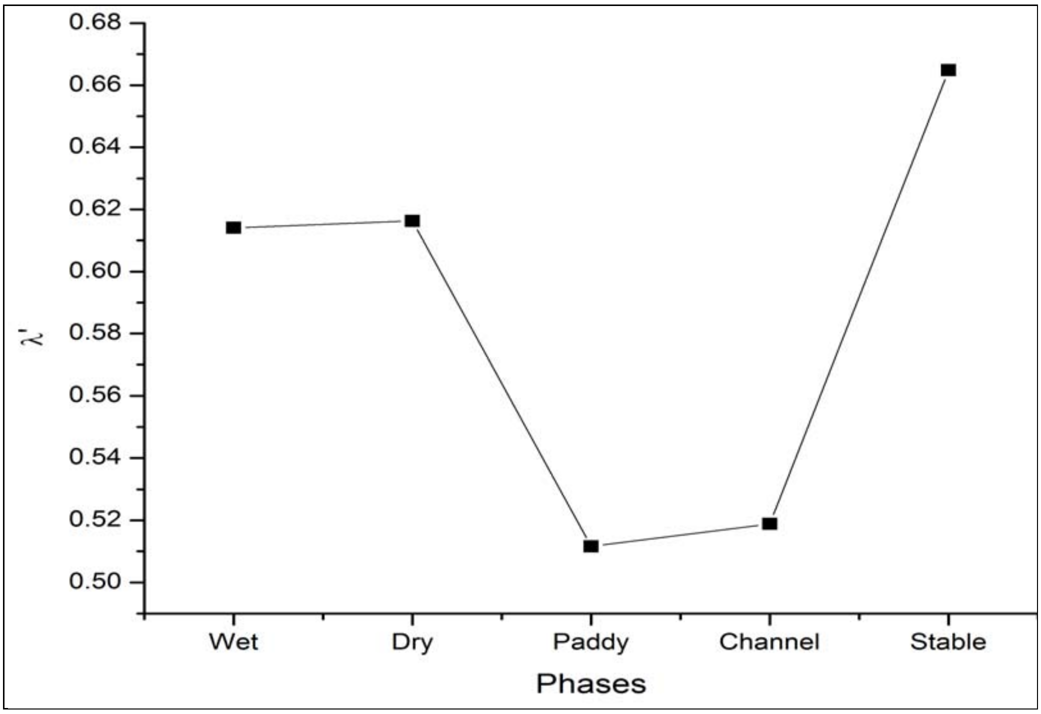

Fig.6.28. Mean variation in dominance of macro benthic faunal groups in the five phases in Maranchery Kole wetlands.

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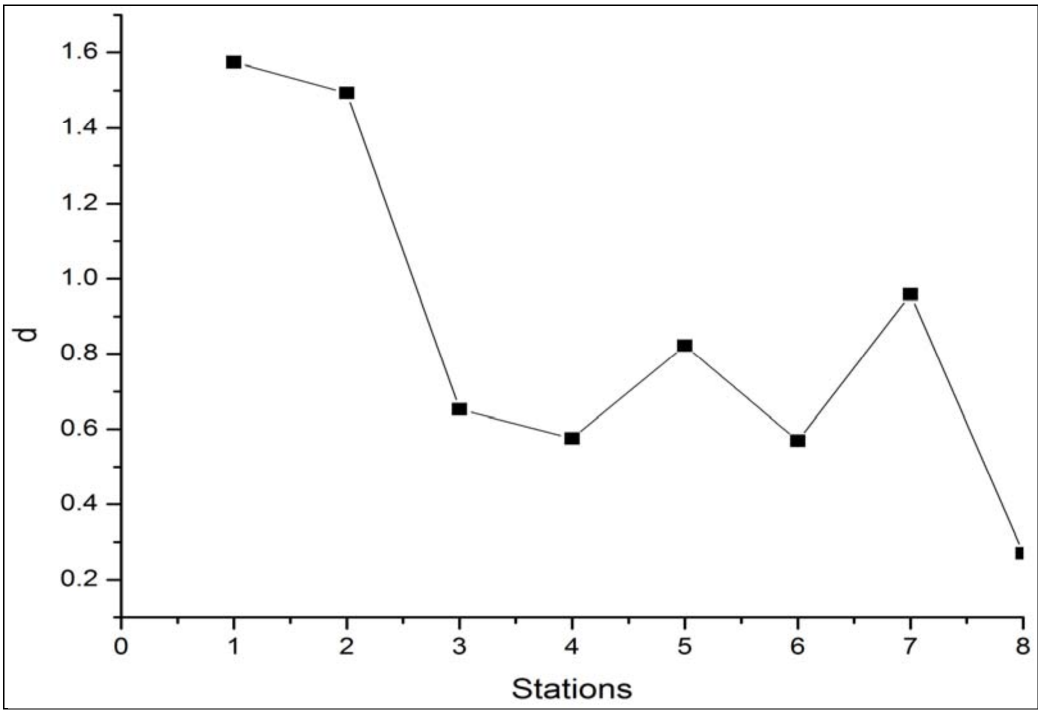

Fig.6.29. Mean variation richness of insect families in the eight stations in Maranchery Kole wetlands.

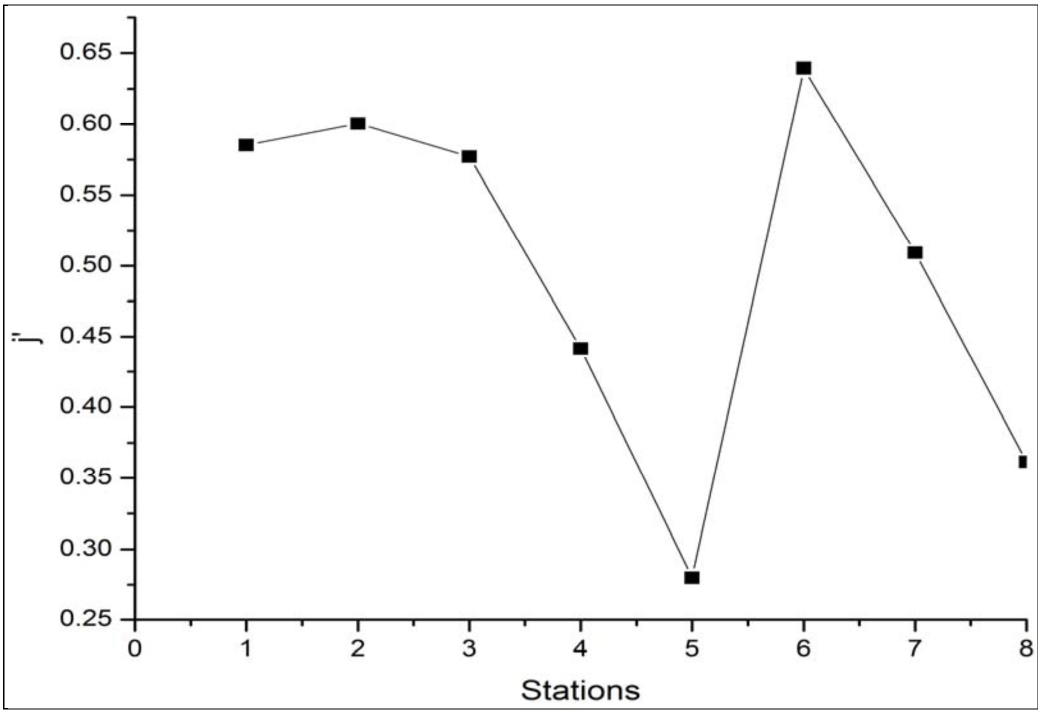

Fig.6.30. Mean variation evenness of insect families in the eight stations in Maranchery Kole wetlands.

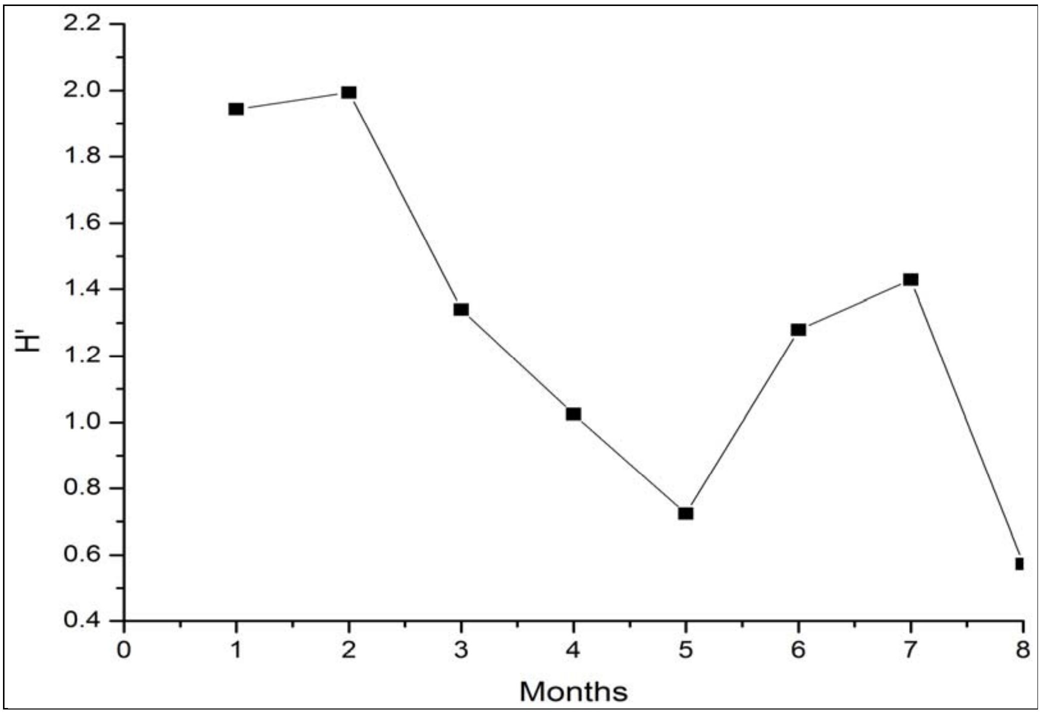

Fig.6.31. Mean variation diversity of insect families in the eight stations in Maranchery Kole wetlands.

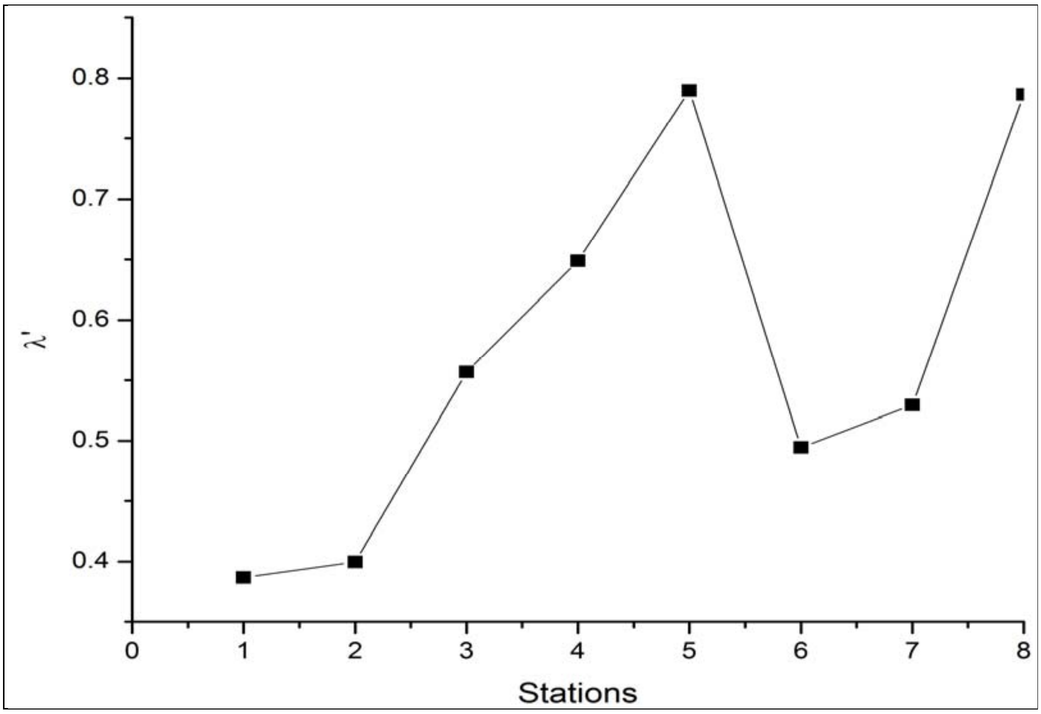

Fig.6.32. Mean variation dominance of insect families in the eight stations in Maranchery Kole wetlands.

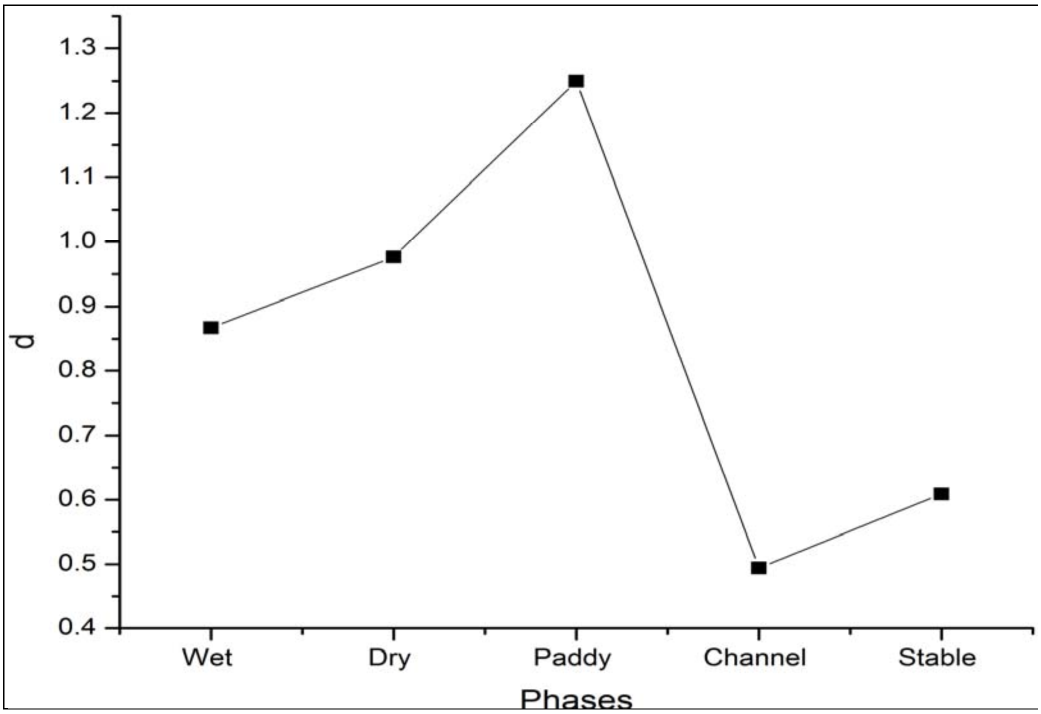

Fig.6.33. Mean variation richness of insect families in the five phases in Maranchery Kole wetlands.

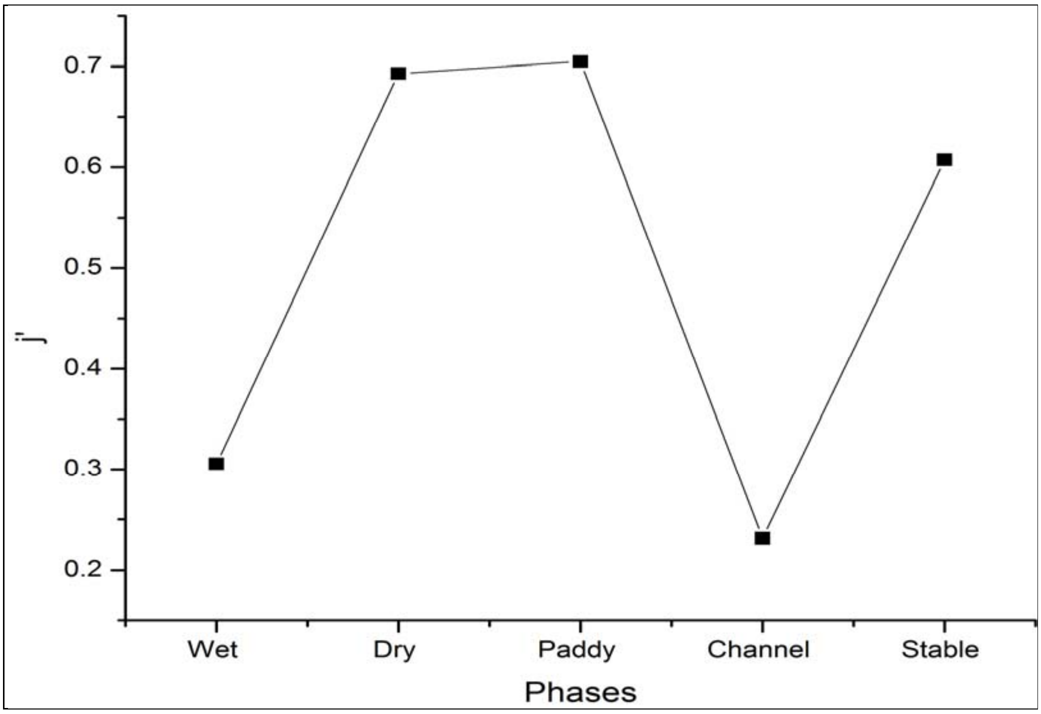

Fig.6.34. Mean variation evenness of insect families in the the five phases in Maranchery Kole wetlands.

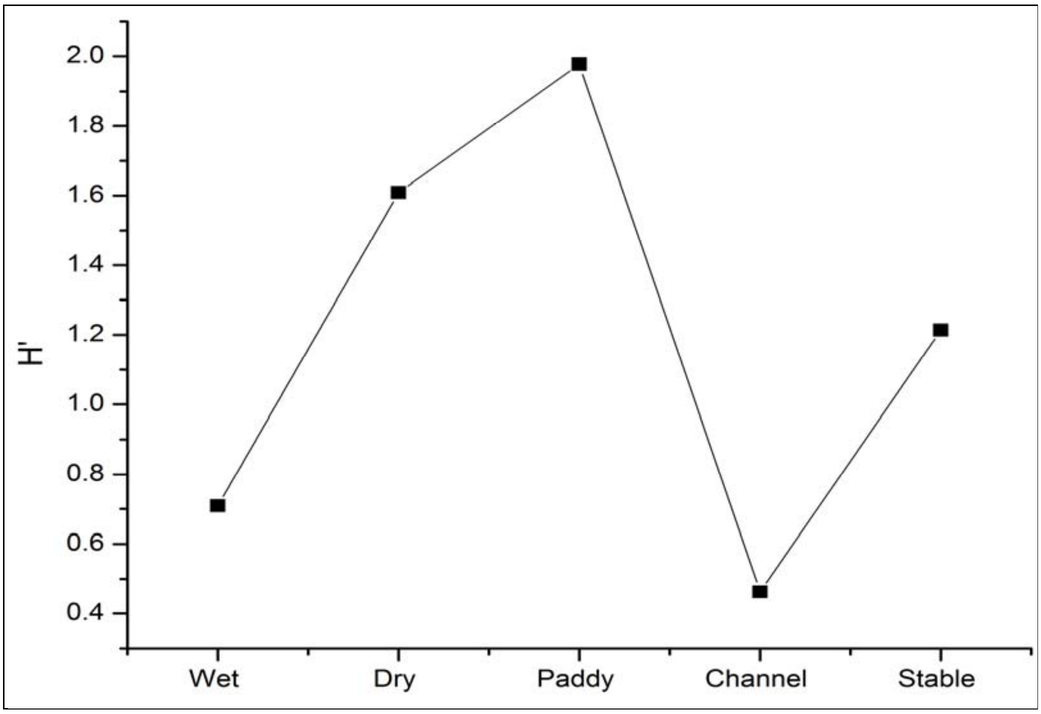

Fig.6.35. Mean variation divsersity of of insect families in the five phases in Maranchery Kole wetlands.

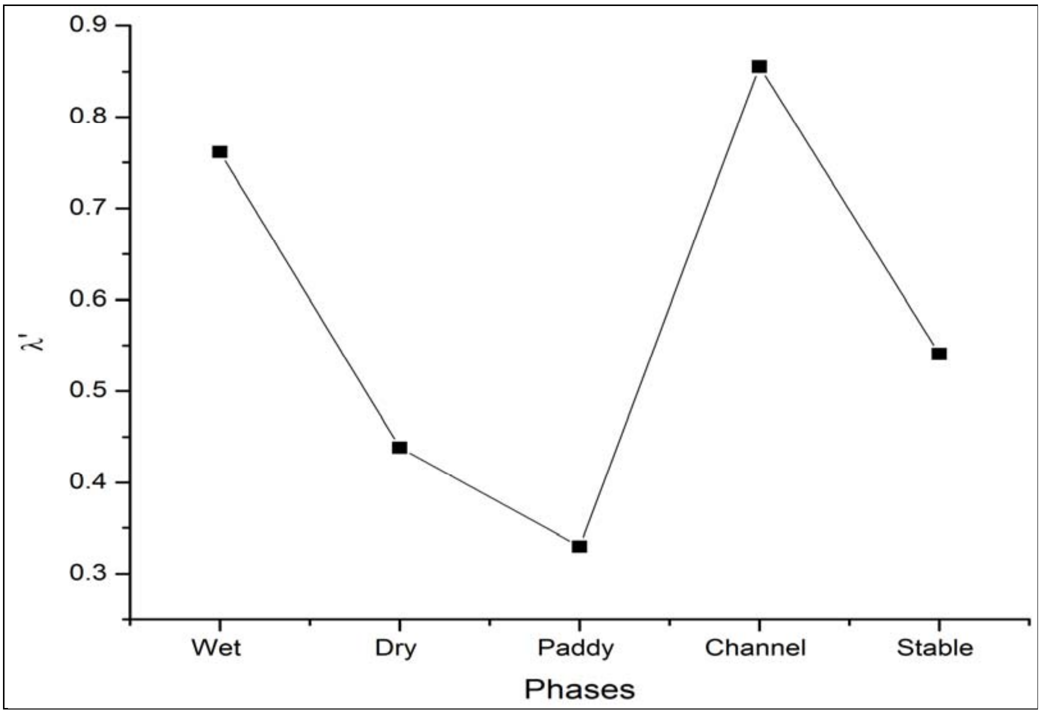

Fig.6.36. Mean variation dominance of of insect families in the five phases in Maranchery Kole wetlands.

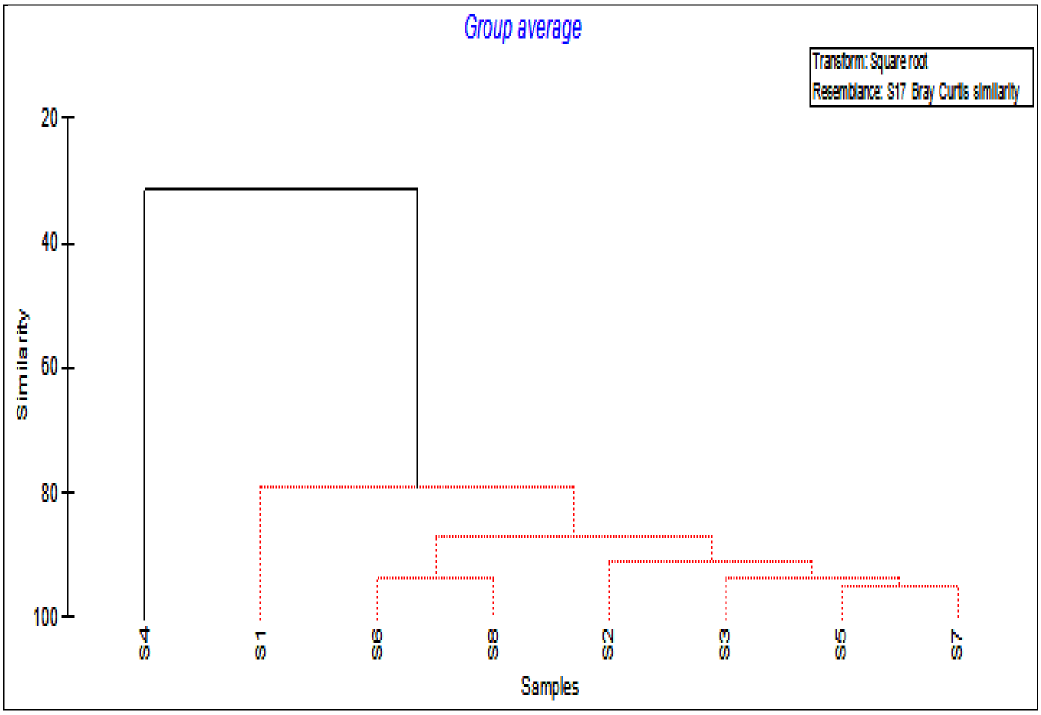

Fig.6.37. Dendrogram of numerical abundance of macro benthic faunal groups showing similarites in the eight stations in Maranchery Kole wetlands during the study period (Solid lines represent significant delineation of groupings by SIMPROF test).

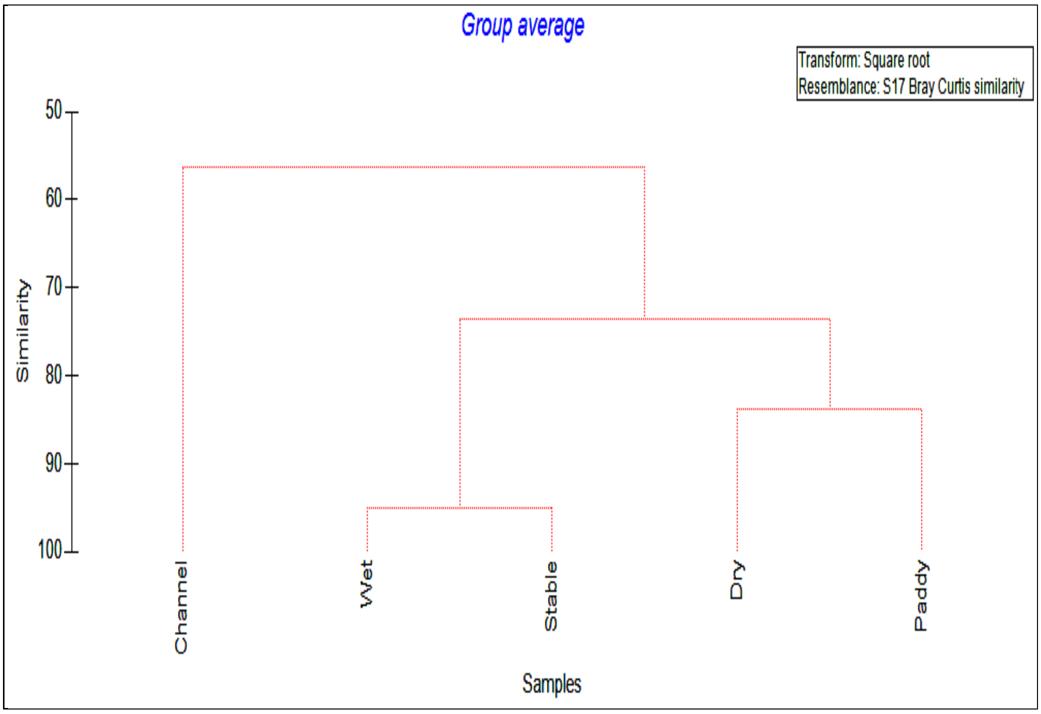

Fig.6.38. Dendrogram of numerical abundance of macro benthic faunal groups showing similarites in the five phases in Maranchery Kole wetlands.

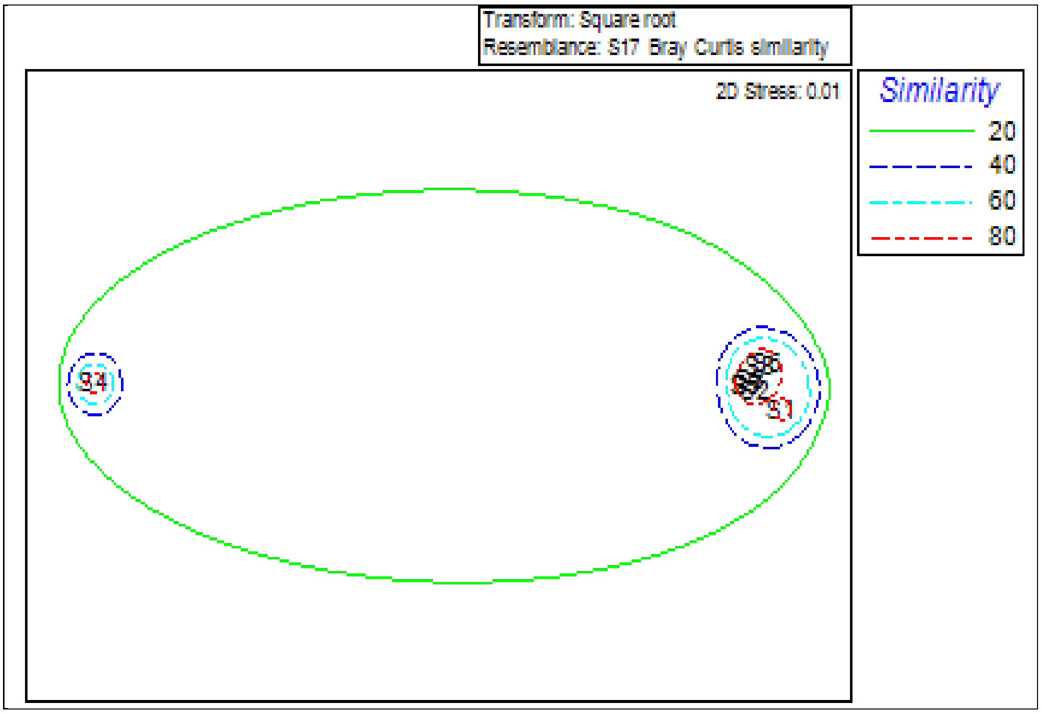

Fig.6.39. Non-metric Multi Dimensional Scaling (MDS) ordination plot in the eight stations with respect to the numerical abundance of macro benthic faunal groups in Maranchery Kole wetlands during the study period.

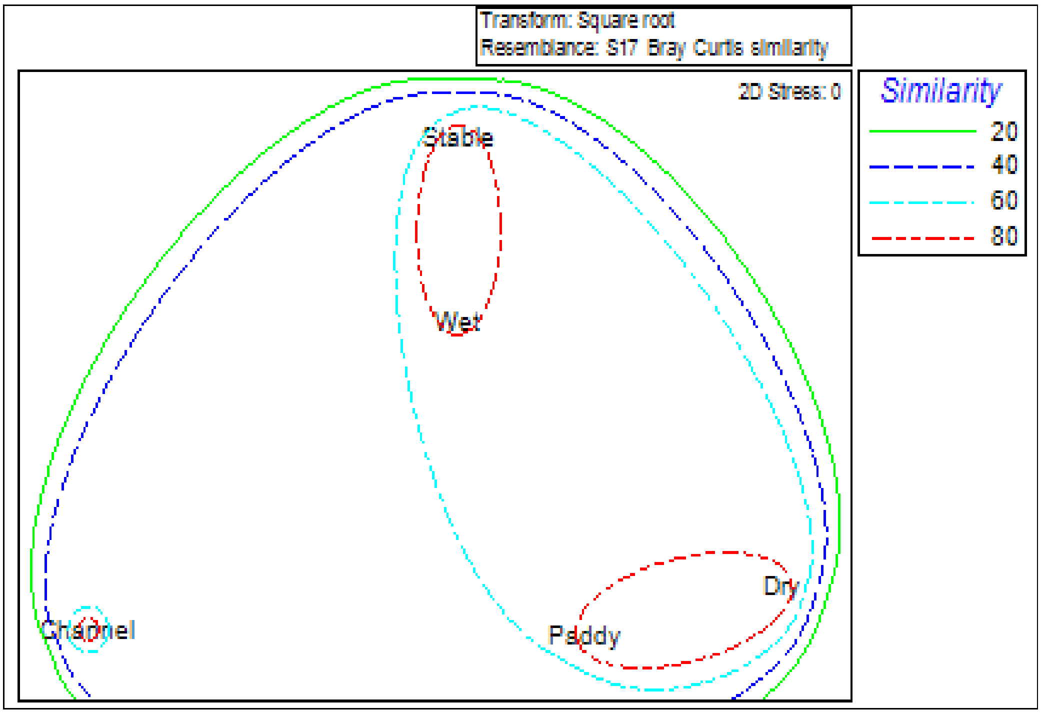

Fig.6.40. Non-metric Multi Dimensional Scaling (MDS) ordination plot in the five phases with respect to the numerical abundance of macro benthic faunal groups in Maranchery Kole wetlands.

Chapter - 7

COMPOSITION AND COMMUNITY STRUCTURE OF OLIGOCHAETES

7.1 Introduction

Oligochaeta is a class of the phylum Annelida (annelid worms) (Chekanovskaya 1962). Oligochaetes were defined by Stephenson (1930) as "worms with internal segmentation and usually corresponding external annulations; possessing setae, usually segmentally arranged throughout the greater part of the body but not situated on parapodia; hermaphrodite, the male and female gonads being few in number (one or two pairs) situated in the anterior part of the body, the male anterior to the female, the genital products discharge by special ducts, a clittellum present at sexual maturity, the eggs deposited in a cocoon, without free larval stage in development". They form an important component of the benthic fauna especially in fresh water ecosystems. Most aquatic oligochaetes are free-burrowing, deposit feeders, ingesting sediment, largely contributing to diet of bottom feeding omnivores. The mass population of oligochaetes are accomplished of extensive reworking of the sediments they occupy. Previous studied documented its impact on grain size distribution, erosion, water content, diffusion, permeability and oxygen demand of the sediments (Chatarpaul et al. 1980). It is reported that oligochaetes could rework the sediments by displacing quantities of mud eight times of their own body weight within 24 hours (Appleby and Brinkhurst 1970). Kikuchi and Kurihara (1977) observed that oligochaetes accelerate nutrient release from soils and water in paddy fields. Aquatic oligochaetes promoted nutrient mineralization and suppress weed germination under laboratory conditions (Kurihara and Kikuchi 1989). These properties make oligochaetes an important asset in agricultural farms. They have also played an important role in ecological assessments due to their occurrences under disturbed conditions (Kolkwitz and Marsson 1909, Verdonschot

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1989). Their ability to reveal organic pollution was observed many centuries ago since the Greek philosopher Aristotle noted the small red threads that grew on the foul mud (Hynes 1960). Later the role of oligochaetes in ecological assessments was reported by Milbrink (1973), Brinkhurst and Jamieson (1974) and Verdonschot (1989).

A review of literature shows that the studies on oligochaetes started from the early 19th century. Pioneers in this field are Michaelsen (1900), Stephenson (1930), Marcus (1944) etc. Sperber (1948) gave a comprehensive contribution to the taxonomy of Naididae. The systematics and taxonomy of aquatic oligochaetes throughout the world was studied extensively by Brinkhurst and Jamieson (1971), Brinkhurst and Wetzel (1984), Timm (1987), Timm (1999) and Timm (2009). The oligochaete fauna of various parts of the world was documented through numerous studies. Oligochaete distribution and abundance were related to substrate composition in Lake Michigan (Stimpson et al. 1975). The influence of sediment composition and leaf litter on the distribution of tubificid worms was observed in field and laboratory studies (Lazim, and Learner 1987). The ecology, spatial and temporal distribution, physical habitat relationships and relationship with sediment parameters of benthic oligochaetes in different parts of Parana River, Argentina was studied extensively (Marchese 1987, Takeda 1999, Marchese and Drago 1992). Diversity and distribution of oligochaetes over a period of 20 years in the rivers Rhine and Meuse in the Netherlands was documented (Nijboer et al. 2004). The correlation of oligochaete species to macrophytes in Liangzi Lake District, China was studied (Xie et al. 2011).

Oligochaetes generally comprise of 50% of the macroinvertebrate communities in Indian lakes, rivers and streams, at least 10% of the benthic community in estuaries near shore, coastal areas etc. and 40% are terrestrial (Singh et al. 2009). The fauna of aquatic Oligochaeta from India has been studied by Stephenson (1923, 1930), Aiyer (1929), Radhakrishna and Saibaba (1977), Sobhana and Nair (1984), Battish and Sharma (1991), Mukhopadhyay (1998), Nesemann et al. (2004), Naidu (2005) and Naveed (2010). The population dynamics of oligochaetes of the lower lake Bhopal was recorded by Oomachan and Belsare (1986). In Indian ricefields, oligochaete populations were dominated by the earthworm *Darwida willsi* (Senapati et al. 1991). Mir and Yousuf (2003) reported that oligochaetes of Dal lake, Kashmir was determined by the nature of the sediment. Nesemann et al. (2004) studied the oligochaete species of the Gnagg River and adjacent water bodies in Patna. The prey-predator relationship between littoral oligochaetes and demersal fish was studied (Shrama 2010). Rashid and Pandit (2014) gave an extensive review of studies on oligochaetes in India.

The earliest account of oligochaetes from Kerala comprising the Travancore region was by Fedarb (1898). An extensive study on oligochaete species from Kerala was done by Naidu (1962, 1963, 1965, 2005). A detailed account of the biology of oligochaete of South Kerala was given by Sobhana (1982). Occurance and seasonal variation of oligochaetes associated with *Salvinia molesta* was studied in Veli Lake by Sobhana and Nair (1983, 1984). Bijoy Nandan (1991) gave information on oligochaetes dwelling on coir retting area in Kerala. Recently oligochaete in selected ponds of Thiruvananthapuram district in Kerala was documented by Ragi and Jaya (2014). Literature reviews revealed a dearth of information on oligochaetes in Kerala, especially from the Northern Kerala.

7.2 Results

7.2.1 Composition of oligochaetes

The list of oligochaete species recorded from Maranchery Kole wetland is given in annexure 3. A total of 27 species of oligochaetes were identified from this wetland during the period November 2009 to October 2011. A brief account of the oligochaete species are given below.

1. ***Aulodrilus pluriseta*** Piguet, 1906
   Genus- *Aulodrilus* Bretscher, 1899
   Subfamily- Aulodrilinae Brinkhurst and Jamieson, 1971
   Family- Tubificidae Beddard, 1895
   Order-Tubificida

Large, cylindrical worms with the posterior part of the body tapering to a narrow unsegmented achaetous gill. Dorsal setae begins in II with 5 hair setae and 6 needle setae, 10-15 hair setae and 9-11 needle setae in pre clitellar segments then reducing to 4-6 hair setae and 5-7 hair setae in post clitellar segments and to 4,3 and 2 hair and needle setae posteriorly. Ventral setae is bifid, 1-14 per bundle in pre clitellar segments then reducing to 10-11 and 3 per bundle in the posterior segments (Fig.7.1 to 7.2). As the name indicates, *Aulodrilus pluriseta* is characterized by the large number of setae compared to other species. They live in mucus tubes of clay and sand. Reported from Thiruvananthapuram in Kerala (Naidu 2005).

Occurrence

Aulodrilus pluriseta was the most abundant oligochaete species forming 42.06% of the total oligochaete abundance. Present in all stations and all phases. The maximum abundance was in May 2010 in station 5 (1822 ind./m2). The species occurred at a range of depth 0.2-3.1 m, water temperature 25.9-32.5 ºC, dissolved oxygen 2.4-9.6 mg/L, sediment temperature 25.1-30.6 ºC, sediment pH 5.06-8.01, organic matter 2.82-12.24 %, moisture content 17.5-56.2% and showed no substrate preference.

2. *Aulodrilus pigueti* Kowalewski, 1914
Genus- *Aulodrilus* Bretscher, 1899
Subfamily- Aulodrilinae Brinkhurst and Jamieson, 1971
Family- Tubificidae Beddard, 1895
Order-Tubificida

Medium sized worms with bluntly conical prostomium. Dorsal setal bundles start in II with hair and needle setae. Single pointed, bifid and oar shaped needle setae occur. The presence of oar shaped setae from VIII is the distinguishable characteristic of *Aulodrilus pigueti*. Ventral bundles have 6-8 bifid setae (Fig.7.3 to 7.4). They live in unbranched mucus tubes of clay and sand in soft mud. Reported from Thiruvananthapuram in Kerala (Naidu 2005).

Occurrence

Aulodrilus pigueti formed 2.42% of the total oligochaete abundance. It was present in all stations except station 1 and was present in all the five phases. The species occurred at a range of depth 0.2-3 m, water temperature 25.9-31.4 ºC, dissolved oxygen 3.2-9.2 mg/L, sediment temperature 24.1-31.1ºC, sediment pH 5.87-7.37, organic matter 0.87-6.86% and moisture content 17.1-41.4%. *Aulodrilus pigueti* preferred sandy silt and clayey silt substrates.

3. *Dero digitata* Muller, 1773
Genus- *Dero* Oken, 1815
Family- Naididae
Order-Tubificida

Medium sized worms with bluntly triangular prostomium with stiff cilia on its margin. Dorsal bundles from VI, with 1 hair and 1 needle. The distal tooth of the needles longer than the proximal. Ventral setae 4-5 in II-V with distal teeth longer than the proximal. From VI onwards, ventral setae 2- 4 with distal and proximal teeth almost equal. Branchial fossa with 4 pairs of foliated gills, one pair dorsal and small, 1 pair lateral and 2 pairs ventral. They live in tubes of mucous and sand in fresh water. Their presence is known from Kottaym and Thiruvananthapuram in Kerala (Naidu 2005). They were also reported from muddy substratum in Chakai Canal, Thiruvananthapuram (Sobhana 1982).

Occurrence

Dero digitata formed 0.25% of the total oligochaete abundance. It made only a single appearance in station 7 in January 2010. The species occurred at a depth of 2.5 m, water temperature 26.8 ºC, dissolved oxygen 6.2 mg/L, sediment temperature 27.1 ºC, sediment pH 6.42, organic matter 7.4%, moisture content 45.7%. *Dero digitata* was present in sandy silt substrate.

4. *Dero dorsalis* Ferroniere, 1899
Genus- *Dero* Oken, 1815
Family- Naididae
Order-Tubificida

Yellowish worms with bluntly triangular and rounded prostomium. Dorsal setae from IV, each bundle with 1 hair and 1 needle setae. Needle setae sickle-shaped, bifid, with distal tooth longer and thinner than proximal. Ventral setae with distal tooth longer and thinner than proximal. Branchial fossa with two broad palp like, non contractile diverging processes on postero ventral boarder and 5 pairs of foliate gills. *Dero dorsalis* and *Dero digitata* are characterized by the presence of 1 hair and 1 needle setae in the dorsal bundle. The difference among them is that in *D.dorsalis*, the hair and needle begin in the IV segment, but in *D. digitata*, the hair and needle begins from the VI segment. *D.dorsalis* are characterized by 5 pairs of gills, and *D. digitata* by the presence of 4 pairs of gills in the branchial fossa (Naidu, 2005). They live in fresh water, swimming is absent. Reported from Veli lake and Thiruvananthapuram, in Kerala (Naidu 2005). They were found attached to the roots of *Salvinia molesta*, and occurred in planktonic samples occationally in Veli lake (Sobhana 1982).

Occurrence

Dero dorsalis formed 0.72% of the total oligochaete abundance showing their presence in present in wet and dry phases. The species occurred at a range of depth 0.3-3.0 m, water temperature 27.2-30.4 ºC, dissolved oxygen 3.4-8.01 mg/L, sediment temperature 27.7-30.1 ºC, sediment pH 6.29-8.01, organic matter 2.15-14.65%, and moisture content 32.6-42.9%. *Dero dorsalis* occurred at sandy silt and clayey silt substrates.

5. ***Dero zeylanica*** Stephenson, 1913
Genus- *Dero* Oken, 1815
Family- Naididae
Order-Tubificida

Medium sized worms with prostomium bluntly triangular having stiff cilia on its margin. Dorsal setae begin in VI, each bundle with 3 hair and 3 needle setae. Needle setae bifid, sickle shaped, with distal tooth longer than proximal. Ventral setae in II-V with 4-6 per bundle, longer and thinner, the distal tooth twice as long as the proximal. Branchial fossa with a flat anterior margin, a convex, ciliated posterior margin and 4 pairs of foliate gills. They bury their head ends in soft mud. Found in tubes of sand and clay particles rarely. They can swim. Reported from Veli lake, Thiruvananthapuram, Kadinamkulam and Chirayinkil in Kerala (Naidu 2005). They were found attached to the roots of aquatic plants and also reported from foul smelling bottom sediments on small ditches and ponds (Sobhana 1982).

Occurrence

Dero zeylanica made a single appearance in station 4 in May 2011 in channel phase, during the unusual abundance forming 0.10% of the total oligochaete abundance. The species occurred at a depth of 1.2 m, water temperature 33 ºC, sediment temperature 30.1 ºC, dissolved oxygen 6.4 mg/L, sediment pH 6.65, organic matter 0.87% and moisture content 19.2%. *Dero zeylanica* occurred in sandy silt substrate.

6. ***Dero nivea*** Aiyer, 1929
   Genus- *Dero* Oken, 1815
   Family- Naididae
   Order-Tubificida

Worms minute and slender. Prostomium bluntly triangular with stiff cilia on its margin. Dorsal setae from VI onwards, 1 hair and 1 bifid needle setae with equal teeth. Ventral setae about 4 per bundle, in II-V longer and thinner than the rest and with the distal tooth almost twice as long as proximal and with a proximal nodulus. In the remaining segments, teeth of the ventral setae are equally long; the nodulus is distal. The distinct characteristic in the identification of this species is funnel shaped branchial fossa with 3 pair of ciliated gills (Naidu 2005). They were found attached to the roots of *Salvinia molesta* and found in plankton samples in Veli lake (Sobhana 1982).

Occurrence

Dero nivea was present only in station 1 in January 2010 which was the beginning of the dry phase forming 0.10% of the total oligochaete abundance. The species occurred at a depth of 0.21 m, water temperature 28 ºC, dissolved oxygen 6.51 mg/L, sediment temperature 24.1 ºC, sediment pH 5.92, organic matter 6.53%, moisture content 36.8%. *Dero nivea* occurred at sandy silt substrate.

7. ***Branchiodrilus semperi*** Bourne, 1890
   Genus- *Branchiodrilus* Michaelsen, 1900
   Family- Naididae
   Order-Tubificida

Large brownish worms with a bluntly conical prostomium. Gills finger-like, dorsolateral, decreasing in length and disappear in the posterior segments. Dorsal setae from VI with 1-2 hair setae and 1-2 needle setae. Hair setae smooth. Needle setae simple pointed, with a peculiar bayonet-shaped distal curve posteriorly. Ventral setae 5-7 in anterior bundles decreasing to 3-4 posteriorly with distal tooth longer and thinner than proximal with nodulus (Fig.7.5). They live in fresh water, make burrows in mud and reside in them, swimming absent. Previous reports are from Thiruvananthapuram in Kerala (Sobhana 1982, Naidu 2005).

Occurrence

Branchiodrilus semperi constituted 8.85% of the total oligochaete abundance. Their presence was in all stations and all the five phases. The maximum abundance was in May 2011 in station 4 (488 ind./m2), during the unusual abundance in May 2011. The species occurred at a range of depth 0.75-1.5 m, water temperature 25.1-31.8 ºC, dissolved oxygen 3.6-9.6 mg/L, sediment temperature 26.3-29.5 ºC, sediment pH 5.87-7.37, organic matter 0.87-13.51%, moisture content 17.5-48.3%. *Branchiodrilus semperi* occurred in sandy silt, clayey silt, silty sand and silty clay substrates.

8. ***Branchiodrilus hortensis*** Stephenson, 1910
Genus- *Branchiodrilus* Michaelsen, 1900
Family- Naididae
Order-Tubificida

Large worms with black granule in anterior segments and a bluntly conical prostomium. Gills start from VI, a pair per segment, gradually diminishing in posterior segments. Dorsal setae from VI with 2-5 hair setae and 1-2 needle setae per bundle, needle setae has straight tips. Ventral setae 4-5 per bundle, all of the same type. The black granule in the anterior, the tips of needle setae and the number of ventral setae makes its distinguishable from *Branchiodrilus semperi*. They live in fresh water among water weeds, attached to *Salvinia molesta* roots and foul smeeling sediments. Reported from Veli lake, Thiruvananthapuram in Kerala (Sobhana 1982, Naidu 2005).

Occurrence

Branchiodrilus hortensis formed 0.46% of the total oligochaete abundance showing their presence in stations 1, 2 3 and 7 and in dry, paddy and stable phases. The maximum abundance was in May 2010 in station 7 (66 ind./m2). The species occurred at a range of depth 0.2-3 m, water temperature 26.8-31.8 ºC, dissolved oxygen 3.6-8 mg/L, sediment temperature 27.1-30.2 ºC, sediment pH 6.05-7.17, organic matter 5.12-7.46%, moisture content 20.8-42.8%. *Branchiodrilus hortensis* occurred at sandy silt and clayey silt substrates.

9. Species- *Pristina breviseta* Bourne, 1891
Genus- *Pristina* Ehrenberg, 1828
Subfamily- Pristininae Lastockin, 1924
Family- Naididae
Order-Tubificida

Medium sized worms with a short mobile proboscis. Dorsal setae begin in II, 1 non serrated hair and 1 needle setae. Needle setae with weak nodulus and with equal distal and proximal teeth. Ventral setae 3-5 per bundle, anteriorly the distal tooth longer than proximal, but in posterior segments the proximal tooth is thinner and slightly longer than the distal. It was reported previously from Chirayilkil, Kovalam and Thiruvananthapuram by Naidu (2005). Recently it was reported from Tiruvallur district in Tamil Nadu (Naveed 2010).

Occurance

Pristina breviseta constituted 0.21% of the total oligochaete abundance. It was endemic to the wet phase, observed in December 2009 and November 2010, maximum population in December 2009 (66 ind./m2). The species occurred at a range of depth 1.5-2.3 m, water temperature 27.5-29.2 ºC, dissolved oxygen 3.56-3.86 mg/L, sediment temperature 26.3-29 ºC, sediment pH 6.29-6.58, organic matter 7.8-12.24%, moisture content 29.6-40.3%. *Pristina breviseta* occurred at clayey silt substrate.

10. *Pristinella minuta* Stephenson, 1914
Genus- *Pristinella* Brinkhurst, 1985

Subfamily- Pristininae Lastockin, 1924
Family- Naididae
Order-Tubificida

Minute, slender, pale white worms with a bluntly triangular prostomium. Dorsal setae begin from II, 1 hair and 2 needle setae. Hair setae was non serrated, straight and needle setae bifid. Ventral setae, 3-5 per bundle decreasing to 2 in the posterior segments.

Occurrence

Pristinella minuta was observed in all stations, contributing 6.23% of the total oligochaete abundance. It showed the maximum population in channel phase (50%) and minimum in dry phase (31%). The species occurred at a range of depth 0.4-1.5 m, water temperature 25.9-31.4 ºC, dissolved oxygen 3.2-9.6 mg/L, sediment temperature 27.1-30.6 ºC, sediment pH 5.87-7.37, organic matter 2.91-13.51%, moisture content 16.2-47.9%. *Pristinella minuta* showed no substrate preference.

11. *Pristinella menoni* Aiyer, 1929
Genus- *Pristinella* Brinkhurst, 1985
Subfamily- Pristininae Lastockin, 1924
Family- Naididae
Order-Tubificida

Small slender, delicate, whitish semi transparent worms with no proboscis and marginal cilia. Dorasl setae beginning in II, hair setae, 1-2 per bundle, non-serrated. Needles 1-2 per bundle, stout, simple pointed, or occasionally with a small distal tooth; bayonet-shaped in the distal half of the setae. Ventral setae 2-5 per bundle, increasing in length posteriorly within the anterior segments; nodulus median in II, distal in the rest. Distal tooth of ventrals longer than the proximal in the anterior segments, changing to equal length in posterior segments (Naidu 2005). They live in fresh water among aquatic vegetation, swimming is absent. *Pristinella menoni* was reported from Thiruvananthapuram and Chirayinkil in Kerala (Naidu 2005).

Occurrence

Pristinella menoni formed 9.6% of the total oligochaete abundance. It was present in all stations except station 1 showing the maximum population in channel phase (76%) and minimum in dry phase (2%) and was absent in paddy fields. The species occurred at a range of depth 0.4-2.9 m, water temperature 26.4-30.5 ºC, dissolved oxygen 3.2-9.6 mg/L, sediment temperature 26.1-31 ºC, sediment pH 5.87-7.17, organic matter 1.15-11.15%, moisture content 16.2-45.7%. *Pristinella menoni* occurred at sandy silt and clayey silt substrate.

12. ***Pristinella jenkinae*** Stephenson, 1931
Genus- *Pristinella* Brinkhurst, 1985
Subfamily- Pristininae Lastockin, 1924
Family- Naididae
Order-Tubificida

Small worms of pale white color with a bluntly triangular prostomium without proboscis. Dorsal and ventral setae from segment II. Dorsal bundles has 1 hair and 1 needle setae. Distal teeth of the needle shorter than the proximal and ventral setae 4-6 per bundle in the anterior segments and 2-3 in the posterior segments. They live in fresh water, swimming is absent but move by forward and backward creeping. Reported from Thiruvananthapuram and Chirayinkil in Kerala (Naidu 2005).

Occurrence

Pristinella jenkinae formed 8.18% of the total oligochaete abundance. It was present in all stations except station 1, also it was present all the five phases. The maximum abundance was in March 2011 in station 4 (444 ind./m2). The species occurred at a range of depth 0.4-2.9 m, water temperature 25.9-31.8 ºC, dissolved oxygen 3.6-8.8 mg/L, sediment temperature 27.2-31 ºC, sediment pH 5.87-8.01, organic matter 0.87-13.51%, moisture content 16.2-60.8%. *Pristinella jenkinae* occurred at sandy silt, clayey silt, silty sand and clayey sand.

13. ***Pristinella acuminata*** Liang, 1958
Genus- *Pristinella* Brinkhurst, 1985

Subfamily- Pristininae Lastockin, 1924

Family- Naididae

Order-Tubificida

Small, creamy white worms with a pointed triangular prostomium. Dorsal setae beginning in II, 1-5 baynot shaped, finely serrated hair setae and 5 bifid needle setae. Ventral setae also bifid, 3-6 in number. Reported from Suraj Kund, Kurishetra (Haryana) in India.

Occurrence

Pristinella acuminata was present in all stations except station 2. The maximum abundance was in May 2011 in station 4 (266 ind./m2). It formed 2.67% of the total oligochaete abundance. The species occurred at a range of depth 0.5-2.8 m, water temperature 26.8-30.5 ºC, , dissolved oxygen 2.4-9.6 mg/L, sediment temperature 26.6-30.6 ºC, sediment pH 5.87-6.87, organic matter 0.87-6.32%, moisture content 17.5-43.1%. *Pristinella acuminata* occurred at clayey silt, sandy silt and silty clay substrates.

14. ***Nais andhrensis*** Naidu and Naidu, 1981

Genus- *Nais* Muller, 1773

Subfamily- Naididae Lastockin, 1924

Family- Naididae

Order-Tubificida

Small, slender, brownish worms having a bluntly triangular prostomium with stiff cilia on its margin. Dorsal setae from V, 1 long hair and 1 bifid, sickle shaped needle setae per bundle. 2-4 less curved ventral setae. They live in fresh water and swim with brisk spiral movements. It is reported only from the Indian sub continent.

Occurrence

Nais andhrensis constituted 0.10% of the total oligochaete abundance. It made a sparse appearance in station 2 in January 2010 which was the beginning of the dry phase. The species occurred at a range of depth 0.34 m, water temperature 28 ºC, dissolved oxygen 6.51 mg/L, sediment temperature 27.1 ºC, sediment pH 5.92, organic matter 6.53%, moisture content 36.8%. *Nais andhrensis* occurred at sandy silt substrate.

15. ***Nais pardalis*** Piguet, 1906

Genus- *Nais* Muller, 1773

Subfamily- Naididae Lastockin, 1924

Family- Naididae

Order-Tubificida

Nais pardalis are medium sized worms with eyes, bluntly triangular prostomium and brown pigmentation in anterior segments. They live in fresh water and swim in spiral movements. They were reported from Asian region (Naidu 2005).

Occurrence

Nais pardalis formed 0.15% of the total oligochaete abundance. They were observed in station 1 in December 2009 and station 5 in November 2009 with a maximum population in November 2009 (44 ind./m2). The species occurred at a range of depth 2-2.1 m, water temperature 29.2 ºC, sediment temperature 29-29.1 ºC, dissolved oxygen 5.87-6.1 mg/L, sediment pH 5.19-5.87, organic matter 4.03-12.24%, moisture content 36.9-40.3%. *Nais pardalis* occurred at clayey silt and sandy silt substrates.

16. ***Aulophorus carteri*** Stephenson, 1931

Genus- *Aulophorus* Schmarda, 1861

Family- Naididae

Order-Tubificida

Small delicate worms with rounded, triangular prostomium. Dorsal setae begins in VI, with 1-2 straight, smooth hair and almost straight, bifid needle setae. Bifid ventral setae, 5-7 per bundle reducing to 3-4 posteriorly. Their peculiar character is the branchial fossa with slightly diverging palps with 3 pair of gills, 1 pair dorsal, 1 pair lateral and 1 pair ventral. They live in tubes, they can swim with horizontal wriggling movements. Reported from Veli lake and Thiruvananthapuram, in Kerala (Naidu 2005).

Occurrence

Aulophorus carteri formed 0.41% of the total oligochaete abundance. It made a single appearance in station 7 in January 2010. The species occurred at a range of depth

3 m, water temperature 26.8 ºC, dissolved oxygen 6.2 mg/L, sediment temperature 27.1 ºC, sediment pH 6.42, organic matter 7.39%, moisture content 45.7%. *Aulophorus carteri* occurred at sandy silt substrate.

17. ***Aulophorus furcatus*** Muller, 1773
Genus- *Aulophorus* Schmarda, 1861.
Family- Naididae
Order-Tubificida

Medium sized worms. Prostomium bluntly conical with stiff marginal cilia. Dorsal setae begin in V, 1 hair and 1 bifid needle with unequal teeth and a distal nodulus. Ventral setae of II-V, 2-5 per bundle, with long teeth, the distal longer than the proximal decreasing to 2-3 posteriorly. Ventral setae from V onwards with teeth nearly equal. Branchial fossa with 3 or 4 pairs of gills and lateral palps is the peculiar characteristic of this species. They live in attached or portable mucous tubes covered with foreign matter, swims with transverse movements. Reported from Veli lake in Thiruvananthapuram, Kerala (Shobhana 1982, Naidu 2005).

Occurrence

Aulophorus furcatus constituted 0.21% of the total oligochaete abundance. They were present in stations 4 and 5, only in February 2010. The species occurred at a range of depth 1.7-1.8 m, water temperature 26.2 ºC, dissolved oxygen 5.69-6.2 mg/L, sediment temperature 28-28.1 ºC, sediment pH 5.69-6.2, organic matter 4.1-.6.52%, moisture content 41.4-41.9% *Aulophorus furcatus* occurred in sandy silt and clayey silt substrate.

18. ***Aulophorus hymnae*** Naidu, 1963
Genus- *Aulophorus* Schmarda, 1861.
Family- Naididae
Order-Tubificida

Large worms with a bluntly conical prostomium with stiff cilia on its margin. Dorsal setae begin from V with 1 simple, smooth, bayonet shaped hair and 1 bifid, smooth, sickle shaped needle setae. Ventral setae 4-5 per bundle decreasing 2-3 posteriorly. Funnel shaped branchial fossa with 1 pair of contractile palps and 3 pairs of digitiform gills. They live in mucus tubes. They swim with horizontal and transverse movements. Reported previously from Coimbatore, Chittoor, Tirupati etc. in India but not reported from Kerala.

Occurrence

Aulophorus hymnae contributed 1.33% of the total oligochaete abundance. It was present in wet and dry phases also in stations station 1, 2 and 4. The species occurred at a range of depth 0.4-3 m, water temperature 26.4-30.3 ºC, dissolved oxygen 6.34-9.2 mg/L, sediment temperature 26.1-31 ºC, sediment pH 5.87-7.37, organic matter 4.7-7.86%, moisture content 26.3-43.2%. *Aulophorus hymnae* occurred at sandy silt and clayey silt substrate.

19. *Allonais inaequalis* Stephenson, 1911
Genus- *Allonais* Sperber, 1948.
Family- Naididae
Order-Tubificida

They are comparatively larger worms with light brown reddish colour and a bluntly conical prostomium. Dorsal setae begin from VI, 1-2 long, smooth, straight hair setae and slightly sickle shaped needle setae. 4-6 ventral setae per bundle. They live among aquatic vegetation and decaying matter, also in colonies of sponges. Swims by wriggling movement and were reported from Thiruvananthapuram previously (Naidu 2005).

Occurrence

Allonais inaequalis showed a sparse appearance in station 1 in December 2009 and station 6 in October 2010, contributing 0.10% of the total oligochaete abundance. It was present only in wet stations. The species occurred at a range of depth 2.1-2.8 m, water temperature 29.2 ºC, dissolved oxygen 5.61-6.1 mg/L, sediment temperature 28.1-29 ºC, sediment pH 5.19-6.83, organic matter 7.86-12.24%, moisture content 32.4-40.3%. *Allonais inaequalis* occurred at clayey silt substrate.

20. *Allonais paraguayensis paraguayensis* Michaelsen 1905

Genus- *Allonais* Sperber, 1948.

Family- Naididae

Order-Tubificida

Small, pale white delicate worms with a bluntly triangular prostomium with stiff cilia. Dorsal setae beginning in V, V I, or VII, 1-2 hairs per bundle, and 1-2 needles either simple pointed, or bifid with long teeth, the proximal being about twice as long as the distal. Ventral setae 2-8 per bundle, all about equally long, or slightly shorter and thinner in the anterior segments with the distal tooth slightly longer than the proximal. In the posterior ventral setae, nodulus is distal and the teeth equally long. In the anterior segments the nodulus may be either median or slightly distal (Fig.7.6). They live among aquatic plants and algae in fresh water and swims by transverse undulations. Reported its presence from Palghat, Malampuzha and Calicut in Kerala (Naidu 2005).

Occurrence

Allonais paraguayensis paraguayensis constituted 0.36% of the total oligochaete abundance. It made a single appearance in station 4 in May 2011 in the channel phase. The species occurred at a range of depth 1.2 m, water temperature 28.5 ºC, dissolved oxygen 6.4 mg/L, sediment temperature 30.1 ºC, sediment pH 6.65, organic matter 0.87%, moisture content 19.2%. *Allonais paraguayensis paraguayensis* occurred at sandy silt substrate.

21. *Allonais gwaliorensis* Stephenson, 1920

Genus- *Allonais* Sperber, 1948.

Family- Naididae

Order-Tubificida

Large yellowish worms with bluntly triangular and rounded prostomium. Dorsal setae from IV, each bundle with 1 hair and 1 needle setae. Needle setae sickle-shaped, bifid, with distal tooth longer and thinner than proximal. Ventral setae with distal tooth longer and thinner than proximal. Branchial fossa with two broad palp like, non contractile diverging processes on postero ventral boarder and 5 pairs of foliate gills.

Occurrence

Allonais gwaliorensis formed 2.6% of the total oligochaete abundance. It was present in all stations except station 5 and 6. It was absent in paddy and channel phases. The maximum abundance was in May 2011 in station 4 (489 ind./m2). The species occurred at a range of depth 0.3-2.8 m, water temperature 26.8-30.2 ºC, dissolved oxygen 3.6-6.4 mg/L, sediment temperature 27.1-30.1 ºC, sediment pH 5.06-6.92, organic matter 0.87-12.77%, moisture content 16.2-60.8%. *Allonais gwaliorensis* occurred at sandy silt and clayey silt substrates.

22. *Haemonais waldvogeli* Bretscher, 1900.
Genus- *Haemonais* Bretscher, 1900
Family- Naididae
Order-Tubificida

Moderate sized worms, light brown in colour with a bluntly triangular prostomium. Dorsal setae begins in VI, losing them as worms mature up to XVII to XIX and later begin in XVIII, XIX or XX with 1 hair and I bifid needle setae per bundle. Ventral setae 2-4 per bundle. They live in soft mud but not tube dwelling. Reported from Calicut in Kerala (Naidu 2005).

Occurrence

Haemonais waldvogeli formed 0.31% of the total oligochaete abundance. Their presence was in all stations except stations 1 and 7, also absent in paddy and channel phases. The maximum abundance was in January 2010 in station 1 (89 ind./m2). The species occurred at a range of depth 0.4-2.8 m, water temperature 26.8-31.4 ºC, dissolved oxygen 4.8-8 mg/L, sediment temperature 27.2-27.8 ºC, sediment pH 6.15-7, organic matter 5.51-7.46%, moisture content 31.7-42.8%. *Haemonais waldvogeli* occurred at sandy silt substrate.

23. *Stephensoniana trivandrana* Aiyer, 1926
Genus- Stephensoniana Cernosvitov, 1938
Subfamily- Stephensonianae Naidu, 1963
Family- Naididae
Order-Tubificida

Small worms, body wall with cutaneous glands, anterior body covered with mucus sheaths where foreign matter adhers. Dorsal setae beginning in II, 3-4 hair setae anteriorly, 1-2 hair setae posteriorly and 3-4 simple pointed needles. Ventral setae 4 per bundle anteriorly, decreasing to 1 posteriorly, all with a proximal nodulus and the distal tooth longer than the proximal. They live in fresh water, found in soft bottom mud of tanks covered with decaying organic matter and other vegetable debris also found attaches to the roots of *Salvinia molesta*, Swims with brisk wriggling movements. Reported from Veli lake and Thiruvananthapuram in Kerala (Sobhana 1982, Naidu 2005).

Occurrence

Stephensoniana trivandrana formed 4.2% of the total oligochaete abundance. It was present in all stations and all phases. The species occurred at a range of depth 0.3-3.1 m, water temperature 26.8-31.4 ºC, dissolved oxygen 4.8-8 mg/L, sediment temperature 24.1-31.1 ºC, sediment pH 6.21-7.23, organic matter 0.87-11.15 %, moisture content 17.0-42.8%. *Stephensoniana trivandrana* occurred at silty sand, sandy silt, clayey silt and clayey sand substrates.

24. *Lumbriculus variegates* Muller, 1773
Genus- Lumbriculus Grube, 1844
Family- Lumbriculidae Vejdovsky
Order-Lumbriculida

Large worms with a bluntly conical prostomium. Bifid setae in four bundles, 2 ventro lateral and 2 dorso lateral of the same type. It has a cosmoplolitan distribution.

Occurrence

Lumbriculus variegates constituted 0.36% of the total oligochaete abundance. Their presence was in stations 3, 4 and 5 and in wet and paddy phases. The species occurred at a range of depth 0.2-2.8 m, water temperature 26.8-30.2 ºC, dissolved oxygen 3.2-8 mg/L, sediment temperature 27.2-30 ºC, sediment pH 5.87-6.83, organic matter 0.87-10.99%, moisture content 17.5-41.4%. *Lumbriculus variegates* preferred sandy silt and clayey silt substrates.

25. *Nais sp.*

Genus- *Nais* Muller, 1773

Subfamily- Naididae Lastockin, 1924.

Family- Naididae

Small worms, eyes and proboscis absent, Dorsal setae from V, 1 hair and 1-2 needle setae, 3-5 ventral setae.

Occurrence

Nais sp. made a single appearance in station 2 in July 2010 forming 0.051% of the total oligochaete abundance. The species occurred at a range of depth 2.9 m, water temperature 30.3 ºC, dissolved oxygen 5.6 mg/L, sediment temperature 27.4 ºC, sediment pH 6.27, organic matter 1.67%, moisture content 40.5%. *Nais sp.* preferred clayey silt substrates.

26. *Aulodrilus sp.*

Genus- *Aulodrilus* Bretscher, 1899

Subfamily- Aulodrilinae Brinkhurst and Jamieson, 1971

Family- Tubificidae Beddard, 1895

Large worms. No eyes and proboscis, dorsal setae from II. 5-7 hair and 6-8 neeedle setae reducing to 1 hair and 1-2 needle setae posteriorly. Ventral setae 6 in II, increasing to 12 in VI , reducing to 4-5 in posterior segments.

Occurrence

Aulodrilus sp. formed 8.06% of the total oligochaete abundance. It was present in all stations except station 1. Also their presence was in all the phases. The maximum abundance was in July 2010 in station 6 and May 2010 in station 7 (200 ind./m2). The species occurred at a range of depth 0.2-3.2 m, water temperature 25.9-32.5 ºC, dissolved oxygen 4.87-15.68 mg/L, sediment temperature 25.3-31 ºC, sediment pH 5.92-7.37, organic matter 0.87-15.68%, moisture content 11.3-60.8%. *Aulodrilus sp.* preferred sand, sandy silt and clayey silt substrates.

27. *Haemonais sp.*

Genus- *Haemonais* Bretscher, 1896

Family- Naididae

Medium sized worms, eyes and proboscis absent, light brown pigmentation in anterior segments. Dorsal setae begins in VI, with 1 hair and 1-2 needle setae per bundle. Ventral setae 2-4 per bundle.

Occurrence

The share of *Haemonais sp.* to the total oligochaete abundance was 0.10%. It was present only in station 1 in January 2010 and April 2011. Their presence was restricted only to dry and paddy phases. The species occurred at a range of depth 0.2-0.4 m, water temperature 26.8-30.2 ºC, sediment temperature 25.1-30.6 ºC, dissolved oxygen 3.2-4.4 mg/L, sediment pH 6.06-6.09, organic matter 5.37-8.63%, moisture content 18.2-29.8%. *Haemonais sp.* preferred sandy silt and clayey silt substrates.

Among the oligochaete species, 23 species belonged to the family Naididae, 3 belonged to Tubificidae and 1 from Lumbriculidae (Fig. 7.7). In station 1, 14 species of oligochaetes were present, where two species belonged to the family Tubificidae and 12 species belonged to the family Naididae. The most abundant species was *Branchodrilus semperi* (28%) followed by *Aulodrilus sp.* (11%) (Fig.7.8). Similarly in station 2 also 14 species were present, of which 3 species were from the family Tubificidae and 11 species from Naididae. The most abundant species present here was *Pristinella menoni* (38%) and *Aulodrilus sp.* (11%). (Fig.7.9). In station 3, out of the total 13 species present, 3 species belonged to the family Tubificidae, 9 species belonged to the family Naididae and 1 species belonged to the family Lumbriculidae, *Aulodrilus pluriseta* being the most abundant (61 %) followed by *Pristinella jenkinae* (6%) (Fig.7.10). A total of 16 oligochaete species were present in station 4, among them 3 species were from the family Tubificidae, 12 species from Naididae and 1 species from Lumbriculidae. The most abundant species was *Aulodrilus pluriseta* (36%) followed by *Pristinella jenkinae* (12%) (Fig.7.11). Sixteen species were present in station 5, of which 3 species were from the family Tubificidae, 12 species from Naididae and 1 species from Lumbriculidae, *Aulodrilus pluriseta* (41%) being the most abundant species followed by *Pristinella minuta* (13%) (Fig.7.12). In station 6, 9 species of oligochaetes were present, 2 species belonged to the family Tubificidae and 7 species belonged to the family Naididae. The most abundant species were *Aulodrilus pluriseta* (47%) followed by *Aulodrilus sp.* (13%) (Fig.7.13). A total of 14 oligochaete species were present in station 7, of which 2 species belonged to the family Tubificidae and 12 species belonged to the family Naididae. *Aulodrilus pluriseta* (36%) was the most abundant species here followed by *Stephansonia trivandriana* (13%). (Fig.7.14). In station 8 also 10 species were present, of which 2 species were from the family Tubificidae and 8 species from Naididae. The most abundant species were *Aulodrilus pluriseta* (47%) and *Aulodrilus sp*. (13%) (Fig.7.15).

The composition of benthic fauna was compared between the wet, dry, paddy, channel and stable phases. In wet phase, 12 species of oligochaetes were present, *Aulodrilus pluriseta* (50%) was the most abundant species followed by *Branchodrilus semperi* (11%) and *Pristinella jenkinae* (11%) (Fig.7.16). Dry phase was characterised by the presence of 15 oligochaete species, which was the maximum number of species among all phases. *Aulodrilus pluriseta* (38%) was the most abundant species here followed by *Aulodrilus sp*. (13%). (Fig.7.17). In paddy phase, only 9 species of oligochaetes were present. The most abundant species was *Aulodrilus sp.* (23%) and *Aulodrilus pluriseta* (18%) (Fig.7.18). A total of 14 oligochaete species were present in the channel phase, *Aulodrilus pluriseta* (37%) being the most abundant species followed by *Branchodrilus semperi* (13%) (Fig.7.19). In stable phase, 9 species of oligochaetes were present, *Aulodrilus pluriseta* (56%) was the most abundant species followed by *Pristinella minuta* (12%) (Fig.7.20). Out of 27 species of oligochaetes, 4 species were observed in all the phases. *Aulodrilus pluriseta, Aulodrilus sp., Branchodrilus semperi, Pristinella jenkinae* and *Pristinella minuta* were the species present in all the phases. Some species were restricted to some phases. *Pristina breviseta, Nais pardalis, Nais sp*. were found exclusively in wet phase. *Dero nivea* in dry phase, *Allonais paraguayensis paraguayensis and Dero zeylanica* in Channel phase and *Aulophorus carteri* in stable phase. The species which were found exclusively were very few in number that made sparse appearances.

The composition of oligochaete species in the dry phase and wet phase was compared using ANOSIM. The dissimilarity between the dry phase and the wet phase was not very strong (R=0.05 p=3.4%). The ANOSIM of oligochaete species pattern between paddy and wet phase also showed that the dissimilarity in oligochaete compostion was not very strong (R-0.091 p=4.2%). When the oligochaete compostition between the wet and channel phase was compared using ANOSIM a negative R value was observed (R=-0.12, p=97.2%). Negative R values indicate that dissimilarities within the group were greater than dissimilarities between groups. Here the channel phase was characterised by the unusual abundance, during which some species like *Allonais gwaliorensis*, *Dero zeylanica*, *Allonais paraguayensis paraguayensis* made an exclusive appearance, that made the oligochaete composition in May 2010 different from the composition in other months in channel which resulted in a negative R value in ANOSIM analysis.

7.2.2 Community structure of oligochaetes

7.2.2.1 Univariate indices of oligochaete community structure

Monthly mean variation in richness of oligochaetes in Maranchery Kole wetlands is given in Fig.7.21. The mean richness was 1.36±0.41. The maximum richness was recorded in December 2009 (d=2.19) and minimum in December 2010 (d=0.41). The evenness showed a mean value of 0.78±0.12 with the maximum evenness in June 2011 (j' =1) minimum in September 2010 (j' =0.36) (Fig.7.22). Shannon wiener diversity was the highest in January 2010 (H'=3.13) and lowest in September 2010 (H'=1.03). The average diversity was 2.27±0.50 (Fig.7.23). Dominance based on oligochaetes ranged from 0.14 in November 2010 to 0.69 in September 2010 with an average value of 0.27±0.12 (Fig.7.24). The univariate indices of diversity in the eight stations are given in Table 7.1. When oligochaete richness was compared among stations, the maximum richness was observed in station 2 (d=1.685) and minimum in station 6 (d=0.9423). (Fig.7.25). The evenness based on oligochaete species showed the maximum evenness in station 1 (j' =0.8094) and station 3 showed the lowest (j'=0.5832). (Fig.7.26). The analysis of the diversity of oligochaetes in the stations were compared. The maximum diversity was in station 4 (H'=3.132) and minimum in station 3 (H'=2.22) (Fig.7.27). When the dominance based on oligochaete species were compared, station 3 showed the maximum dominance (λ'=0.3966) and station 1 the lowest (λ'=0.1716) (Fig.7.28).

The community structure of oligochaete species in various phases were analyzed (Table 7.2). Richness showed the maximum value in the dry phase (d=3.293) and minimum in the stable phase (d=1.423) (Fig.7.29). The maximum evenness was noticed in paddy phase (j'=0.9451) and minimum in wet phase (0.6674) (Fig.7.30). The maximum diversity was in paddy phase (H'=2.99) followed by the dry phase (H'=2.96) and channel phase (H'=2.63). The lowest diversity was observed in the stable phase (H'=2.144) (Fig.7.31). Stable phase showed the maximum dominance value (λ'=0.3468) and paddy phase showed the minimum value (λ'=0.1243) (Fig.7.32).

7.2.2.2 Multivariate analyses of oligochaete community structure

Cluster analysis (Bray Curtis similarity)

The similarity analysis between stations based on the numerical abundance of oligochaetes showed that station 4 and station 5 were clustered at 91% similarity (Fig. 7.33). SIMPROF analysis showed that Station 1 and station 2 showed a significant difference from the other stations. The similarity analysis based on the abundance of oligochaetes among the phases showed that wet phase and stable phase were clustered at 62% similarity whereas the dry and paddy phases were clustered at 62% similarity. SIMPROF analysis showed that dry and paddy, wet and stable groups were clustered together at 40% similarity (Fig. 7.34).

MDS ordination (Non metric multi dimensional scaling)

MDS plots were constructed to analyze the similarity between stations and phases with respect to numerical abundance of oligochaetes. MDS plots for total numerical abundance between stations showed that all the stations were grouped at 40% similarity. Station 1 was standing apart with a similarity of 40% with other stations. The other stations were clustered together at 60% similarity. A stress value of 0 was observed (Fig 7.35). MDS plots for total oligochaete abundance between phases revealed that wet phase and stable phase were clustered together at 60% similarity. Similarly dry and paddy phase were also clustered together at 60% similarity. Channel phase was standing apart with an overall similarity of 40% with the other phases. The MDS plots gave a good ordination having a stress value of 0 for phase wise distribution (Fig 7.36).

Abundance Biomass Curve (ABC)

In the present study, the ABC plot showed that the biomass curve was lying above the abundance curve in all stations depicting an undisturbed condition. W values ranged from 0.03 in station 4 to 0.3 in station 6 (Figs.7.37 to 7.44).

7.3 Discussion

The composition of oligochaetes in this study showed that the largest number of species were represented by the family Naididae (23 species), followed by Tubificidae (3 species) and by Lumbriculidae (1 species). The total oligochaete species reported from India revealed a similar trend in composition. Naididae represented 59 species and 2 subspecies, 16 species of Tubificidae, comprising 8 species of Aeolosomatidae, 8 species of Enchytraeidae, 1 species of Phreodrilidae, 1 species of Lumbriculidae out of the 102 species of aquatic oligochaetes (Naidu 2005). 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. Naididae contributed the largest number of species in most of the studies. Behrend et al. (2009) observed that in Baia and Ivinhema rivers, the oligochaete community consisted of 14 species of the family Naididae, 4 species of the family Tubificidae, 1 species each from the families Alluroididae, Haplotaxidae, Opistocystidae and Narapidae. The oligochaetes of lake Kovada, Turkey comprised of 8 species of Naididae, 7 species of Tubificidae and 1 species each of Enchytraeidae and Lumbriculidae (Arslan and Sahin 2006). Thirteen species of the family Naididae, 3 species of the family Tubificidae and 1 species of the family Enchytraeidae constituted the oligochaete community of Taichung water basin, China (Lin and Yo 2008). Verdonschot (1999) recorded oligochaetes belonging to 12 species of Naididae, 9 species of Tubificidae and 2 species of Lumbriculidae from a stream Elsbeek, The Netherlands. In Lake Biwa, Japan, 41 taxa of oligochaetes belonging to 23 species of the family Naididae, 15 species of the family Tubificidae and 1 species each of the family Biwadrilidae, Lumbriculidae and Enchytraeidae was recorded (Ohtaka and Nishini 1999). Sinha et al. (1991) recorded 5 species of Naididae, 8 species of Tubificidae and 1 species Aelosomatidae from a fresh water habitat, India.

When the oligochaete composition of paddy fields were analyzed, the oligochaete populations in Philippines was dominated by *Limnodrilus hoffmeisteri* and *Branchiodrilus sowerbyi* of the family Tubificidae (Simpson et al. 1993). Heckman (1974) and (1979) recorded oligochaete species exclusively of the family Nadidae from the paddy fields from Laos and Thailand respectively. According to Senapati et al. (1991), the earthworm *Darwida willsi* dominated the paddy fields in India. The families Aeolosomatidae, Tubificidae and Megascolecidae constituted oligochaete fauna in Chapra, Bihar (Ojha et al. 2010). A recent study from the paddy fields of Dakshin Kannada revealed a very high density of *Aulophorus furcata* of the family Naididae (Hegde and Sreepada 2014).

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 (Hegde and Sreepada 2014). A difference in the sampling strategy would have resulted in a higher number of species from Maranchery Kole wetlands. 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 (Ojha et al. 2010). Ten oligochaete species belonging to 8 genera were identified in ponds from Thiruvananthapuram, Kerala (Ragi and Jaya 2014). Ojha et al. 2010).More oligochaete species were documented from wetlands/paddy fields than ponds

The ANOSIM results revealed that the composition of oligochaete species remained similar in all the phases. The survival strategy used by oligochaetes during extreme environments by forming cysts etc. would have ensured the presence of oligochaetes throughout the phases. 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 the phases, 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 (Verdonschot 1989, Verdonschot 1999). Further, the phases explored in this study were very close to each other or the same site in a different temporal scale, even they behaved as single water body for a particular period. So a very different oligochaete composition among them is not expected.

In benthic communities disturbances have been related to changes in community parameters such as species richness, diversity and numerical abundance (Widdicomb and Austen 2001) to changes in community structure (Warwick and Clarke 1993). In the present study, the phases which were different from the normal condition could be regarded as disturbance. Disturbances can be categorized by their temporal patterns as pulses, presses, and ramps. Pulses are short-term and sharply delineated disturbances. Floods are usually pulses, especially in constrained rivers. Presses are disturbances that may arise sharply and then reach a constant level that is maintained. Ramps, which occur when the strength of a disturbance steadily increases over time (and often simultaneously in spatial scale). Droughts are classified as ramps (Grigg 1996). The incremental spread of an exotic organism is also considered as ramp, hence the paddy phase can be included as ramp. The reduced water level in paddy field can be considered as drought also as it fits into the recent definition of drought. Drought has been defined as 'an unpredictable low-flow period, which is unusual in its duration, extent, severity or intensity' (Humphries and Baldwin 2003). The dry and paddy phase could be considered as disturbed phases whereas wet and stable as undisturbed phases.

When the diversity was compared among the different phases, the paddy and dry phases which were considered as disturbed phases showed a slightly higher diversity compared to the stable and wet phases which were considered as disturbed phases. Similarly dominance values were higher in the stable phases than unstable phases. In 1978 Connel proposed the Intermediate Disturbance Hypothesis (IDH) to explain the high species diversity in rain forests and on coral reefs which was applied to other ecosystems later. He reasoned that there was a competitive hierarchy of species where, in the absence of disturbance, superior species would outcompete inferior ones, thus reducing species diversity. In this model when a disturbance occurs individuals are removed, opening up space for inferior competitors and thus increasing species richness. Under severe disturbance regimes, most individuals may be removed and species richness is low. Thus, highest diversity is to be expected at intermediate disturbances. According to IDH theory, at intermediate levels of disturbance, diversity is maximized because both competitive k-selected and opportunistic r-selected species can coexist. The main difference between both types of species is their growth and reproduction rate. These characteristics attribute to the species that thrive in habitats with higher and lower amounts of disturbance. k-selected species generally demonstrate more competitive traits. Their primary investment of resources is directed towards growth, causing them to dominate stable ecosystems over a long period of time. In contrast, r-selected species colonize open areas quickly and can dominate areas that have been recently cleared by disturbance. In the case of oligochaetes, the life histories and reproductive strategies of naidids and tubificids vary considerably. Growth in naidid populations mainly depends on asexual reproduction (paratomy, fragmentation) within a short period of individual life spans, whereas sexual outbreeding plays only a minor role. Naidid populations are characterized by considerable fluctuations of abundance. Various species of naidids can disperse actively in the water column (Learner et al. 1978) and can thus more easily colonize different habitats. Due to these characteristics of naidids, they could be considered as r strategists. Aquatic and mesopsammic tubificids represent a 'conservative' type of sexual reproduction within well defined breeding periods and their population structure is fairly stable (Giere and Pfannkuche 1982). Further as tubificids live mostly within the substrate, they are slow colonizers (Elissen et al. 2008, Levin et al. 1996). As these characters ideal for k strategists tubificids were considered as k strategists (Marchese and Ezcurra de Drago 1992, Ezcurra de Drago et al. 2007). Though the life strategy of naidids and tubificids arbitrarily fit their classification into r strategists and k strategists respectively, researchers opined that the classification of oligochaetes into r and k strategists is difficult. Further the distinction between r- and K-strategists is relative, since every species has a position in an r-k-continuum (Schaefer 2003). According to Pianka (1970), an organism's position along *r-k* selection continuum depends on the particular environment at the particular instant in time. The classification of an organism as an "*r*-

strategist" or a "*k*-strategist" is only relative to some other organism. Though oligochaetes are generally considered as *r*-strategists, within oligochaetes depending upon the colonization ability, reproductive strategy, population structure etc. Tubificidae are considered as k strategists and Naididae as *r*-strategists. In this study, in wet and stable phases, the species *Aulodrilus pluriseta* which belongs to the family Tubificidae, which was considered as k strategists constituted 50% and 56% respectively while in the other phases their contribution was less where the Naididae which were r strategists also co occurred in large number along with this (*Aulodrilus pluriseta* represented 38% in dry phase). But In the paddy phase though *Aulodrilus pluriseta* was only 20% *Aulodrilus sp.* also showed 22% abundance. The slightly increased diversity in the disturbed phases compared to undisturbed phases reflects a glimpse of IDH theory, though not very prominent.

IDH theory also states that once k-selected and r-selected species can live in the same region, species richness can reach its maximum. The results of the present study also agree with this statement. The species richness in the disturbed phases (dry phase d=3.293) was found to be more compared to that of the undisturbed phases (stable phase d=1.423). In wet and stable phases, the more uniform habitat pattern and the consistent environment might have resulted in the establishment of the characteristic species *Aulodrilus pluriseta* thus high dominance and low diversity while in dry and paddy phases, the heterogeneity in the habitat and the changing environment would have resulted in modifying the species pattern ending up in high diversity. Gascon et al. (2007) compared the effects of hydrological disturbance on plankton and benthic communities in Emporda wetlands, Spain where he observed that in benthic communities, hydrological disturbance caused a decrease in dominance in the characteristic species. High diversity in dry phases compared to wet phase was observed in many studies. Contradictory results were also seen in some studies, Deeley and Paling (1999) stated that naturally variable systems are usually characterised by the dominance of pioneering species that are resilient to environmental fluctuations. Conversely, stable systems subject to minimal or infrequent disturbance generally support diverse communities with low species dominance.

Similarity analysis showed that station 1 was standing apart from other clusters mainly due to the reduced oligochaete abundance in this station, further the presence of *Haemonais sp.* was unique to this station. Station 2 also was charecterized by a reduced abundance compared to other stations (except station1), also the presence of *Nais andhrensis* and *Nais sp.* was unique to station 2, which separated this from the other stations. The cluster analysis groupings based on oligochaete abundance between phases closely reflected the difference in depth and habitat type. Group 1 consisted of 2 phases, wet and stable phases characterized by deep, large and continuous water body. Group 2 contained dry and paddy phases which were shallow and discontinuous in nature. Group 3 was the channel phase of intermediate depth. The unusually high abundance in channel phase, which was not comparable to the other phases and the presence of *Dero zeylanica* and *Allonais paraguensis paraguensis* which were unique to channels separated channel phase from the other phases. Dry and paddy phases were characterized by similar abundance and the absence of a clear dominance of *Aulodrilus pluriseta*, which resulted in clustering of these phases together. In wet and stable phases, a clear domination of *Aulodrilus pluriseta* was apparent, also oligochaete abundance also showed similarity among them, these lead to the clustering of wet and stable phases together. The MDS plots showed a stress factor of 0, a stress value revealing a good biological ordination (Clark 1993).

Abundance-Biomass Curve (ABC) showed biomass curve above the abundance curve in all the stations. Positive values in all the stations showed an undisturbed condition of benthos inspite of the disturbances associated with the habitat alterations. There is some controversy on whether the ABC method has a universal application in identifying community disturbance. Since its introduction (Warwick 1986) it has been successfully applied on many occasions in temperate and tropical soft bottom communities (Warwick and Ruswahyuni 1987, Anderlini and Wear 1992), in mesocosm experiments (Gray et al. 1988) and at fish culture sites (Ritz et al. 1989). On other occasions, ABC curve did not correctly characterize the disturbance status of some sites like Gialova Lagoon in the Ionian Sea (Ibanez and Dauvin 1988, Weston 1990, Craeymeersch 1991).

Table 7.1. Mean diversity indices of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

	Richness (d)	**Evenness (J')**	**Diversity (H')**	**Dominance (λ')**
Station 1	1.491	0.8094	2.902	0.1716
Station 2	1.685	0.7497	2.929	0.1961
Station 3	1.513	0.5832	2.22	0.3966
Station 4	1.638	0.7831	3.132	0.1729
Station 5	1.525	0.7295	2.85	0.215
Station 6	0.9423	0.7456	2.364	0.276
Station 7	1.504	0.7906	3.01	0.1813
Station 8	1.04	0.7558	2.511	0.268

Table 7.2. Mean diversity indices of oligochaetes in the five phases in Maranchery Kole wetlands.

	Richness (d)	**Evenness (J')**	**Diversity (H')**	**Dominance (λ')**
Wet phase	1.993	0.6674	2.393	0.285
Dry phase	3.293	0.7578	2.96	0.1882
Paddy phase	2.026	0.9451	2.996	0.1243
Channel phase	1.68	0.7854	2.906	0.1905
Stable phase	1.423	0.6763	2.144	0.3468

Fig.7.1. Aulodrilus pluriseta

Fig 7.2. Aulodrilus pluriseta- ventral setae (IVth segment)

Fig 7.3. Aulodrilus pigueti

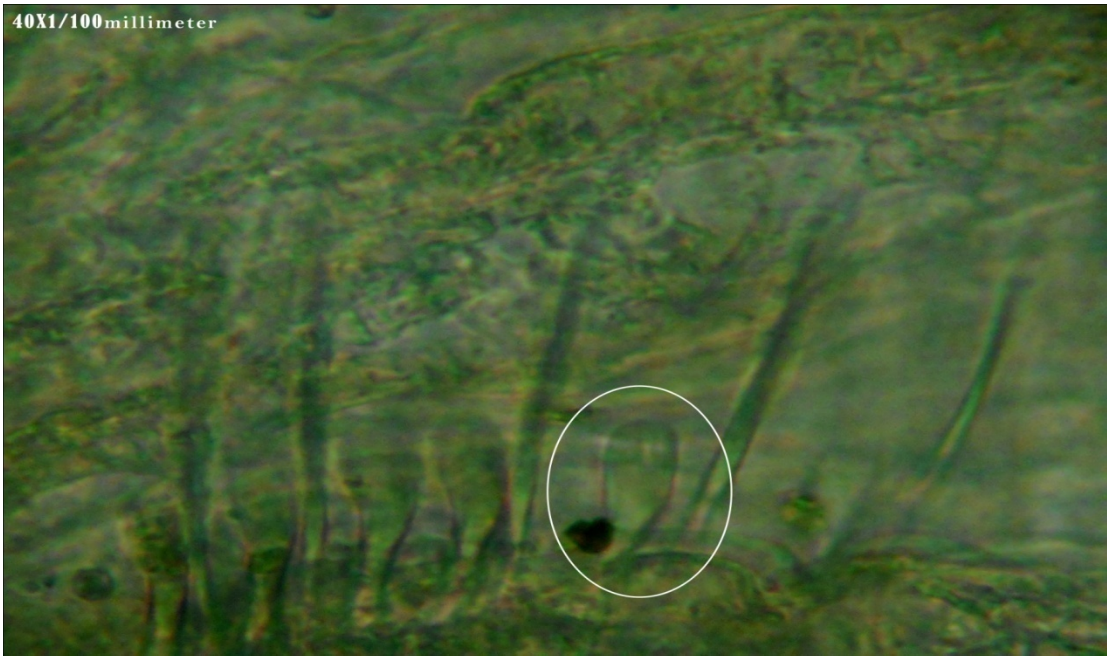

Fig 7.4. Aulodrilus pigueti **Dorsal setae (Xth segment - Oar shaped setae)**

Fig 7.5. Branchiodrilus semperi

Fig 7.6. Allonais paraguayensis paraguayensis

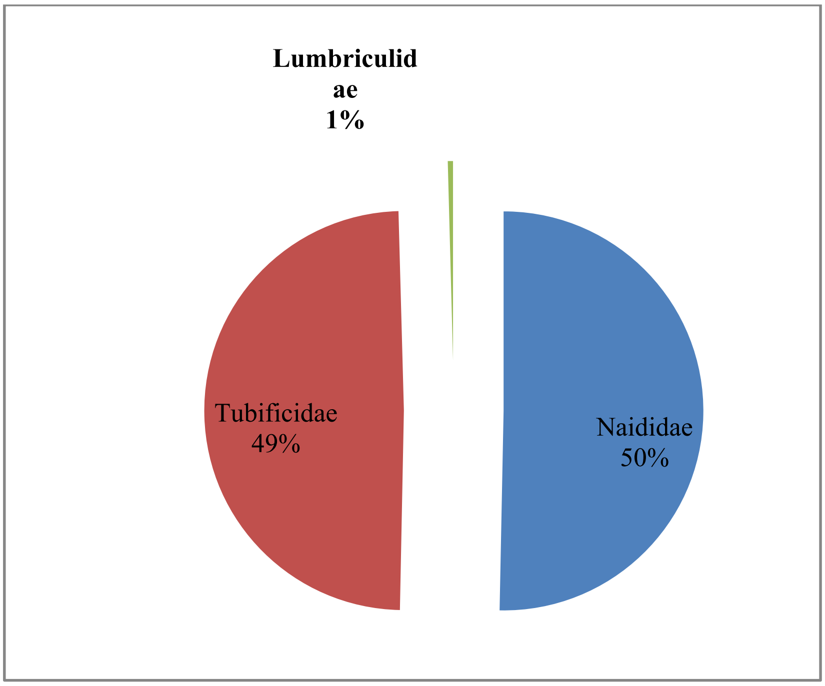

Fig.7.7. Mean percentage composition of oligochaete families in Maranchery Kole wetland during the study period.

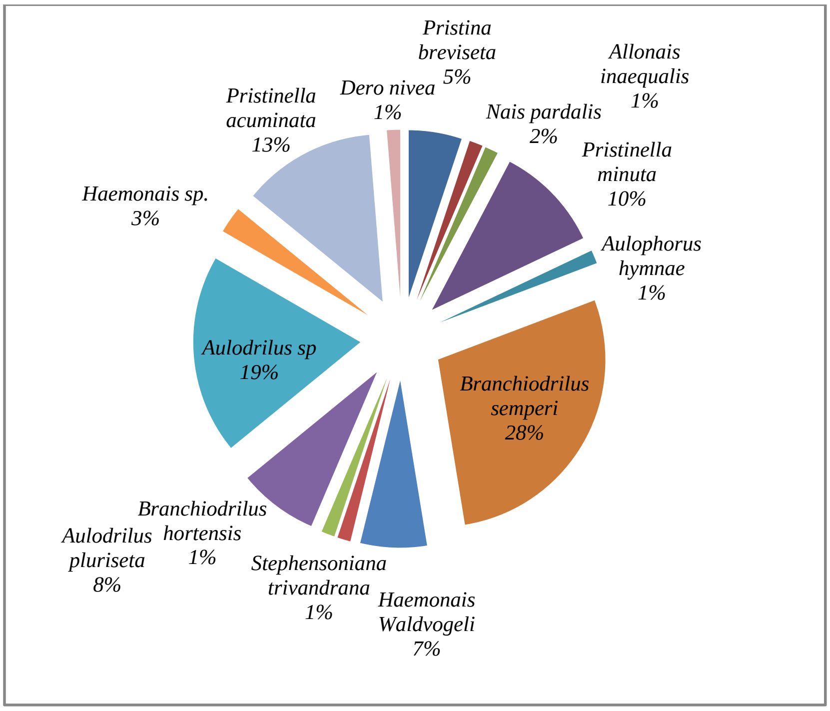

Fig.7.8. Mean percentage composition of oligochaete species in station 1 during the study period.

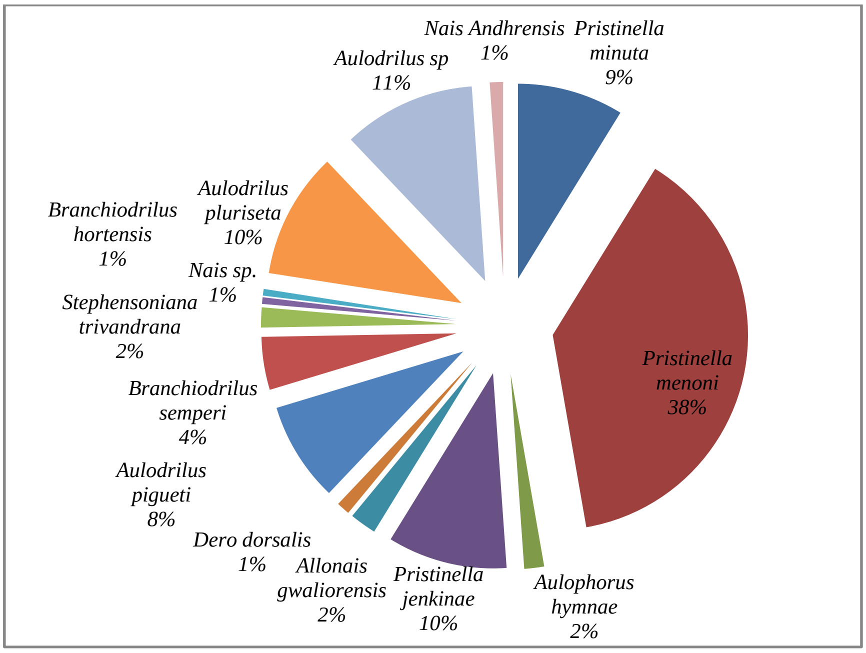

Fig.7.9. Mean percentage composition of oligochaete species in station 2 during the study period.

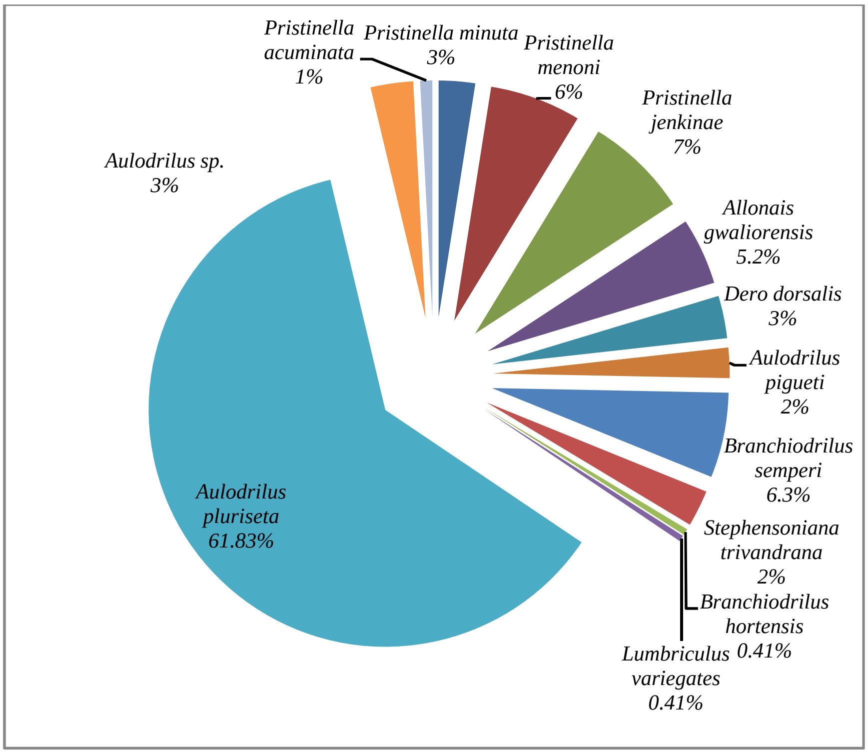

Fig.7.10. Mean percentage composition of oligochaete species in station 3 during the study period.

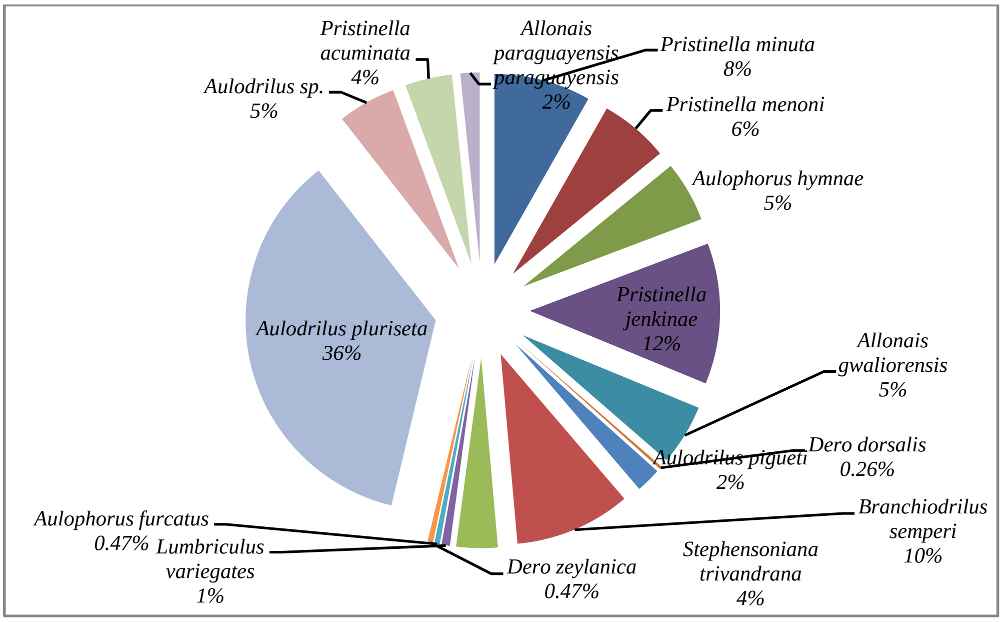

Fig.7.11. Mean percentage composition of oligochaete species in station 4 during the study period.

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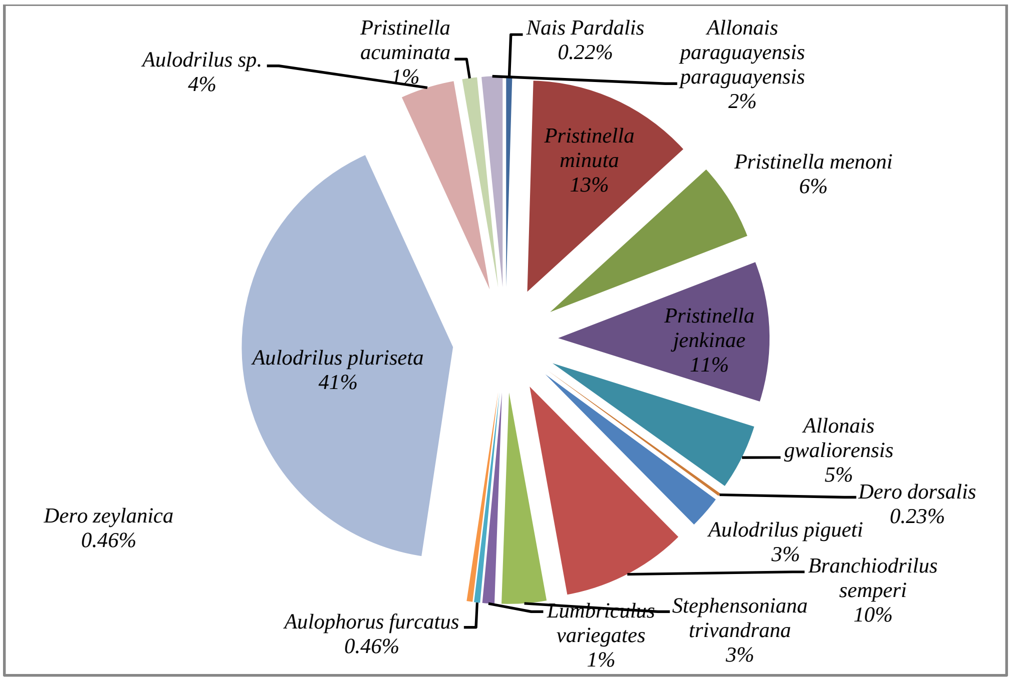

Fig.7.12. Mean percentage composition of oligochaete species in station 5 during the study period.

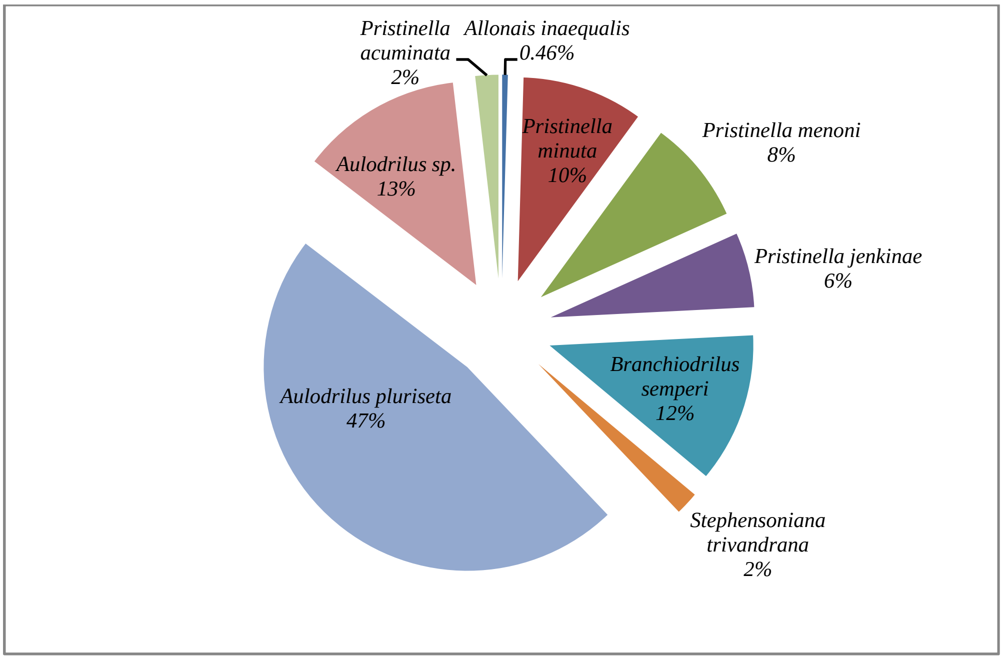

Fig.7.13. Mean percentage composition of oligochaete species in station 6 during the study period.

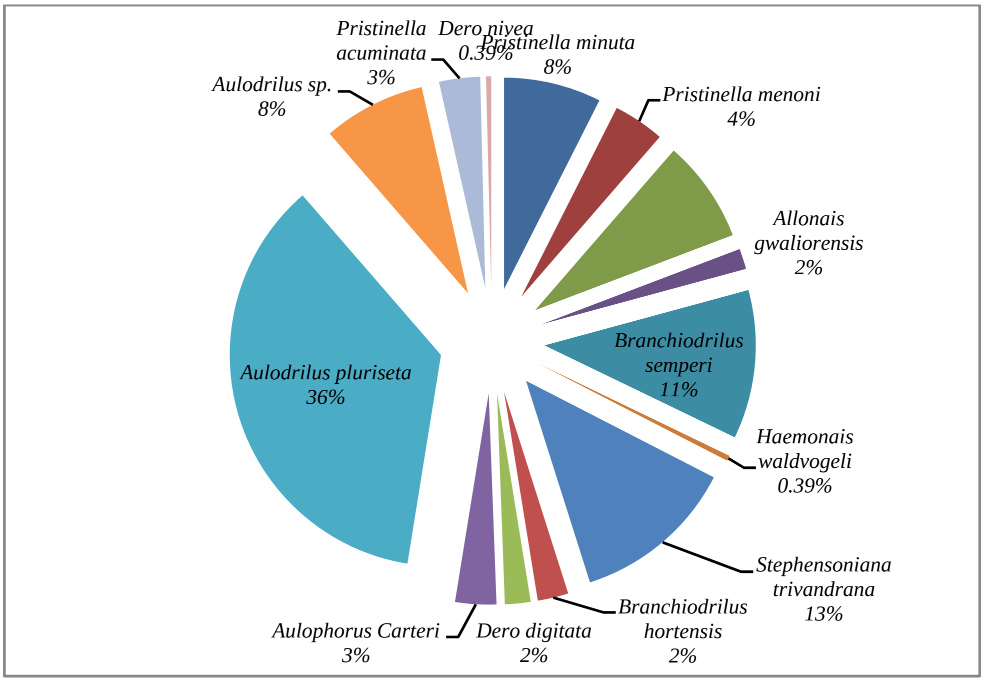

Fig.7.14. Mean percentage composition of oligochaete species in station 7 during the study period.

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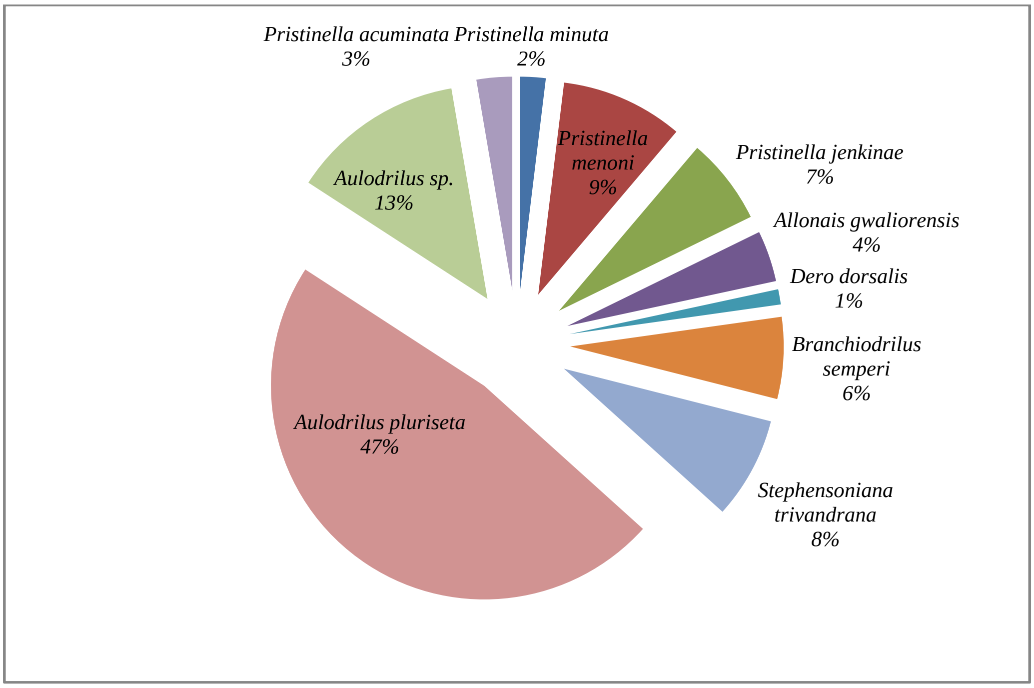

Fig.7.15. Mean percentage composition of oligochaete species in station 8 during the study period.

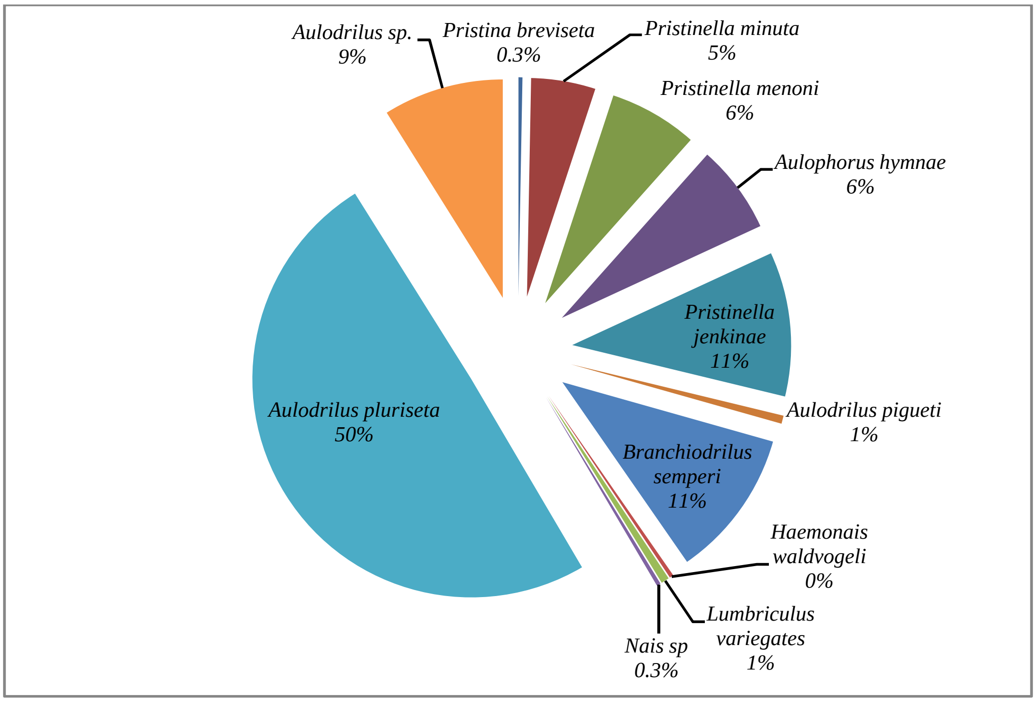

Fig.7.16. Mean percentage composition of oligochaete species in wet phase.

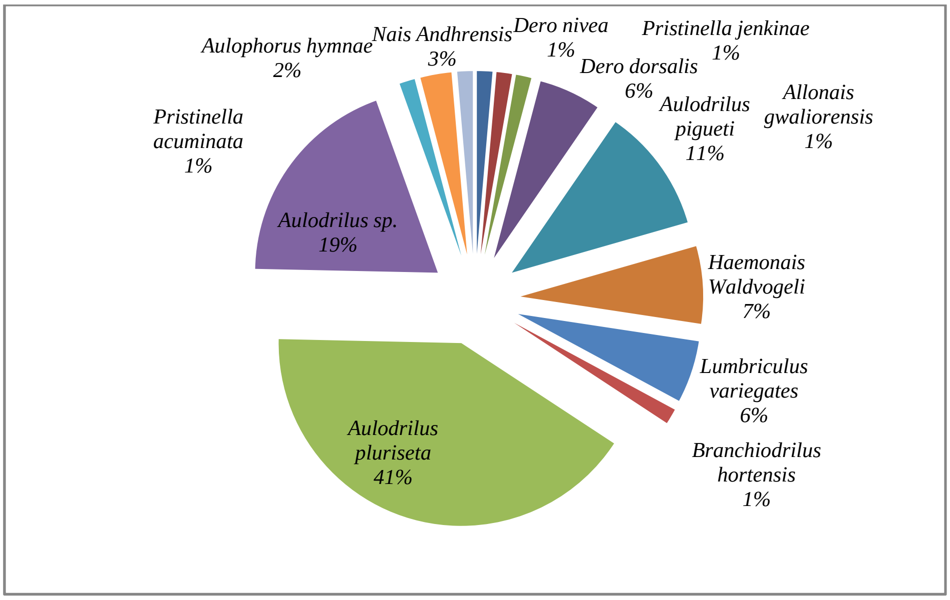

Fig.7.17. Mean percentage composition of oligochaete species in dry phase.

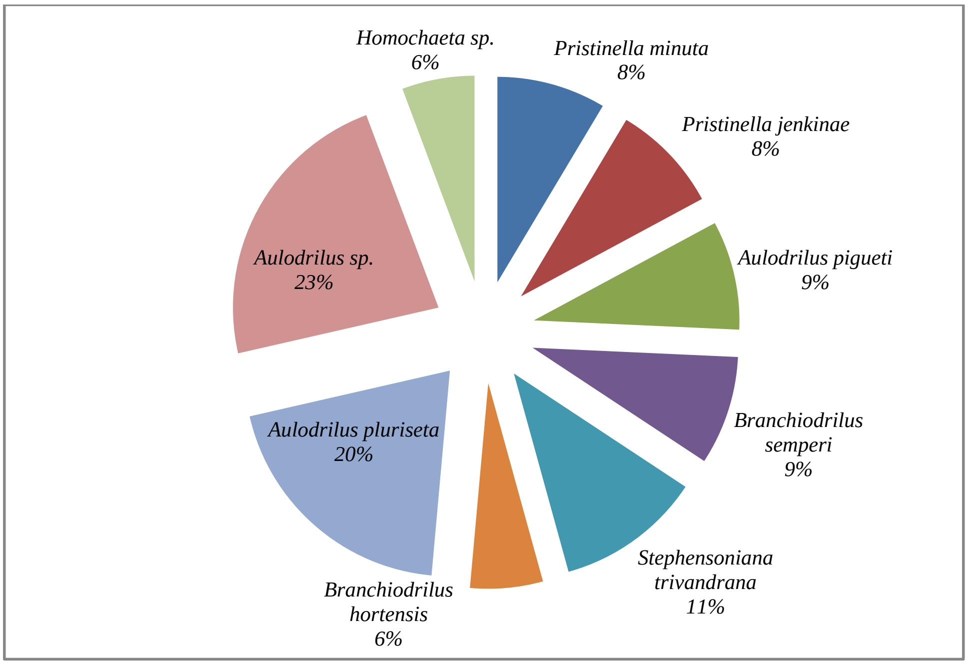

Fig.7.18. Mean percentage composition of oligochaete species in paddy phase.

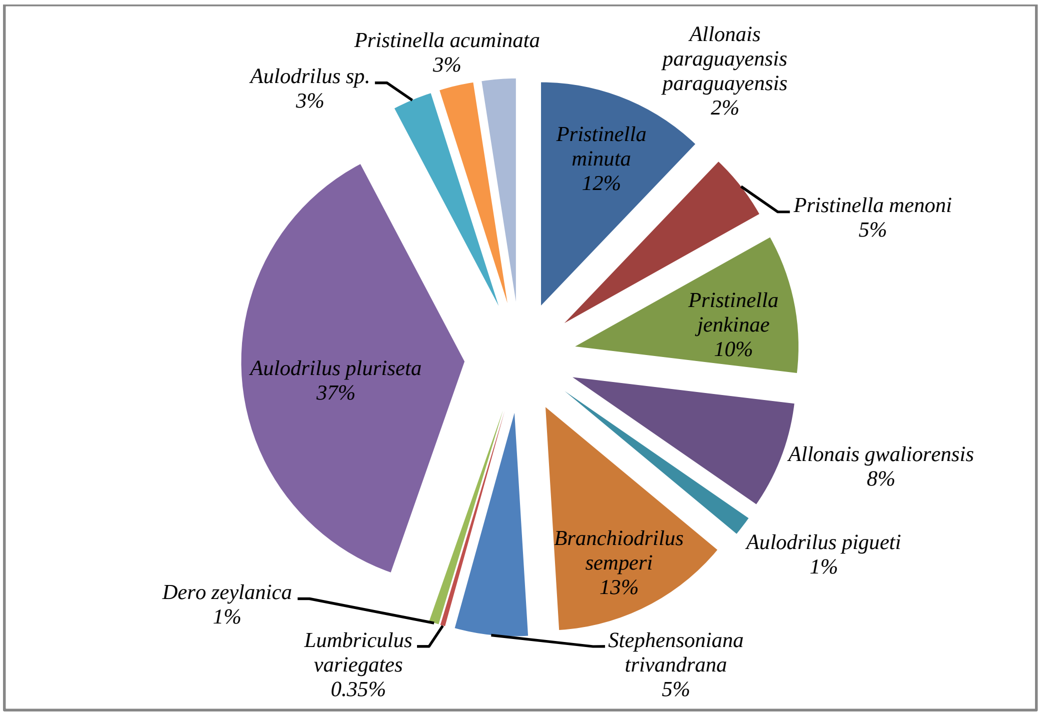

Fig.7.19. Mean percentage composition of oligochaete species in channel phase.

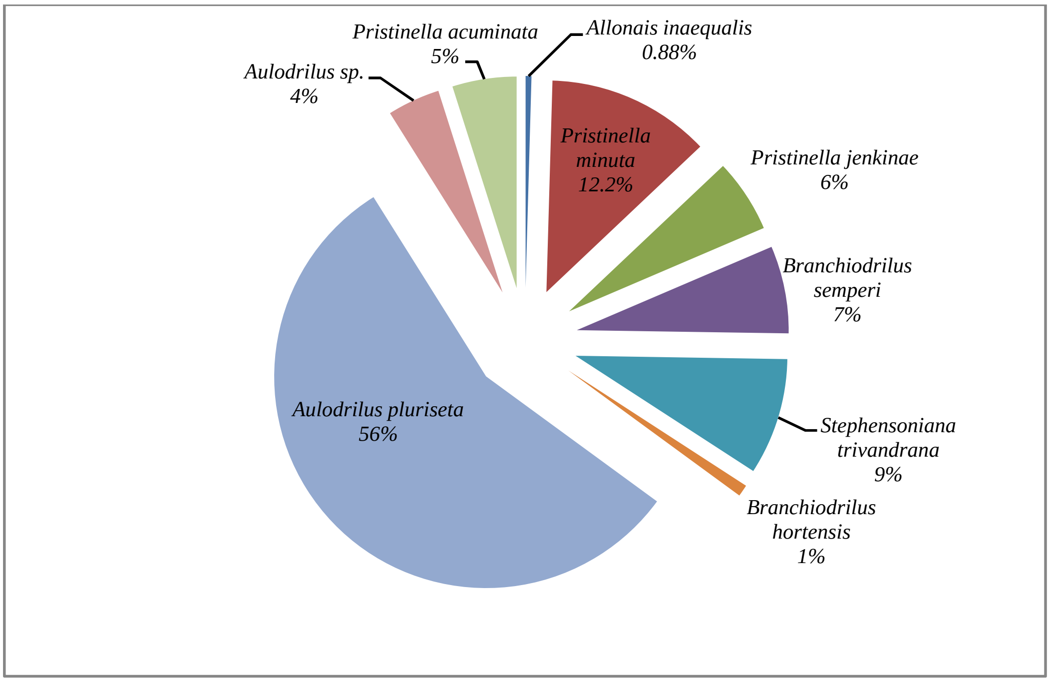

Fig.7.20. Mean percentage composition of oligochaete species in stable phase.

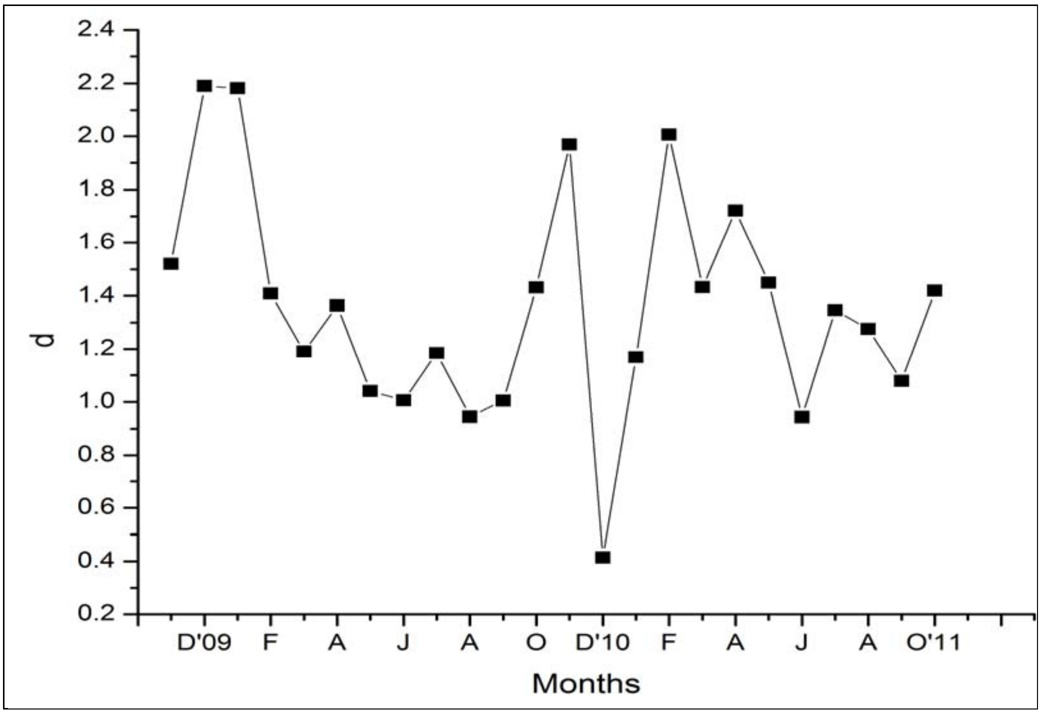

Fig.7.21. Monthly mean variation in richness of oligochaetes in Maranchery Kole wetlands during the study period.

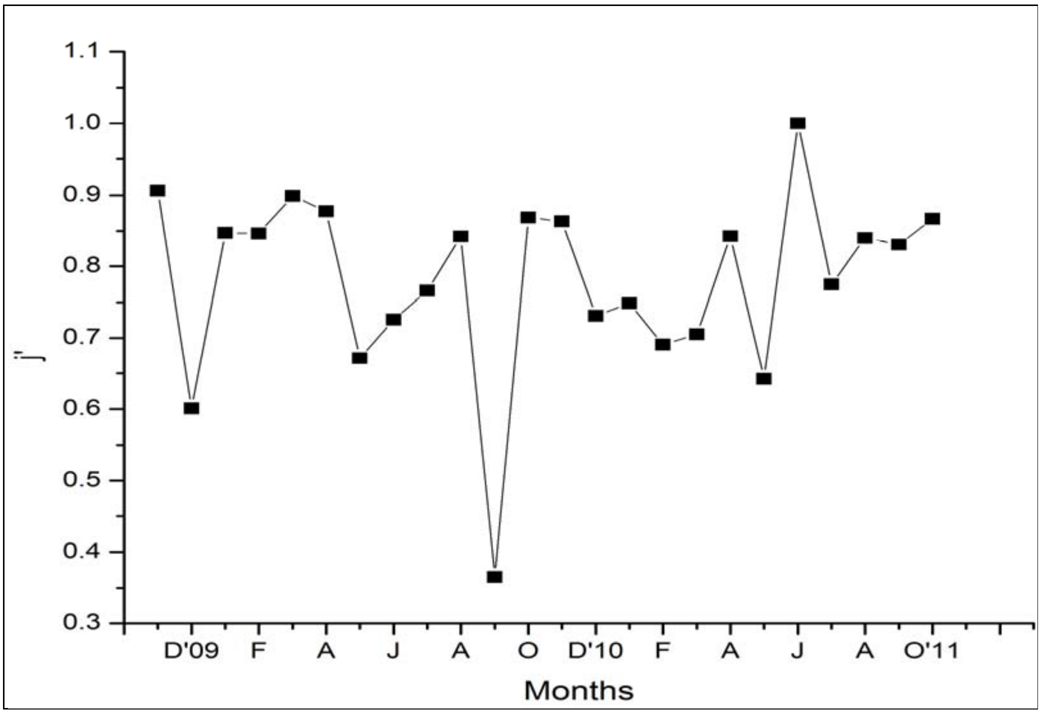

Fig.7.22. Monthly mean variation in evenness of oligochaetes in Maranchery Kole wetlands during the study period.

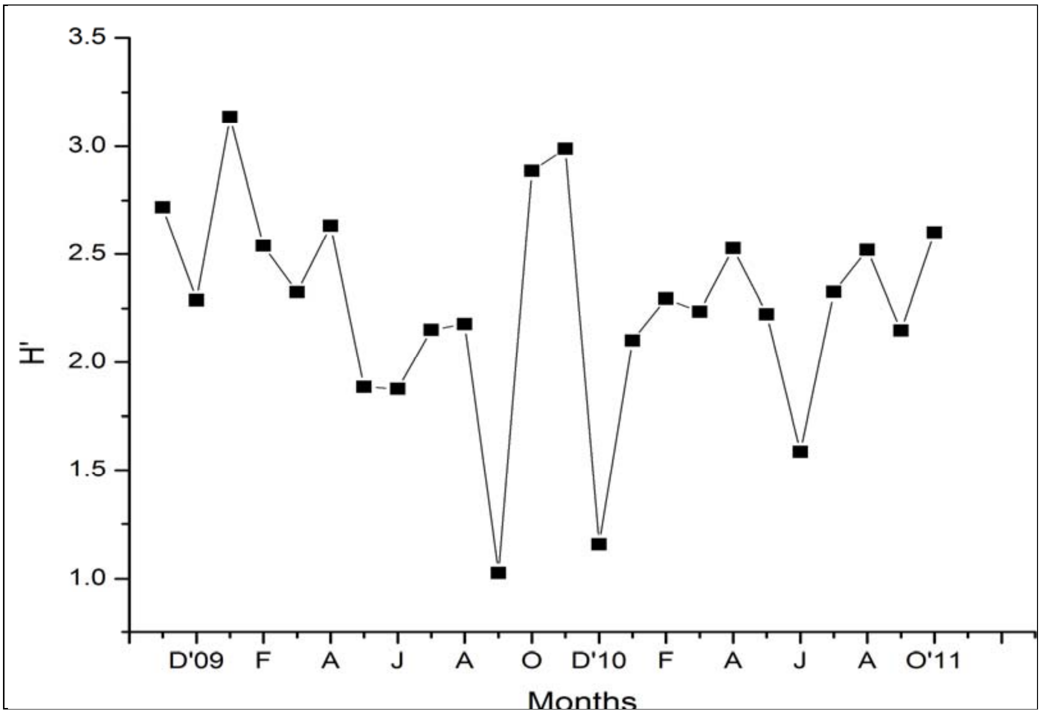

Fig.7.23. Monthly mean variation in diversity of oligochaetes in Maranchery Kole wetlands during the study period.

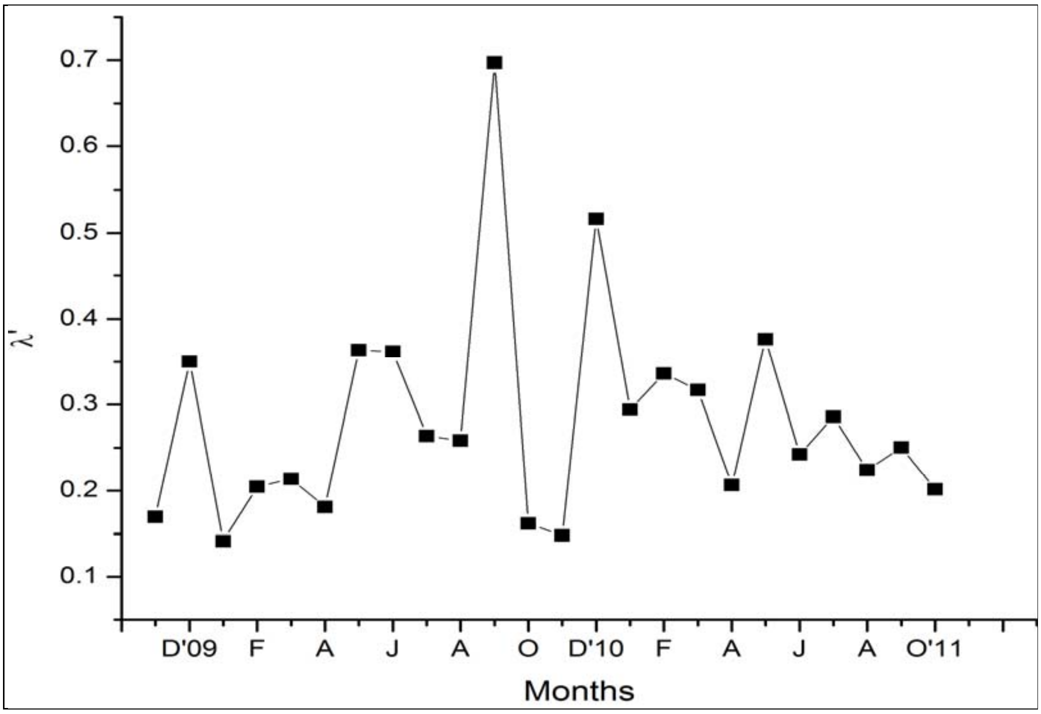

Fig.7.24. Monthly mean variation in dominance of oligochaetes in Maranchery Kole wetlands during the study period.

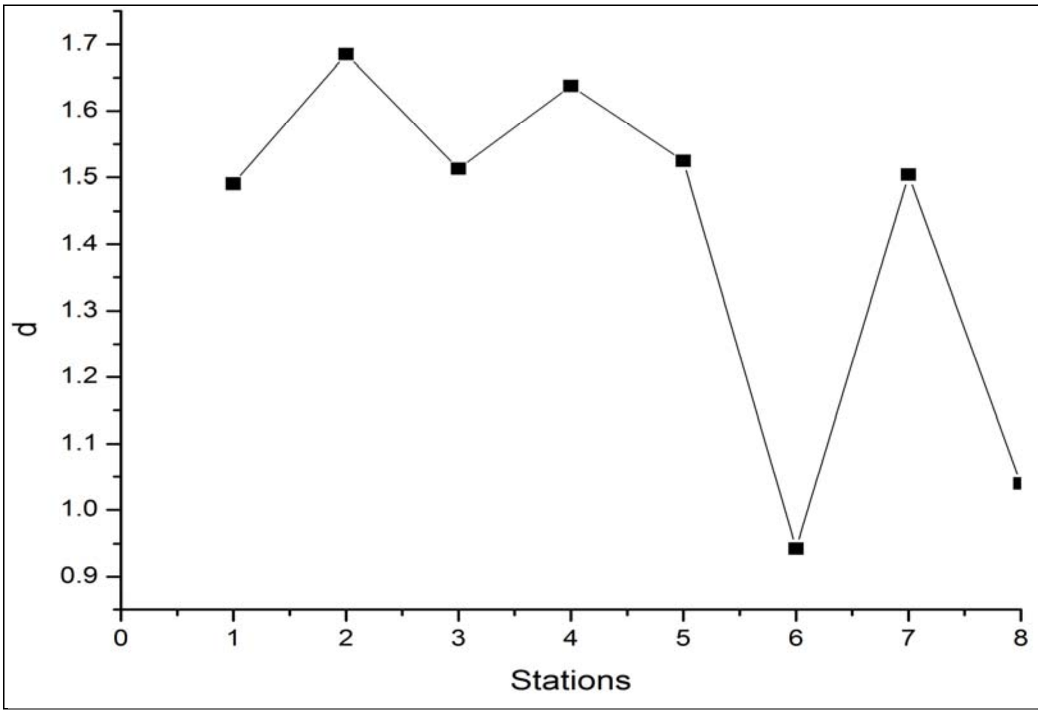

Fig.7.25. Mean variation richness of oligochaetes in the eight stations in Maranchery Kole wetlands.

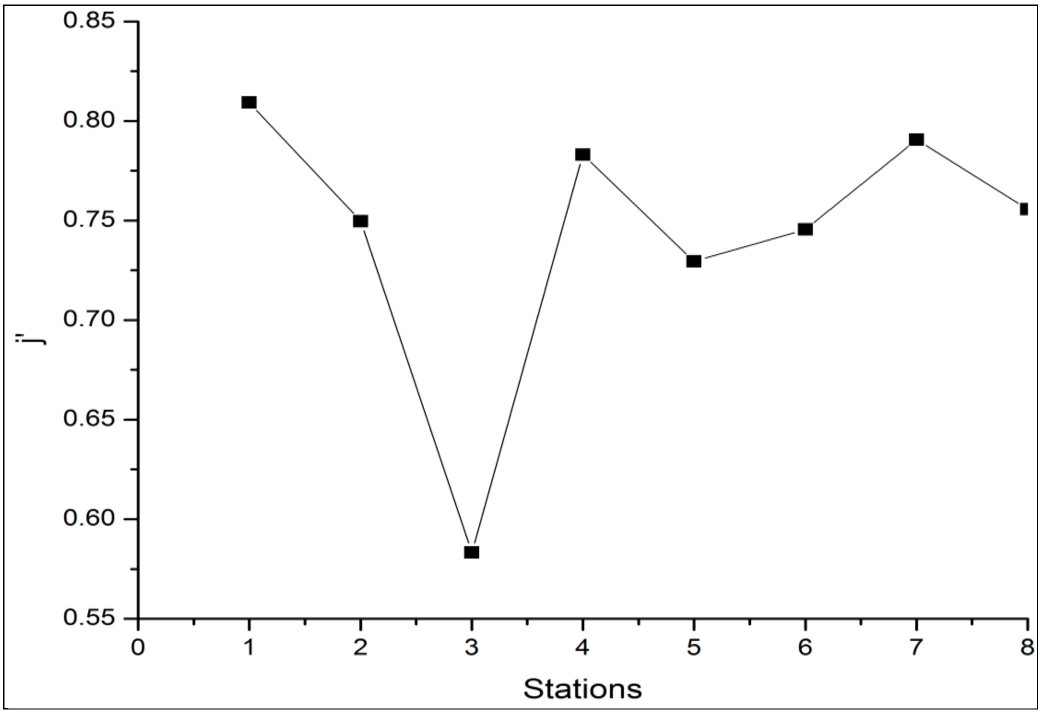

Fig.7.26. Mean variation evenness of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

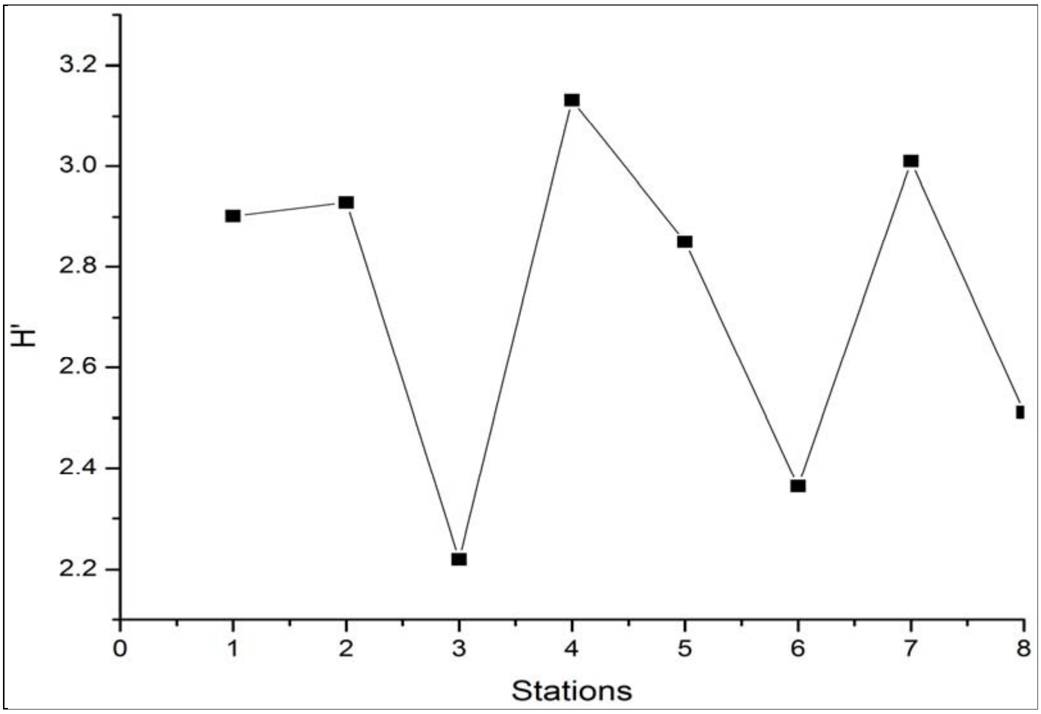

Fig.7.27. Mean variation diversity of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

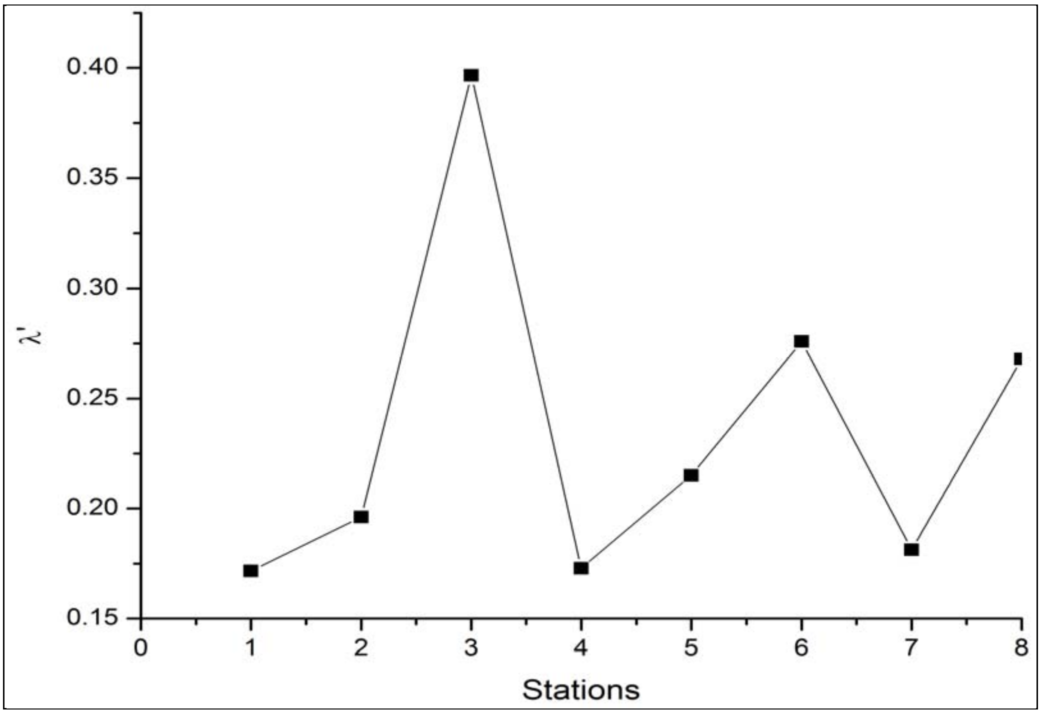

Fig.7.28. Mean variation dominance of oligochaetes in the eight stations in Maranchery Kole wetlands during the study period.

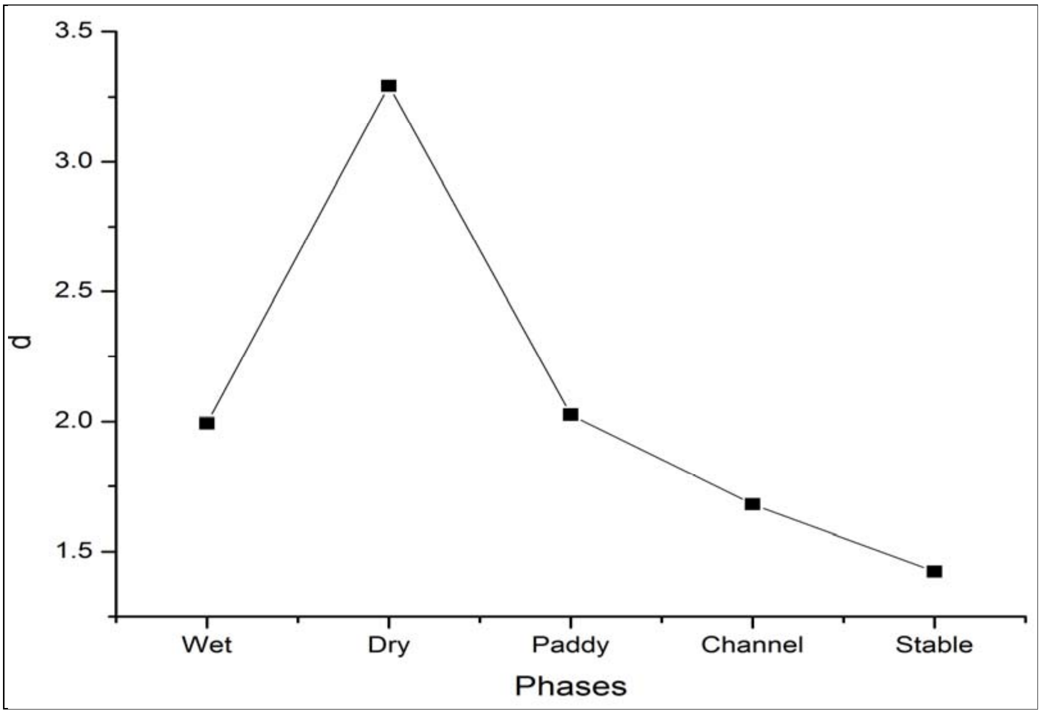

Fig.7.29. Mean variation in richness of oligochaetes in the five phases in Maranchery Kole wetlands.

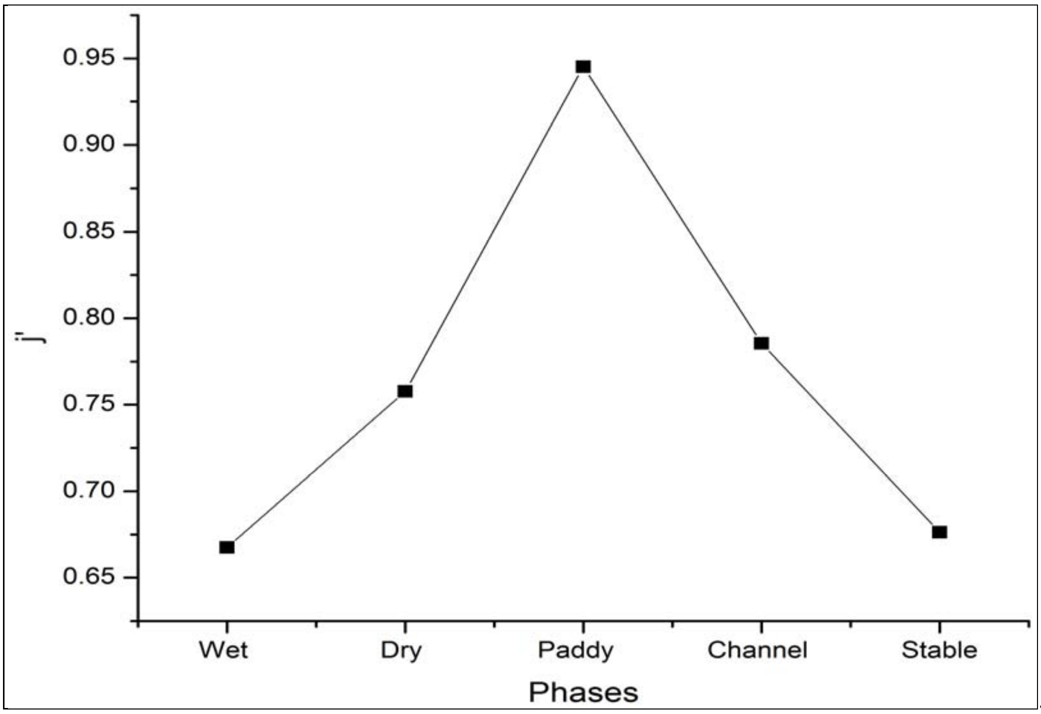

Fig.7.30. Mean variation in evenness of oligochaetes the five phases in Maranchery Kole wetlands.

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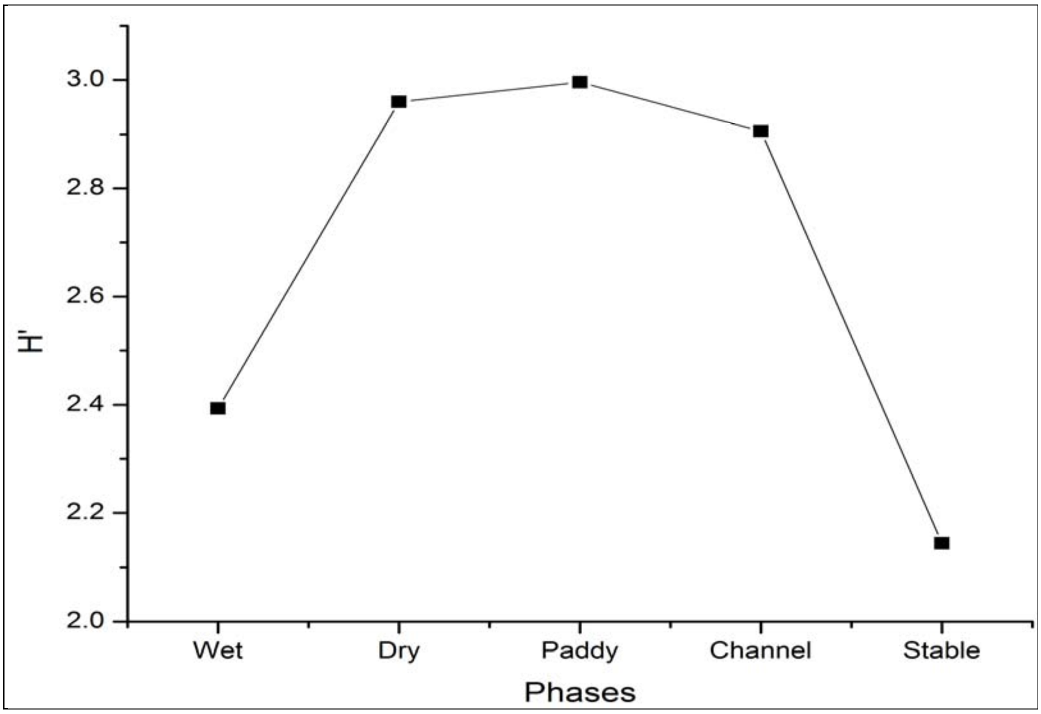

Fig.7.31. Mean variation in diversity of oligochaetes in the five phases in Maranchery Kole wetlands.

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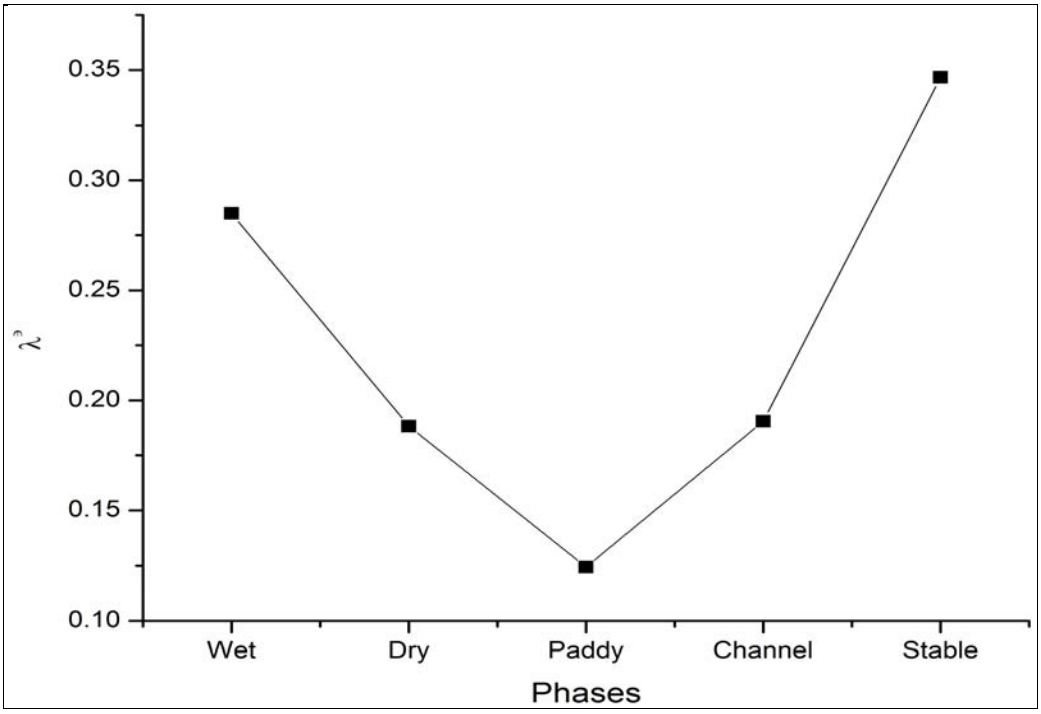

Fig.7.32. Mean variation in dominance of oligochaetes the five phases in Maranchery Kole wetlands.

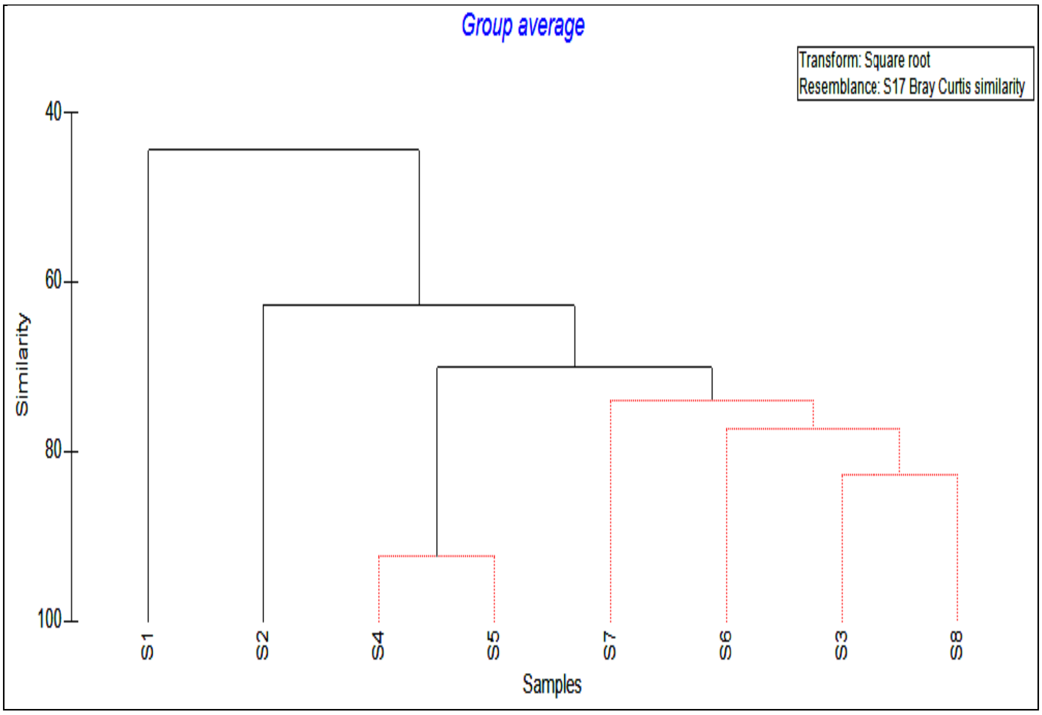

Fig.7.33. Dendrogram of numerical abundance of oligochaetes showing similarites in the eight stations in Maranchery Kole wetlands during the study period. (Solid lines represent significant delineation of groupings by SIMPROF test).

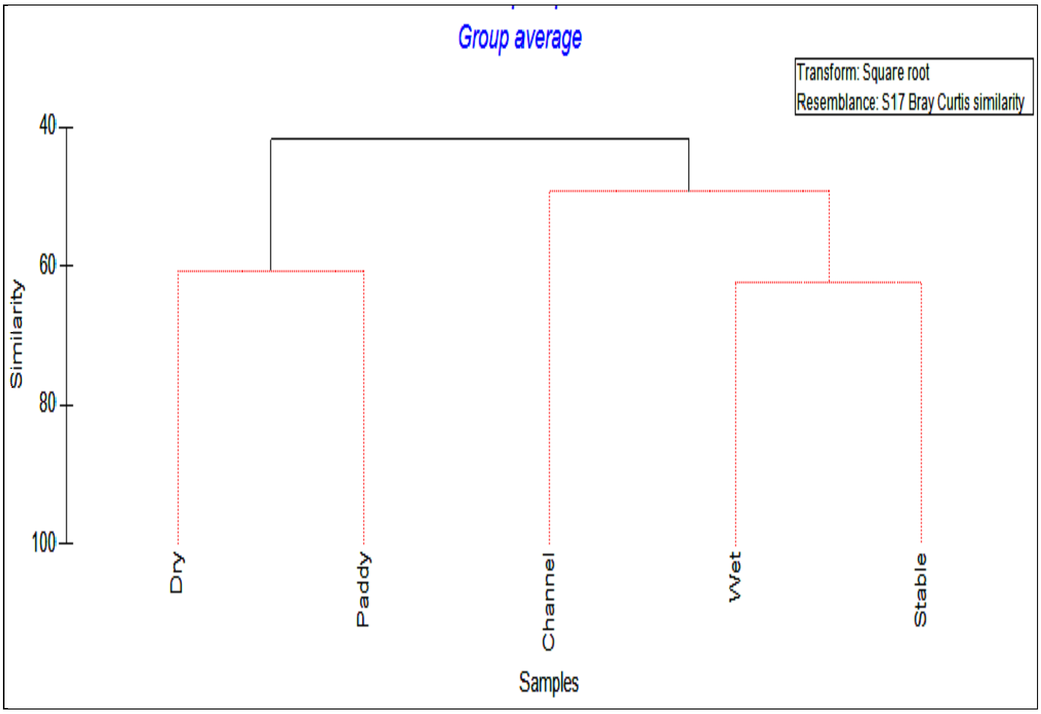

Fig.7.34. Dendrogram of numerical abundance of oligochaetes showing similarites in the five phases in Maranchery Kole wetlands. (Solid lines represent significant delineation of groupings by SIMPROF test).

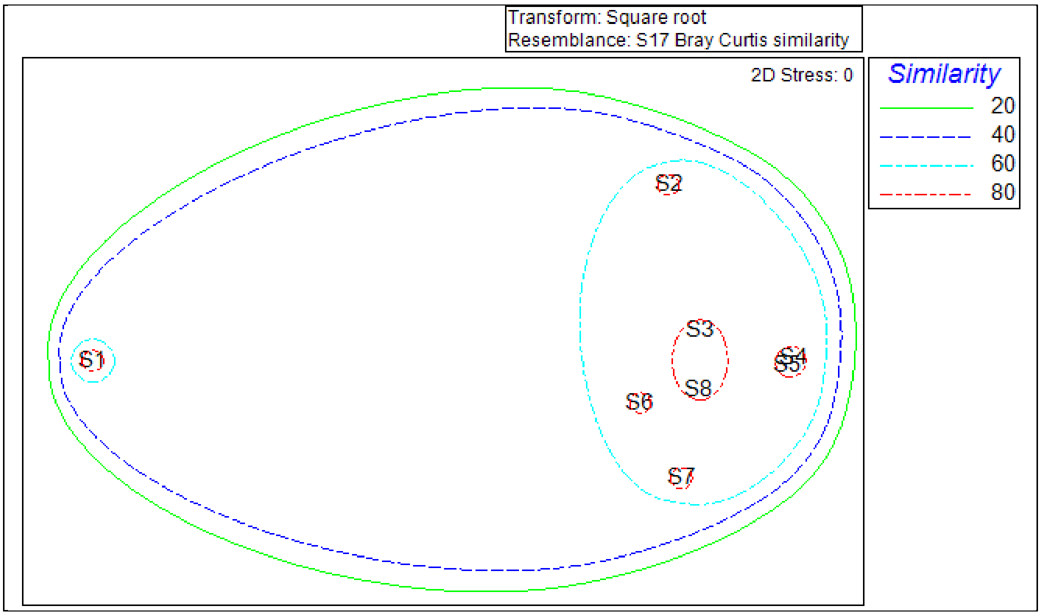

Fig.7.35. Non-metric Multi Dimensional Scaling (MDS) ordination plot in the eight stations with respect to the numerical abundance of oligochaetes in Maranchery Kole wetlands during the study period.

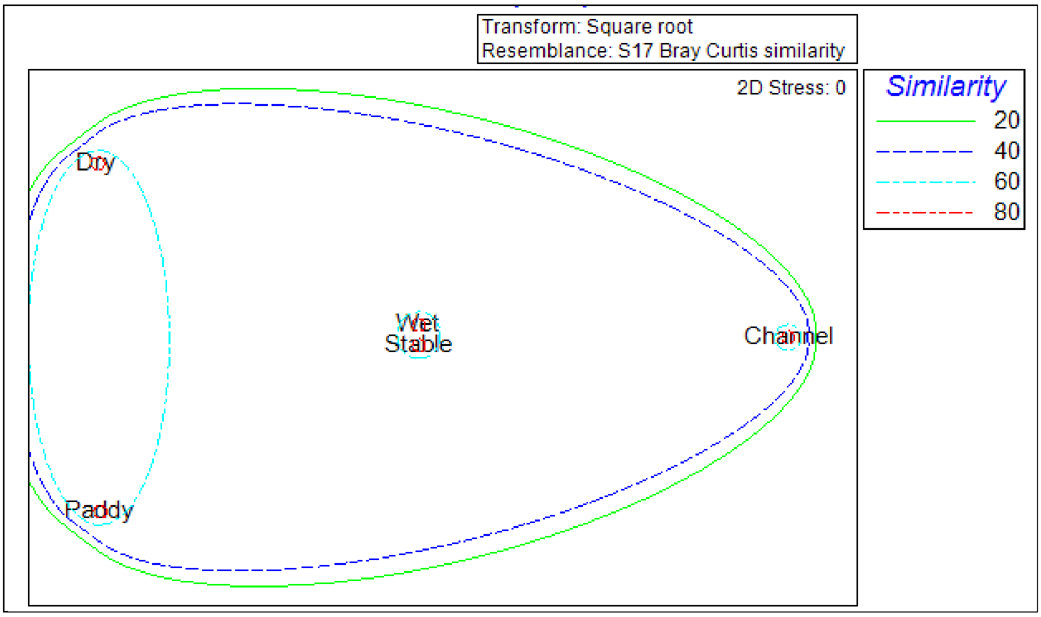

Fig.7.36. Non-metric Multi Dimensional Scaling (MDS) ordination plot in the five phases with respect to the numerical abundance of oligochaetes in Maranchery Kole wetlands.

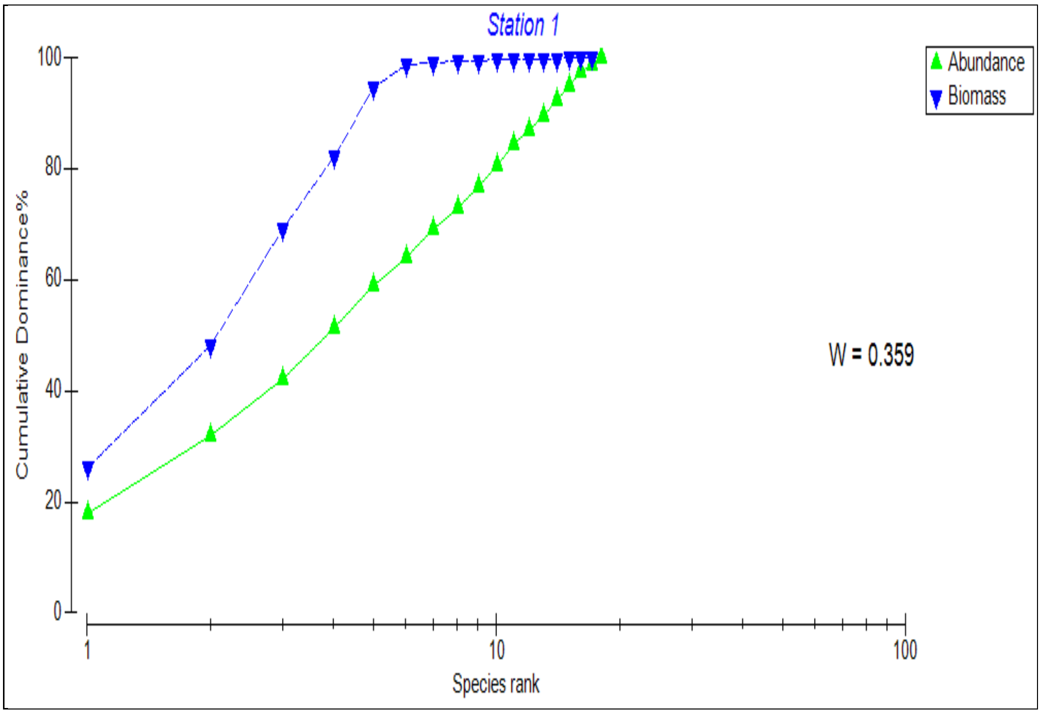

Fig.7.37. Abundance biomass curve in station 1 in Maranchery Kole wetlands during the study period.

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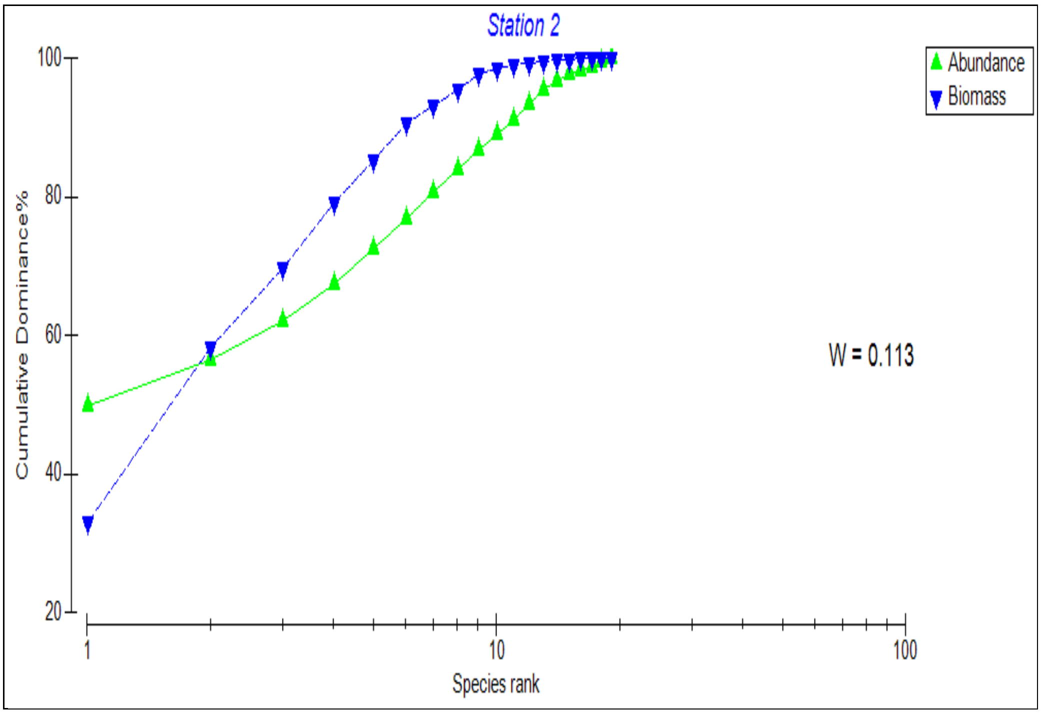

Fig.7.38. Abundance biomass curve in station 2 in Maranchery Kole wetlands during the study period.

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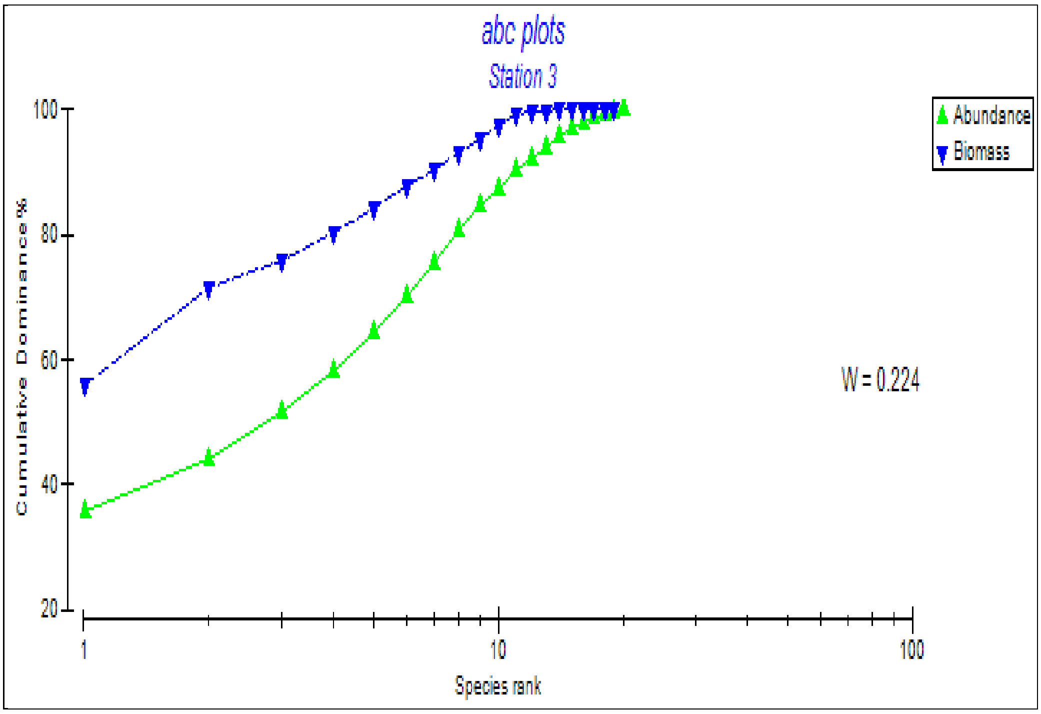

Fig.7.39. Abundance biomass curve in station 3 in Maranchery Kole wetlands during the study period.

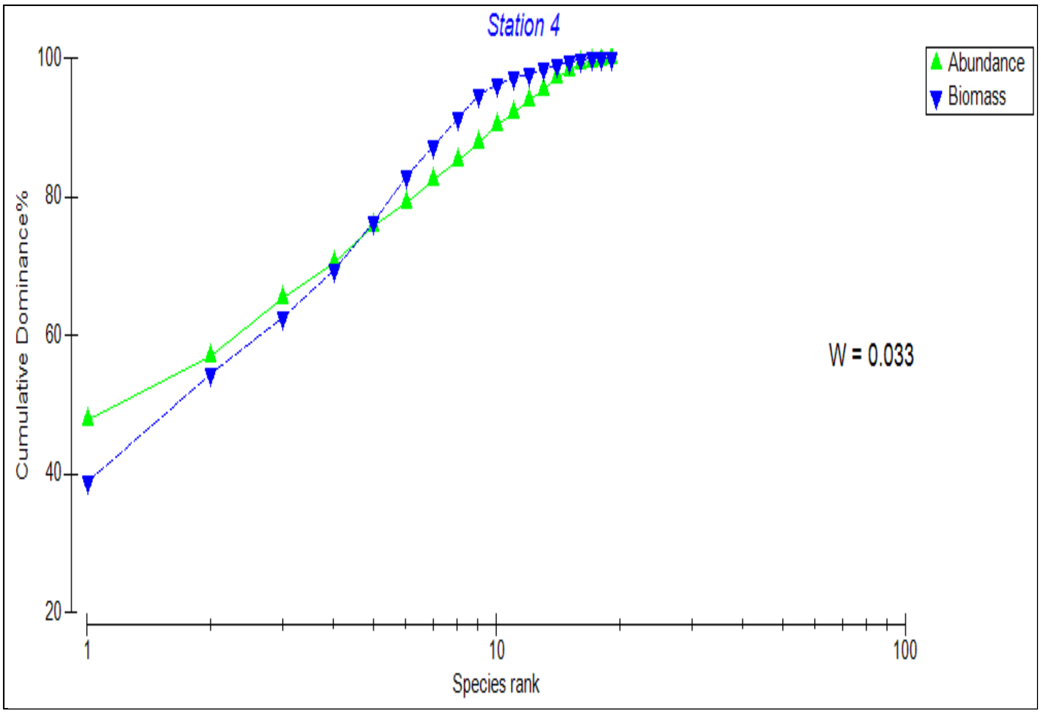

Fig.7.40. Abundance biomass curve in station 4 in Maranchery Kole wetlands during the study period.

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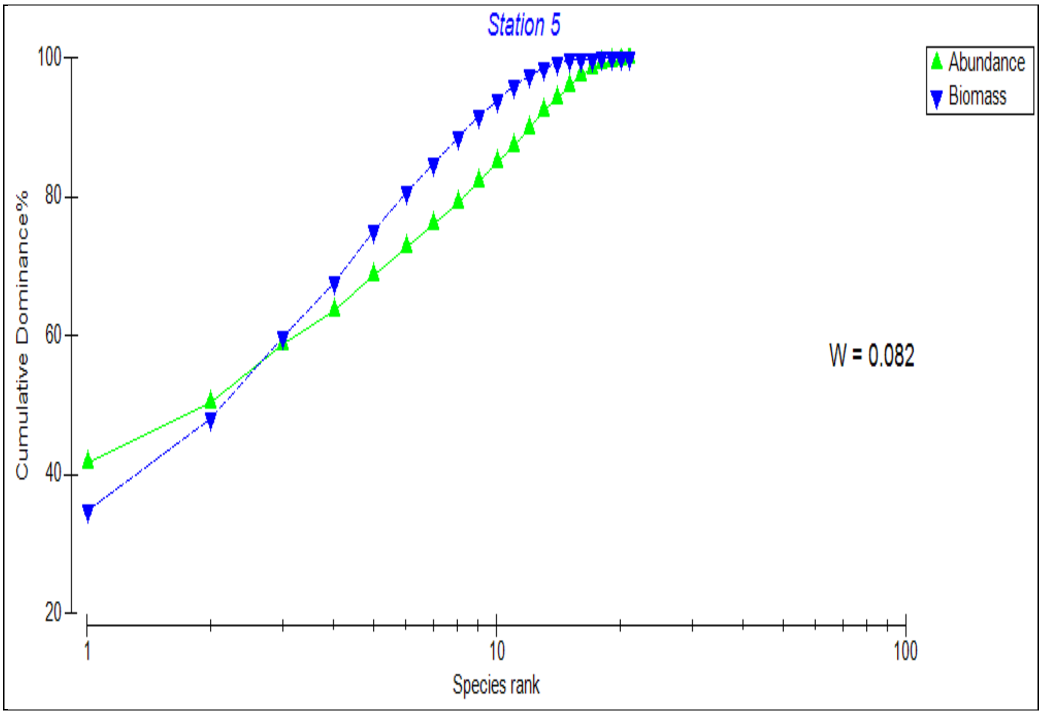

Fig.7.41. Abundance biomass curve in station 5 in Maranchery Kole wetlands during the study period.

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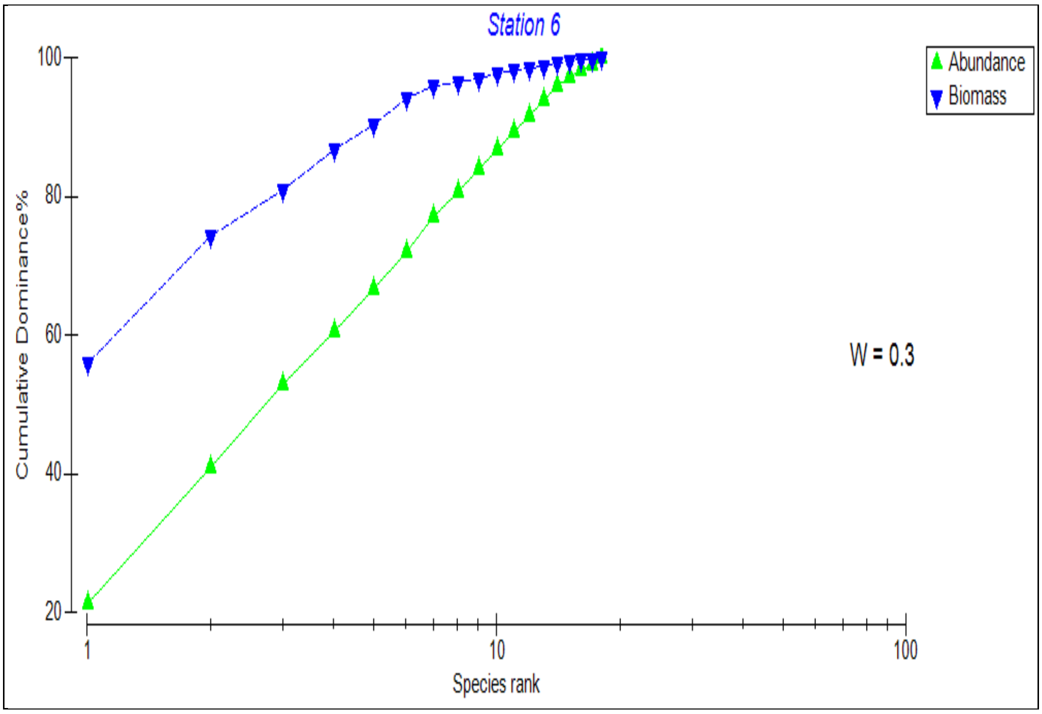

Fig.7.42. Abundance biomass curve in station 6 in Maranchery Kole wetlands during the study period.

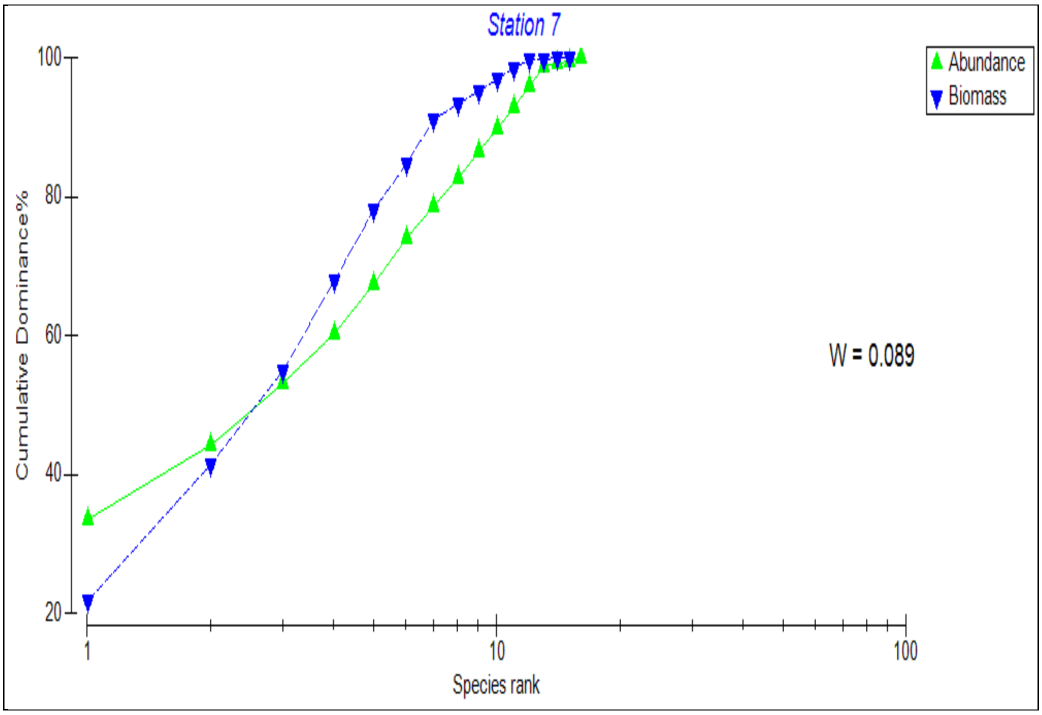

Fig.7.43. Abundance biomass curve in station 7 in Maranchery Kole wetlands during the study period.

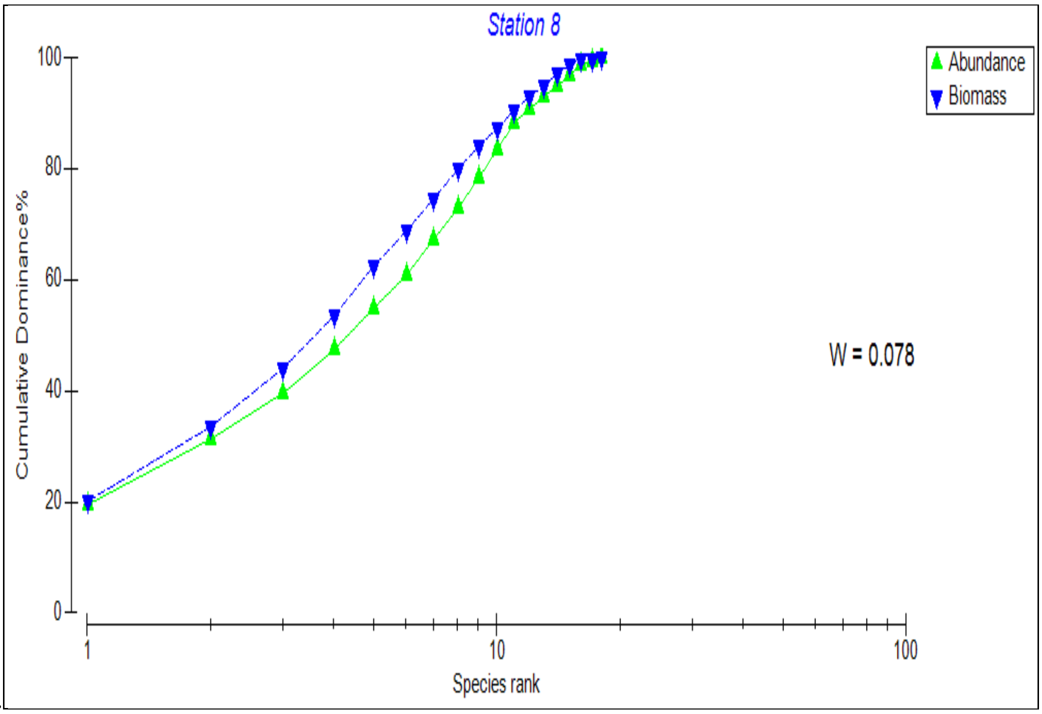

Fig.7.44. Abundance biomass curve in station 8 in Maranchery Kole wetlands during the study period.

Chapter - 8

ECOLOGICAL RELATIONSHIPS

8.1 Introduction

"A sower went out to sow his seeds; some fell along the path and was trodden under foot, and the birds of the air devoured it. Some fell on the rock; and as it grew up, it withered away, because it had no moisture. Some fell among thorns; and the thorns grew with it and choked it. Some fell into good soil and grew and yielded a hundredfold" (Luke 8: 5–8). The above words of a religious writer, about 2000 years ago indicates that even the ancients were aware of the physical diversity of the nature and the relationship, of the biotic community to the environmental frame work (Downing 1991).

The significance of many biotic and abiotic factors in influenting distributional patterns of shallow water benthic fauna has already been recognized like the physical factors such as salinity, pH, seasonal variation (Alcocer et al. 2001), depth (Gray 1981), organic matter contents of the sediment (Boulton and Lake 1992), sediment structure (Butman and Grassle 1992, Sundberg and Kennedy 1993) habitat characteristics (Hynes 1970, Peeters and Gardeniers 1998), water quality (Hellawell 1986), toxicity, dissolved oxygen concentration, contaminants (Clements and Kiffney 1993, Phipps et al. 1995) and hydrology (Pearson and Rosenberg 1987). Similarly biological factors such as predation (Peterson 1979, Kneib 1991), competition (Peterson and Andre 1980, Wilson 1990) and recruitment (Butman 1987, Olafsson et al. 1994) were also proved factors. The importance of food for macroinvertebrate communities was also highlighted in some studies (Marsh and Tenore 1990, Goedkoop et al. 1998). The vital role played by vegetations as a structuring feature for macroinvertebrate communities and as a source of organic matter was discussed in the benthic studies in Parana river floodplain, Argentina (Zilli et al. 2008), Dudgeon and Wu (1999) mentioned the importance of detritus as a habitat, food source and refuge to avoid predators for benthic macroinvertebrates. Though all the abiotic and biotic factors seems important for the benthic fauna, a detailed study on their role in structuring benthic community in different ecosystem revealed that different factors acts as master factors in determining the benthic community depending upon the peculiarities of the system.

The interactions between the environmental factors and benthic fauna in ecosystems experiencing hydrological fluctuations were an area of interest to the researchers. According to Hastie and Smith (2006) the change in the hydrodynamic environment would have an impact on both physicochemical processes such as water movement, salinity and biological processes such as recruitment and trophic supply, which can have an influence on the benthic pattern. The benthic macrofaunal community structure in intermittent estuaries showed significant correlations with catchment size of the estuaries (Hastie and Smith 2006). The study on macrozoobenthos of the Karavasta lagoon system, Albania showed that hydrological confinement and salinity were the decisive factors determining the benthic community composition. The study also highlighted the facts that the separation and geographical closeness of the ecosystems as well as colonization and dispersal ability of the species played an important role in structuring the faunal community (Marzano et al. 2010).

Though many studies highlighted the relationship between the benthos and the environmental characteristics, the lack of relationship have also been emphasized. A reliable relationship between abiotic factors and species richness, diversity or abundance of particular taxa was not observed by Williams (1996). In Port Curtis estuary (north-eastern Australia) all the variations in community structure were not explained by the environmental variables (Currie and Small 2006). When the benthic macrofaunal communities in intermittent estuaries was studied, the physicochemical characters showed no significant correlation with benthic assemblage patterns (Hastie and Smith 2006). During a drought year, the macrobenthic fauna of the St. Lucia Estuary showed a weak relationship between macrofaunal community structure and physicochemical parameters (Pillay and Perissinotto 2008). In the estuary, during a prolonged drought, habitats were found to be highly variable with a number of different habitats and environmental conditions hence it was difficult to delineate spatial or temporal patterns of macrobenthic ecology and its association with environmental conditions. MacKay et al. (2010) also observed a lack of correlation between benthic community and environmental parameters in an estuary.

The rapid habitat loss and the impact of global climate change demands the prediction of the occurrence of habitats and species (Clark et al. 2001). Models are widely used for such predictions throughout the word. According to Jeffers (1978), a model is any formal expression of the relationship between two defined symbols, and thus, may be used to simulate the behaviour of ecological systems. A prediction is a statement about the nature of an ecological condition in unknown circumstances and is derived from a model (Underwood, 1990). There are three classes of mathematical models applicable in ecology: conceptual, deterministic and statistic/stochastic (Jorgenson 1986). The models can be useful in environmental monitoring and management studies since they can either be used to predict species and parameters for unknown areas or to categorize departures of the observed biota from that predicted by the models for unpolluted areas (Clarke et al. 1996). The pioneering work on predictive models was in the early 1980s, in England with the development of the RIVPACS (River In vertebrate Prediction and classification System) for aquatic communities (Wright et al. 1989). Benthic species distribution in the Westerschelde estuary in the Netherlands was modeled by Ysebaert et al. (2002), that in New Zealand estuaries by Thrush et al. (2003), that in Belgium waters by (Meibner et al. 2008), that in New Zealand rivers by Clapcott et al. (2013). The benthic infauna in Cochin back waters was modelled by Sheeba (2000). Joydas (2002) predicted the macrobenthic abundance of the shelf waters in the west coast of India. Concenptual model prediction was done to predict the benthic fauna in response to variations in total organic carbon in the Indian coast by Ansari et al. (2014). An attempt has been made to predict the total benthic abundance and oligochate abundance for Maranchery Kole wetland in relation to environmental variables based on regression models.

8.2 Results

8.2.1 Correlation Analysis

The results of correlation analysis between environmental parameters and the numerical abundance of the benthic fauna is given in Table 8.1. The correlation analysis revealed a positive correlation significant at 5% between water pH, and a negative correlation significant at 5% level with Eh and available phosphorus when the total benthic fauna was considered. The oligochetes which were the numerically dominant benthic fauna also showed a positive correlation significant at 1% with water pH and 5% with depth. However, the insect fauna showed a negative correlation significant at 1% level with depth and available phosphorus. Molluscs showed no significant correlation with any of the environmental parameters whereas crustaceans showed a postitive correlation significant at 1% level with sand which agreed with the findings of Jayaraj et al. (2008) in the shelf region of the northwest Indian coast. Molluscs also showed a negative correlation significant at 1% level with silt and clay. The remaining group which was included as others consisting of pisces and hirudinae showed no significant correlation with any of the environmental parameters. The relationship between the benthic biomass and the environmental parameters were studied (Table 8.2). The total benthic biomass showed a significant positive correlation at 5% level with clay percentage. Oligochaete biomass showed a postitive correlation significant at 1% level with sediment temperature. Insect biomass showed no significant correlation with any of the environmental parameters.

The relationship between the species richness, evenness, diversity and dominance of the macrobenthic faunal groups with the environmental parameters were analyzed. Richness was negatively correlated to available phosphorus significant at 1% level and positively correlated to sand at 5% significance. The evenness was negatively correlated at 1% significance with depth. Diversity showed a negative correlation significant at 5% level with available phosphorus whereas dominance was positively correlated to available phosphorus at 5% level of significance (Table 8.3). The analysis of correlation between diversity indices of oligochaetes to environmental parameters, richness was negatively correlated to moisture content significant at 5% level. (Table 8.4).

8.2.2 BEST Analysis

The BEST analysis in PRIMER also showed that the best environmental variables predicting the distribution of macro benthic groups were different for different phases. In wet phase, clay and sand were the best matching variables (σ=0.794), in dry phase Eh, moisture content, available nitrogen and sediment temperature (σ=0.697), in paddy phase depth and available phosphorus (σ=0.697), in channel phase available phosphorus (σ=0.818) whereas in stable phase moisture content and water pH (σ=0.656) were the BEST matching variable. But none of the values were statistically significant. In the case of oligochaete species, in wet phase, available phosphorus and organic matter were the best matching variable (σ=0.411), in dry phase Eh and available phosphorus (σ=0.406), in paddy phase sediment temperature, organic matter, sediment pH, sand and available phosphorus (σ=0.988), in channel phase Eh, clay and silt (σ=0.522) whereas in stable phase it was Eh, moisture content and water pH (σ=0.187) (Tables 8.5 to 8.14, Figs. 8.1 to 8.10).

8.2.3 Predictive models

Due to the heterogenous nature of the phases, predictive models were prepared for each phase separately for total macrobenthic abundance and oligochaete abundance.

Wet phase

The model equation predicting total macrobenthic abundance in wet phase is:

$$Y=313.316 +0.081 X1-12.059X2+0.679X3+49.293X4-10.849X5-5.814X6+34.495X7-0.003X1*X2-0.024X2*X3-.610X2*X4+0.411X2*X5+0.251X2*X6-1.252X2*X7-0.033X3*X4-0.593X4*X5-0.008X4*X6+0.153X5*X7+0.221X4*X7-0.145X6*X7$$

Where y	=	total mcrobenthic abundance
X1	=	rainfall
X2	=	sediment temperature
X3	=	Eh
X4	=	available phosphorus
X5	=	clay
X6	=	sand
X7	=	dissolved oxygen

Relative importance of parameters is: Available phosphorus>dissolved oxygen >-sediment temperature>–clay>–sand>–sediment temperature*available phosphorus>-sediment temperature*dissolved oxygen >Eh>–available phosphorus*clay>sediment temperature*sand>available phosphorus*dissolved oxygen> clay* dissolved oxygen>-sand* dissolved oxygen>rainfall>–Eh*available phosphorus>-sediment temperature* Eh >available phosphorus * sand >- rainfall * sediment temperature

R^2	=	0.318
Adjusted R^2	=	0.058
F (19,69)	=	1.224 $p < 0.01$

The model equation predicting oligochaete abundance in wet phase is:

$$Y=108.214+0.017X1-10.874X2-15.901X3-0.453X4-3.542X5+0.499X2X5+0.524X3X5+1.133X2X3$$

Where

Y	=	oligochaete abundance
X1	=	rain fall
X2	=	Eh
X3	=	clay
X4	=	sand
X5	=	dissolved oxygen

Relative importance of parameters is:-clay>–Eh>-dissolved oxygen>Eh*clay> dissolved oxygen* clay> dissolved oxygen* Eh> – sand> rain fall

R^2	=	0.300
Adjusted R^2	=	0.034
F (8, 29)	=	1.127 $p < 0.01$

Dry phase

The model equation predicting total macrobenthic abundance in dry phase is:

$$Y=267.530-10.128X1+51.911X2 +9.396X3-25.853X2X3+4.101X2X4$$

Where

Y	=	total mcrobenthic abundance
X1	=	sediment temperature

X2 = depth

X3 = moisture content

X4 = organic matter

Relative importance of parameters is: Depth >– depth* moisture content >- sediment temperature >moisture content> depth *organic matter

R^2 = 0.560

Adjusted R^2 = 0.444

F(5,24) = 4.827 p >0.01

The model equation predicting oligochaete abundance in dry phase is:

Y=-78.139+2.244X1+10.233X2-6.103X3+3.337X1X4+0.271X1X5+14.247X4X5-44.092X4X2+9.773X4X6+1.025X2X6

Where

Y = oligochaete abundance

X1 = sediment temperature

X2 = organic matter

X3 = Eh

X4 = depth

X5 = moisture content

Relative importance of parameters is: -depth* organic matter >depth*moisture content > organic matter > depth *Eh> Eh > sediment temperature* depth>- moisture content* Eh>sediment temperature>organic matter*Eh>sediment temperature*moisture content

R^2 = 0.598

Adjusted R^2 = 0.312

F(10,24) = 2.086 p >0.01

Paddy phase

The model equation predicting total macrobenthic abundance in paddy phase is:

Y= -701.448+151.635X1+81.489X2+15614.920X3+3.464X4-10.365X1X2-289.194X1X2-1.794X1X4-3312.377X2X3+118.872X3X4+67.284X4X5

Y = total mcrobenthic abundance

X1 = moisture content

X2 = pH

X3 = available nitrogen

X4 = silt

X5 = sand

Relative importance of parameters is: available nitrogen> – pH* available nitrogen> -moisture content* available nitrogen> moisture content> available nitrogen* silt >pH> available nitrogen* sand >-moisture content* pH> silt> - moisture content* silt >–pH*silt

R^2 = 0.952

Adjusted R^2 = 0.778

$F(11,14)$ = 5.456 $p > 0.01$

The model equation predicting oligochaete abundance in paddy phase is:

Y=-780.391+29.290X1+146.517X2+97.440X3+4862.677X4+51.327X5+51.327X6-9.788X7-21.797X1X4-18.994X2X3-928.927X2X4+437.923X3X4-5.711X3X5+9.076X4X6-775.744X4X5

Where

Y = oligochaete abundance

X1 = depth

X2 = organic matter

X3 = pH

X4 = available nitrogen

X5 = dissolved oxygen

X6 = sand

Relative importance of parameters is: available nitrogen >- organic matter* available nitrogen> -available nitrogen* dissolved oxygen >pH* available nitrogen >organic matter > pH> dissolved oxygen> depth> depth* available nitrogen> organic matter* pH> available nitrogen* sand> pH *dissolved oxygen

R^2 = 0.995

Adjusted R^2 = 0.934

$F(13,14)$ = 16.148 $p > 0.01$

Channel phase

The model equation predicting total macrobenthic abundance in channel phase is:

$$Y=-126.632-1.394X1+126.474X2-10.351X3+4.306X4+3.853X5-3.025X2X5$$

Where

Y	=	total mcrobenthic abundance
X1	=	sediment temperature
X2	=	depth
X3	=	organic matter
X4	=	clay
X5	=	sand

Relative importance of parameters is: Depth >- organic matter >clay> sand> depth* sand > sediment temperature

R^2	=	0.958
Adjusted R^2	=	0.875
F(6,9)	=	11.528 $p > 0.01$

The model equation predicting oligochaete abundance in channel phase is:

$$Y=-269.594-27.874X1+142.137X2-7.142X3+43.088X4+0.949X1X5+1.385X5X2-1.049X4X5-6.907X2X4$$

Where

Y	=	oligochaete abundance
X1	=	sediment temperature
X2	=	organic matter
X3	=	Eh
X4	=	silt
X5	=	dissolved oxygen

Relative importance of parameters is: organic matter> silt> sediment temperature> Eh> dissolved oxygen* organic matter> – silt* dissolved oxygen> - sediment temperature * dissolved oxygen

R^2	=	0.986
Adjusted R^2	=	0.875
F(8,9)	=	8.911 $p > 0.01$

Stable phase

The model equation predicting total macrobenthic abundance in stable phase is:

$$Y=428.6-39.375X1-171.161X2+219.630X3+11.837X1X2+2.654X1X4-55.890X2X3-4.093X2X4+15.310X2X5-15.122X3X4-5.962X3X5-8.199X4X5$$

Where

Y	=	total mcrobenthic abundance
X1	=	sediment temperature
X2	=	depth
X3	=	moisture content
X4	=	organic matter
X5	=	available phosphorus

Relative importance of parameters is: moisture content >– depth> – depth* moisture content> -sediment temperature> depth* available phosphorus> - moisture content* organic matter > sediment temperature* depth> - organic matter* available phosphorus> - moisture content* available phosphorus> –depth* organic matter> sediment temperature*organic matter

R^2	=	0.877
Adjusted R^2	=	0.652
F(11,17)	=	3.895 $p > 0.01$

The model equation predicting oligochaete abundance in stable phase is:

$$Y=568.059-314.946X1+122.158X2-55.157X3-96.525X4+10.607X1X2+37.090X1X2+31.282X1X4-22.093X2X3$$

Where

Y	=	oligochaete abundance
X1	=	sediment temperature
X2	=	depth
X3	=	moisture content
X4	=	organic matter
X5	=	available nitrogen

Relative importance of parameters is: Depth>organic matter>clay>available nitrogen> depth* available nitrogen>depth*clay>organic matter*available nitrogen>depth* organic matter

R^2 = 0.630

Adjusted R^2 = 0.302

$F(8,17)$ = 1.918 $p > 0.01$

8.3 Discussion

The relationship between benthos and the environmental parameters are clearly seen in majority of the studies, there are also studies where no relationship is observed between them (Prenda and Gallardo 2007, Morrisey et al. 1992, Shobhana and Nair 1983, Batzer 2013). In Maranchery kole wetland ecosystem the numerical abundance and biomass of the total macrobenthic fauna and oligochaetes showed a significant correlation with only few of the environmental parameters. BEST results also revealed an insignificant relationship between benthic community and environmental factors. The results could be explained by the fluctuating nature of Maranchery kole wetland ecosystem and by the marked generalist character and ubiquity of the oligochaete species, the most abundant taxa in Maranchery. Niche discrimination in aquatic oligochaetes is less obvious than zoogeographic factors. The majority of these worms are adapted to live in sediments ranging from mud to sand. They survive in stony, sandy and muddy habitats, lowland rivers or lakes and ponds wherever soft substrates exist (Thorp and Couch 2001). Thienemann (1924) opined that rheo-, psammo-, pelo- and other bionts, i.e., species exclusively associated with a particular biotope and never found in other biotopes, rarely occur among oligochaetes. Even the typical peculiarity of lacustrine and palustrine species which prevails in most of the aquatic organisms are also less evident in the case of oligochaetes (Thorp and Couch 2001). Prenda and Gallardo (1992) documnented the ability of oligochaetes to colonize any kind of environment, from his observations in Mediterranean ecosystems where predictable wet and dry cycles exist. However a negative correlation between benthic density and available phosphorus was apparent in this study which was in agreement with a similar study from rice fields which showed that benthic densities were negatively correlated with available phosphorus.

Oligochaetes are characterized by their capability to survive in extreme conditions. Their wide range of tolerance to the environmental conditions could be the reason for the absence of relationship of oligochaetes to many of the environmental parameters. In the case of the environmental parameters, the ranges of them were mostly within the survival limits for the organisms. For eg. pH was near neutrality, dissolved oxygen was within the limits for inland waters, so the chance of a stress condition was absent. Although salinity has been widely described as a community constraint (Boix et al. 2004) as Maranchery wetland is a freshwater body, the salinity variation was also not existed; the values never reached a critical level for invertebrate communities (Boix et al. 2004). Hence the variability in the environmental factors in Maranchery kole wetlands could not be strong enough to cause sensible changes on benthic dynamics. Further *Aulodrilus pluriseta* was the most abundant species present in Maranchery Kole wetlands. There are studies where the relationship between *Aulodrilus pluriseta* and the environment remains ambiguous (Verdonschot 1999, Nijboer et al. 2004).

When the total numerical abundance was accounted, chironomidae was the second numerically abundant taxa present. Like oligochaetes, chironomids also had a wide survival range ensuring its existence in a variety of environmental conditions. Random distribution of chironomous larve was reported by McLachlan (1976) and Taylor (1961). This could be the reason for the absence of correlation of the benthic fauna and the environmental parameters. Though insects, crustaceans and other groups showed a significant correlation with the environmental factors, their reduced numerical abundance might be insignificant to make a significant correlation when the total abundance was taken. There was no significant relationship between oligochaetes and the physico chemical nature of the water in Veli lake (Shobhana and Nair 1983). The absence of correlation of macrobenthic fauna and physicochemical parameters was reported across the floor of the South basin of Lough Hyne, a small sea-lough in south-west Ireland. Various localized disturbances such as smothering of areas of sediment by anoxic water, deposition of accumulations of detached seaweed and sediment excavations by *Cancer pagurus* were considered to contribute to that pattern (Thrush and Townsend 1986). Similarly in Maranchery wetland also, the disturbance associated with the fluctuating physical environment could be the reason for the insignificant correlation pattern.

There are many studies which documented the absence of relationship between organisms and environmental factors. A recent and comprehensive study by Batzer (2013) highlighted the lack of predictable patterns of wetland invertebrates with environmental factors in several well studied wetland systems.The studies of benthic community in Playas of West Texas showed no consistent relationship with abiotic fators and species richness, diversity or abundance of benthic organisms (Hall 1997). The composition and community parameters would have been determined more strongly by biotic factors, such as life history characteristics, competition and predation, which influence invertebrate assemblages in other temporary aquatic habitats (Reisen 1973, McLachlan 1985). In Port Curtis estuary (north-eastern Australia) all the variations in community structure was not explained by the environmental variables, some factors not measured in the study played a role in determining benthic faunal composition in the estuary (Currie and Small 2006). The taxa existed there showed resilience to wide ranging environmental changes associated with drought. When the benthic macrofaunal communities in intermittent estuaries was studied, the physic chemical characters showed wide variation among estuaries and a significant correlation was not observed with benthic assemblage patterns (Hastie and Smith 2006). Multivariate correlations indicated weak associations of macrofauna with physico-chemical parameters St. Lucia estuary during drought period. The result indicated that under drought conditions, these habitats functioned differently, with different physical factors determining the structure of macrofaunal assemblages between them which further supports the hypothesis that habitat fragmentation imposed by the drought might be a key determinant of macrofaunal assemblages in the St. Lucia estuary (Pillay and Perissinotto 2008).

In paddy fields, while analyzing the relationship between the macroinvertebrates and water and sediment variables, showed that that no relationship was evident between them, Although the macroinvertebrate structure in wetlands has been related to factors such as sediment organic matter, water chemistry, and water depth and temperature (Zimmer et al. 2000, Tarr et al. 2005, Stenert et al. 2008), the suggested reason for the absence of correlation was that, inspite of the environmental variables, the agricultural practices adopted in rice fields (water level control, herbicide application, and machinery usage) were more important driving forces for the macroinvertebrate structure (Stenert et al. 2009).

The studies mentioned above especially the studies from temporary wetlands indicates that the benthic distribution pattern need not be related to physico chemical parameters as there were many other factors which could affect the benthic distribution. The pattern of ecological relationship evolved in this study reveals that in Maranchery Kole wetland, some abiotic (e.g. habitat availability) or biotic variables (e.g. species interactions) that could cause the association with benthic fauna were not directly measured, or our variables were not good surrogates for them. Some factors which we have not measured but known to play a key role like the intensity of disturbance (Sailer 2005) hydrological stability, length of hydroperiod, (Williams 2006), habitat duration, life history strategy (Williams 1996) macrophyte density (Balcombe et al. 2005) area of the habitable patch (Fleishman et al. 2002), proximity and size of the neighbouring habitat (Russel 2005), predation, wetland shape and size (Culler et al. 2013) etc. would have played a master role in the distribution of benthic fauna in spite of the physico chemical parameters. This suggests that the relationship with the measured environmental variables might be weaker or overridden by other unmeasured variables.

The macrophyte cover which we have not measured is an important factor determining oligochaete community. Many studies have found that species richness, density, and composition of oligochaetes associated with macrophytes typically vary with the species, and abundance of macrophytes (Beckett et al. 1992, Lbhlein 1996). Previous studies indicated a positive relationship between a number of oligochaete taxa and plant cover and submerged plant. Plant cover and submerged biomass resulted in a distinct oligochaete community due to number of oligochaete taxa, especially naidids and *Aulodrilus sp*. (Lbhlein 1996, van den Berg et al. 1997). In Maranchery wetland, naidids and *Aulodrilus* species were the most abundant, so the macrophytes would have played a very crucial role which is not measured in this study.

Anderson and Smith (2000) considered that biotic interactions may play an important part than abiotic factors regulating invertebrate assemblages, although biotic interaction could not be judged in isolation from abiotic influences. Cressa (1997) considered that the abiotic factors could regulate the populations at times of low flow when resources may be limited. In addition Boulton and Lake (1992) recognized that biotic interactions, such as competition and predation are likely to be important in regulating macroinvertebrate distribution and abundance. Predation by fish, in particular has been shown to have considerable influence on benthic community structure and population dynamics (Crowder and Cooper 1982, Tatrai et al. 1994). However every taxon does not respond to the same environmental variables, and especially not always in a linear way (Vlek et al. 2004).

When the models were analyzed, wet, dry and stable phases showed less predictability whereas paddy phase and channel phases showed a good predictability based on adjusted R^2 values. But the p-values of all the models indicated that models were statistically insignificant. The benthic community in Maranchery wetland showed a week relationship between the environmental parameters so while modelling using these environmental parameters, a statistically significant predictability is not expected. It is already documented that the absence of a clear cause-effect relationship between environmental data and biological communities reduce the validity of models (Calow 1992, Chessman et al. 1999). Many authors opined that models for description and prediction of ecological systems should include variables reflecting the way organisms interact with the environment (organism-sediment relationships, physiological tolerances, etc.) and with other organisms (predation, competition, commensalism, etc.), as well as variables related to the natural history of the species (fertility, birth rate, mortality, etc.) (Snelglove and Buttman 1994, Manino and Montagna 1997). So a better predictive model could be evolved only after gauging the biotic interactions also, especially in ecosystems like Maranchery Kole wetlands where the interaction of biota and physico chemical variables were overridden by some other factors.

Table 8.1. Correlation between benthic abundance and environmental parameters in Maranchery Kole wetlands

	Water Temperature	Water pH	Depth	Dissolved oxygen	Sediment Temperature	Moisture content	Organic matter	Eh	pH	Available nitrogen	Available phosphorus	clay	silt	sand
Macrobenthos	0.149	0.150*	-0.022	0.034	0.054	-0.023	-0.109	-0.176*	0.072	-0.036	-0.157*	0.051	0.104	-0.105
Oligochaetes	0.137	0.246**	0.150*	0.139	0.059	-0.056	-0.100	-0.245	0.024	0.039	--0.021	0.033	0.091	-0.087
Insect	0.074	-0.129	-0.321**	0.041	0.024	-0.006	-0.073	0.049	0.076	--0.104	-0.302**	-0.005	0.024	-0.016
Molluscs	0.064	-0.060	-0.076	-0.049	0.118	0.037	0.087	0.043	0.078	-0.072	0.016	0.126	-0.016	-0.037
Crustacea	-0.159	0.058	-0.057	0.056	-0.050	-0.018	-0.021	-0.033	0.017	-0.054	-0.118	0.304**	-0.421**	0.465**
Others	0.028	0.050	0.066	0.122	-0.082	0.036	0.072	-0.007	0.053	-0.035	-0.056	0.066	0.011	-0.036

** Correlation is significant at 0.01
* Correlation is significant at 0.05 level

Table 8.2. Correlation between benthic biomass and environmental parameters in Maranchery Kole wetlands

	Water Temperature	Water pH	Depth	Dissolved oxygen	Sediment Temperature	Moisture content	Organic matter	Eh	pH	Available nitrogen	Available phosphorus	clay	silt	sand
Macrobenthos	0.065	0.053	-0.049	0.072	0.061	0.021	-0.009	0.007	0.102	-0.140	-0.047	0.153*	-0.022	-0.043
Oligochaetes	0.027	0.045	-0.078	0.065	0.236**	0.010	-0.121	-0.014	0.0742	-0.104	-0.0784	-0.065	0.053	-0.017
Insect	0.074	-0.046	-0.137	0.031	0.071	-0.129	-0.135	-0.014	0.014	0.003	-0.121	-0.024	-0.021	0.027

** Correlation is significant at 0.01
* Correlation is significant at 0.05 level

Table 8.3. Correlation between diversity indices of macro benthos and environmental parameters in Maranchery Kole wetlands during Study period.

	Water pH	Dissolved oxygen	Sand	Silt	Clay	Available nitrogen	Available phosphorus	Organic matter	Moisture content	pH	Sediment Temperature	Depth	Eh	Water Temperature
Richness	-0.005	0.118	0.145*	0.042	-0.060	0.024	-0.234**	-0.240	-0.410	0.143	-0.189	-0.118	0.012	0.011
Evenness	0.075	-0.046	0.168	-0.160	-0.039	-0.002	0.068	0.054	0.095	0.138	0.095	-0.267**	0.146	0.021
Diversity	-0.012	-0.107	0.001	0.045	-0.087	-0.186	-0.224*	-0.128	-0.285	-0.059	-0.099	-0.015	0.169	0.013
Dominance	-0.062	0.103	-0.174	0.166	0.133	0.080	0.205*	0.063	0.066	-0.030	-0.034	0.122	-0.196	-0.024

** Correlation is significant at 0.01
* Correlation is significant at 0.05 level

Table 8.4. Correlation between diversity indices of oligochaetes and environmental parameters in Maranchery Kole wetlands during Study period.

	Water pH	Sand	Silt	Clay	Available nitrogen	Available phosphorus	Organic matter	Moisture content	pH	Sediment Temperature	Depth	Eh	DO	Water Temperature
Richness	-0.165	-0.007	0.042	-0.060	0.024	-0.021	-0.240	-0.410*	0.143	-0.180	-0.118	0.156	-0.247	0.032
Evenness	-0.075	0.226	-0.222	-0.159	-0.022	0.068	0.054	0.095	0.138	0.095	-0.175	0.146	-0.014	0.021
Diversity	-0.012	0.001	-0.045	-0.087	-186	0.285	-0.128	-0.285	-0.059	-0.099	-0.015	0.169	-0.049	0.019
Dominance	-0.062	-0.174	0.1666	0.133	-0.080	-114	0.063	0.066	-0.030	0.034	122	-0.196	0.061	-0.014

* Correlation is significant at 0.05 level

Table 8.5. BEST results for macrobenthic abundance in wet phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 water pH	11,13	0.794
2 water temperature	8,11,13	0.758
3 sediment temperature	2,11-13	0.745
4 Eh	6,8,10,11	0.733
5 organic matter	8,10,11,13,14	0.733
6 dissolved oxygen	11	0.721
7 available phosphorus	2,11-14	0.721
8 sediment pH	6,11-14	0.721
9 available nitrogen	6,11,13	0.709
10 moisture content	10,11,13	0.709
11 clay		
12 silt		
13 sand		
14 depth		

Table 8.6. BEST results for macrobenthic abundance in dry phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 organic matter	2,3,5,9	0.697
2 Eh	5,9	0.673
3 moisture content	3,9	0.661
4 available phosphorus	5,7,9	0.624
5 available nitrogen	5,9,10	0.6
6 sediment pH	2,3,5,9,11	0.6
7 silt	1,3,5,9	0.576
8 depth	3,5,6,9	0.576
9 sediment temperature	1,3,5,9,11	0.576
10 sand	3,5,9	0.564
11 clay		

Table 8.7. BEST results for macrobenthic abundance in paddy phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 water temperature	3,9	0.697
2 water pH	2,3,8	0.648
3 depth	1-3,5,9	0.636
4 sediment temperature	9	0.6
5 moisture content	1-3,6-9	0.588
6 organic matter	1,2,9	0.564
7 dissolved oxygen	2,9,14	0.552
8 available nitrogen	1-3,9	0.552
9 available phosphorus	1,2,7,9	0.552
10 sediment pH	2,3,9,11	0.552
11 clay		
12 silt		
13 sand		
14 Eh		

Table 8.8. BEST results for macrobenthic abundance in channel phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 water pH	10	0.818
2 water temp	1,10	0.818
3 depth	1,10,13	0.77
4 sediment temperature	1,10,12,13	0.733
5 Eh	1,6,10	0.709
6 moisture content	1,2,6,10	0.709
7 organic matter	1,2,10	0.697
8 dissolved oxygen	1,2,6,10,13	0.697
9 available nitrogen	1,2,9,10,13	0.697
10 available phosphorus	1,6,10,12,13	0.697
11 sediment pH		
12 clay		
13 silt		
14 sand		

Table 8.9. BEST results for macrobenthic abundance in stable phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 Eh	5,12	0.656
2 available nitrogen	3,5,12	0.57
3 dissolved oxygen	12	0.545
4 sediment temperature	3,5,11,12	0.545
5 moisture content	3,11,12	0.487
6 organic matter	2,5,11,12	0.473
7 available phosphorus	2,5,12	0.47
8 sediment pH	5,11,12	0.47
9 silt	2,3,5,11,12	0.466
10 clay	3-5,11,12	0.466
11 sand		
12 water pH		
13 water temperature		
14 depth		

Table 8.10. BEST results for oligochaete abundance in wet phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 sediment temperature	2,3	0.441
2 available phosphorus	2-4	0.441
3 organic matter	2,3,6	0.433
4 Eh	2,3,6,8	0.433
5 available nitrogen	3,4	0.431
6 sediment pH	2,3,10	0.434
7 silt	1-3,6	0.425
8 depth	3	0.285
9 moisture content	3,8,11	0.425
10 sand	3,11	0.408
11 clay		

Table 8.11. BEST results for oligochaete abundance in dry phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 organic matter	2,3	0.406
2 Eh	2-4	0.382
3 moisture content	2,3,6	0.382
4 available phosphorus	2,3,6,8	0.37
5 available nitrogen	3,4	0.321
6 sediment pH	2,3,10	0.309
7 silt	1-3,6	0.297
8 depth	3	0.285
9 sediment temperature	3,8,11	0.273
10 sand	3,11	0.261
11 clay		

Table 8.12. BEST results for oligochaete abundance in paddy phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 water temperature	4,6,9,10,13	0.988
2 water pH	4,6,10	0.976
3 depth	6,9,10	0.964
4 sediment temperature	4-6,10	0.964
5 moisture content	4,6,9,10	0.964
6 organic matter	4,6,8-10	0.964
7 dissolved oxygen	5,6,9,10,13	0.964
8 available nitrogen	5,6,10	0.952
9 available phosphorus	4,5,7,13	0.952
10 sediment pH	4,6,8,10	0.952
11 clay		
12 silt		
13 sand		
14 Eh		

Table 8.13. BEST results for oligochaete abundance in channel phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 water pH	5,12,13	0.624
2 water temp	3,5,8,10,13	0.576
3 depth	3,10,12,13	0.552
4 sediment temperature	3,8,10,13	0.467
5 Eh	3,5,7,10,13	0.467
6 moisture content	3,12,13	0.442
6 organic matter	3,5,7,10	0.442
7 dissolved oxygen	3,8,13	0.43
8 available nitrogen	3,10,13	0.418
9 available phosphorus	3,8,10,12,13	0.406
10 sediment pH		
12 clay		
13 silt		
14 sand		

Table 8.14. BEST results for oligochaete abundance in stable phase in Maranchery Kole wetland.

Variables	Variables selected	BEST correlation values (Rho)
1 Eh	1,5,8	0.187
2 available nitrogen	1,5	0.169
3 dissolved oxygen	1,2,5,8	0.169
4 sediment temperature	1,3,5	0.139
5 moisture content	1,3,10	0.115
6 organic matter	3-1	0.109
7 available phosphorus	1,8	0.103
8 sediment pH	1,3,8	0.103
9 silt	1,3,5,8	0.103
10 clay	1,3	0.097
11 sand		
12 water pH		
13 water temperature		
14 depth		

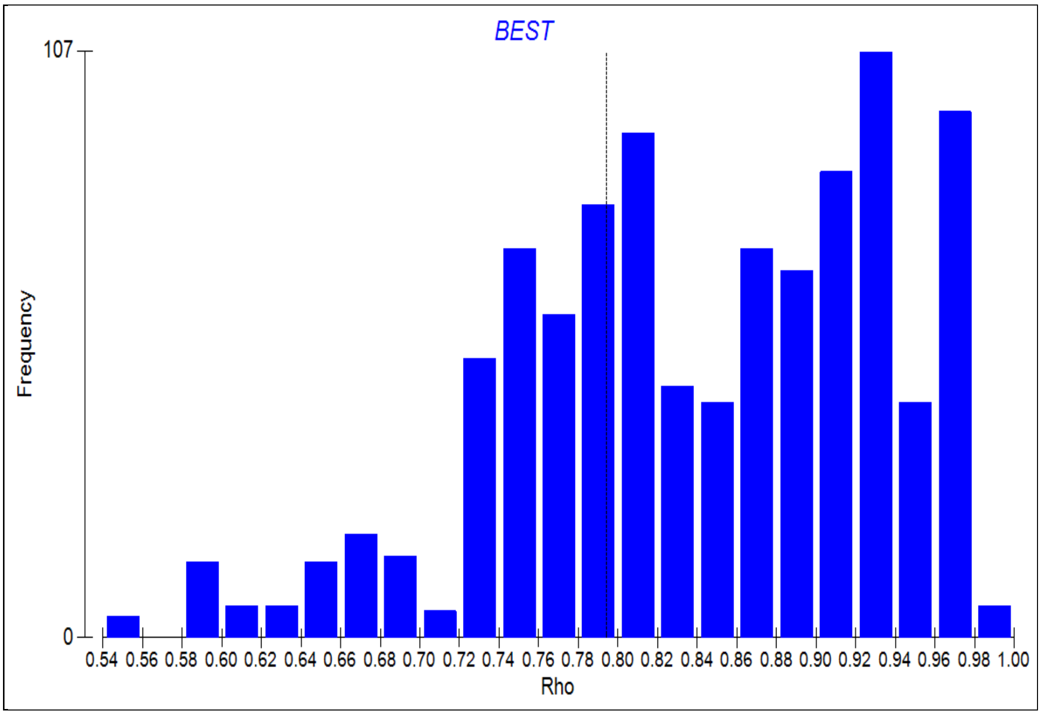

Fig. 8.1. Histogram showing the BEST results for macrobenthic abundance (Rho 0.794) in wet phase in Maranchery Kole wetland.

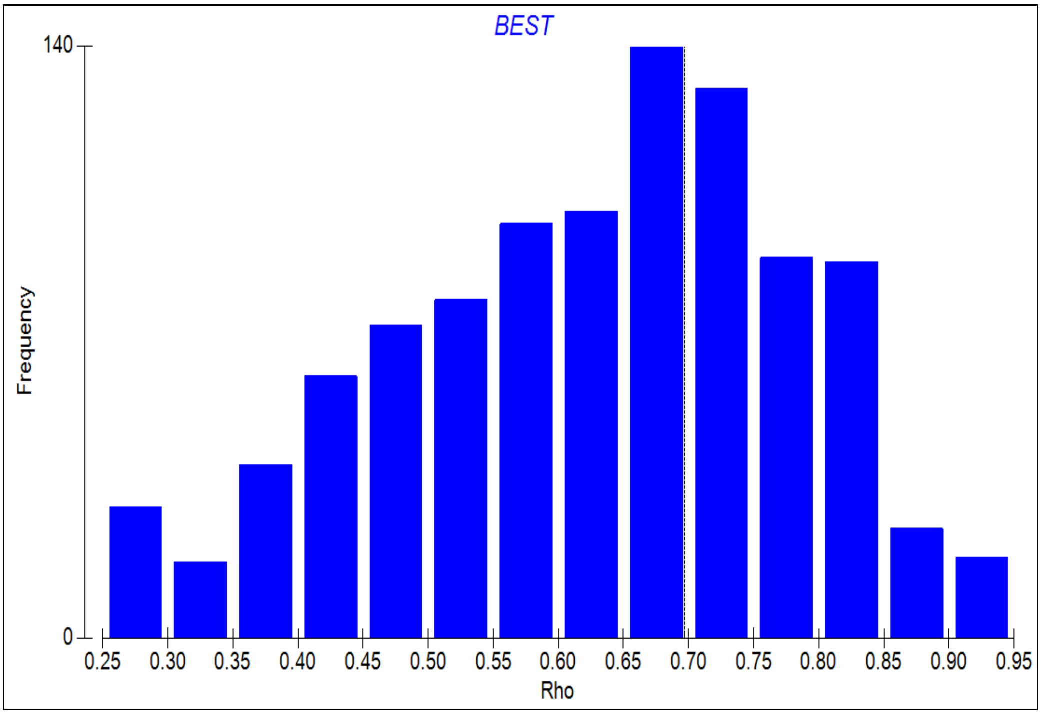

Fig. 8.2. Histogram showing the BEST results for macrobenthic abundance (Rho 0.697) in dry phase in Maranchery Kole wetland.

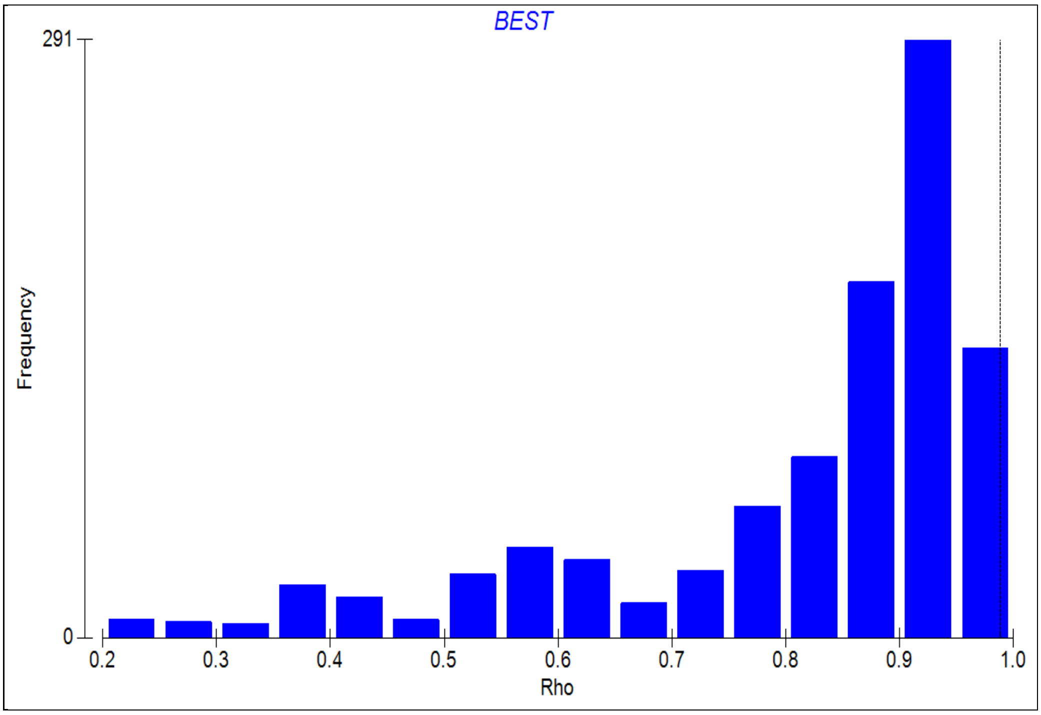

Fig. 8.3. Histogram showing the BEST results for macrobenthic abundance (Rho 0.697) in paddy phase in Maranchery Kole wetland.

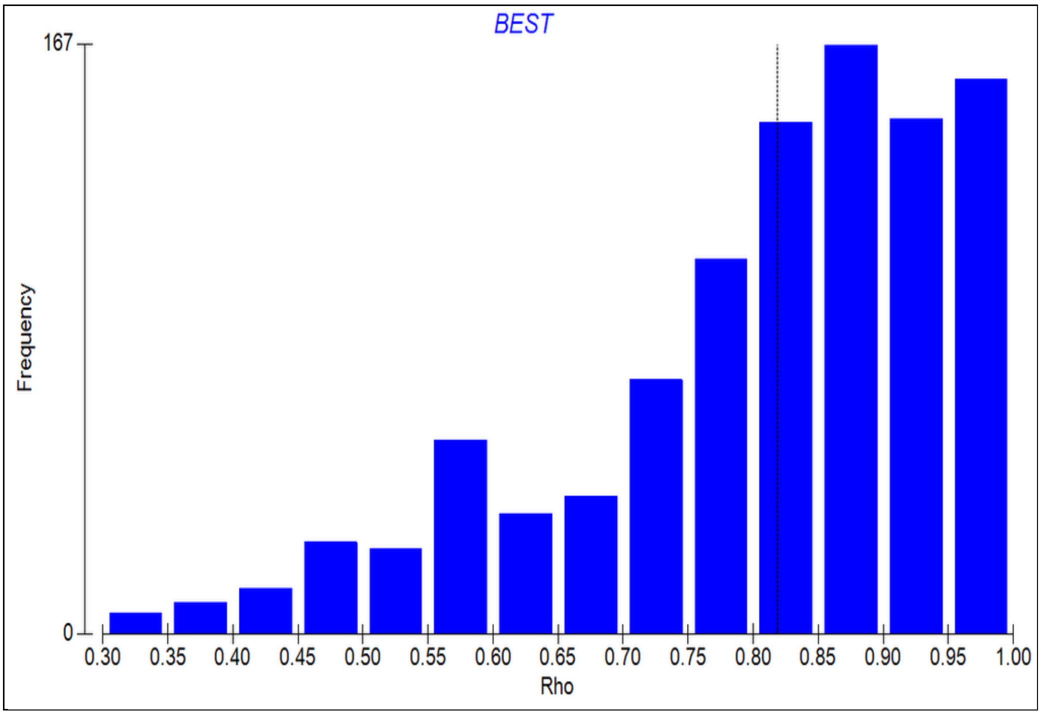

Fig. 8.5. Histogram showing the BEST results for macrobenthic abundance (Rho 0.818) in Channel phase in Maranchery Kole wetland.

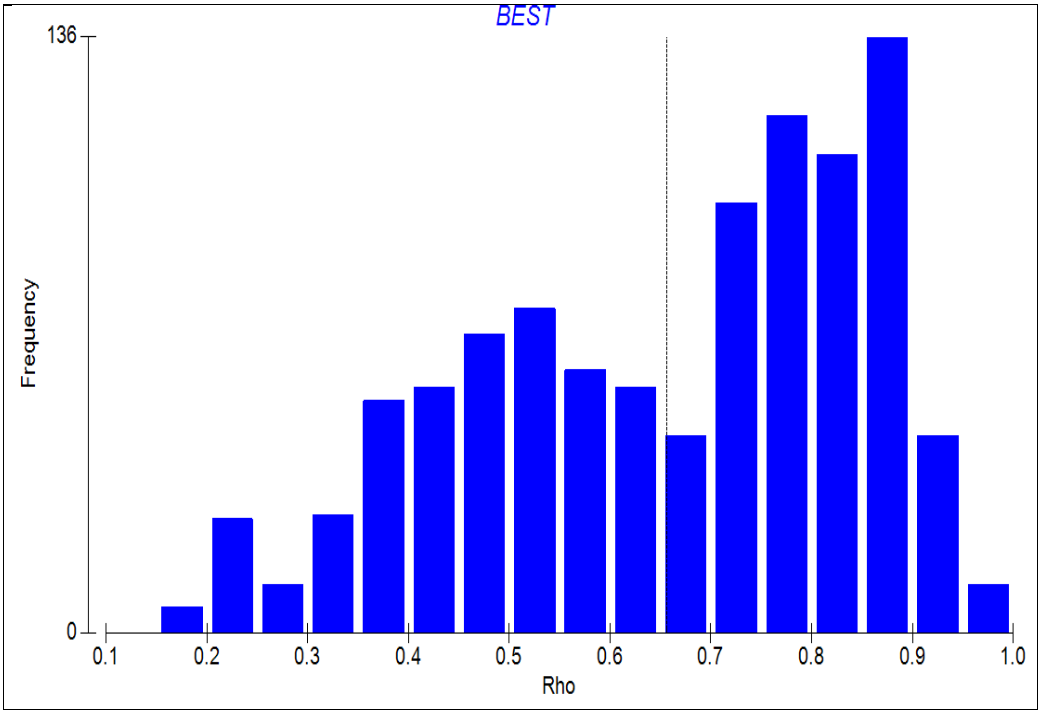

Fig. 8.5. Histogram showing the BEST results for macrobenthic abundance (Rho 0.656) in stable phase in Maranchery Kole wetland.

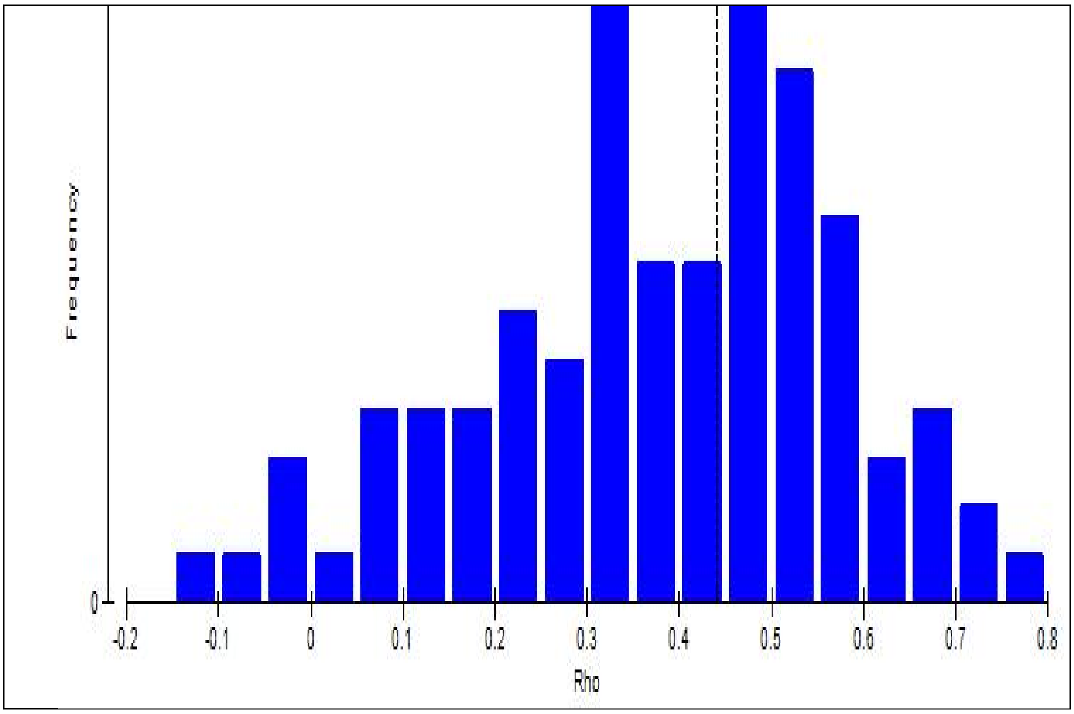

Fig. 8.6. Histogram showing the BEST results for oligochaete abundance (Rho 0.522) in wet phase in Maranchery Kole wetland.

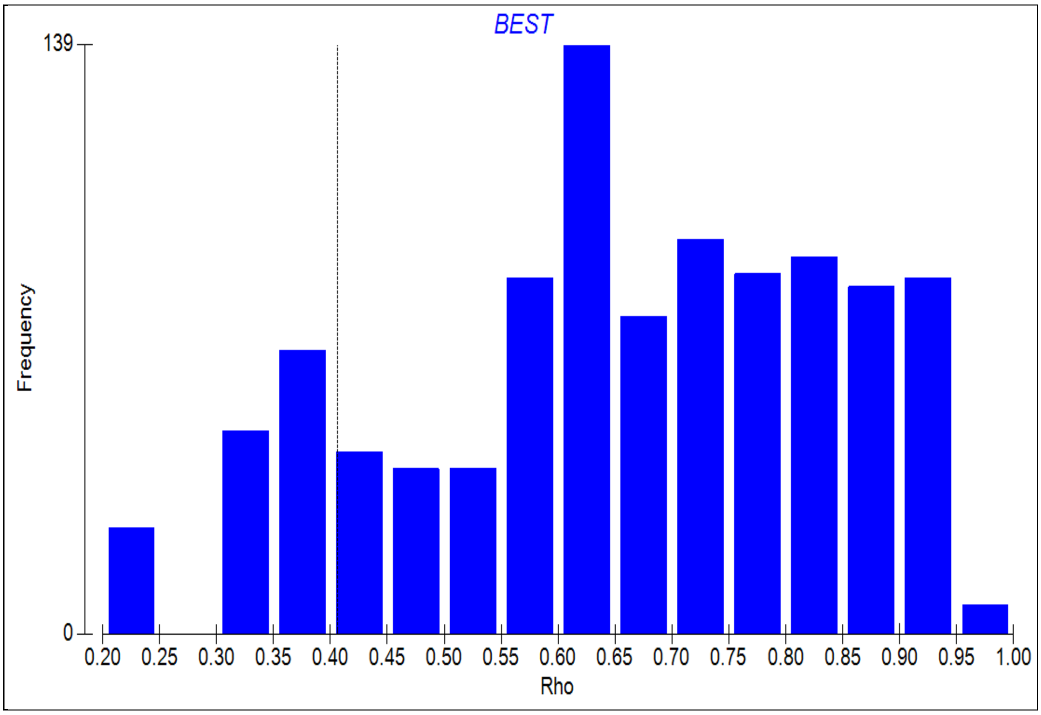

Fig. 8.7. Histogram showing the BEST results for oligochaete abundance (Rho 0.406) in dry phase in Maranchery Kole wetland.

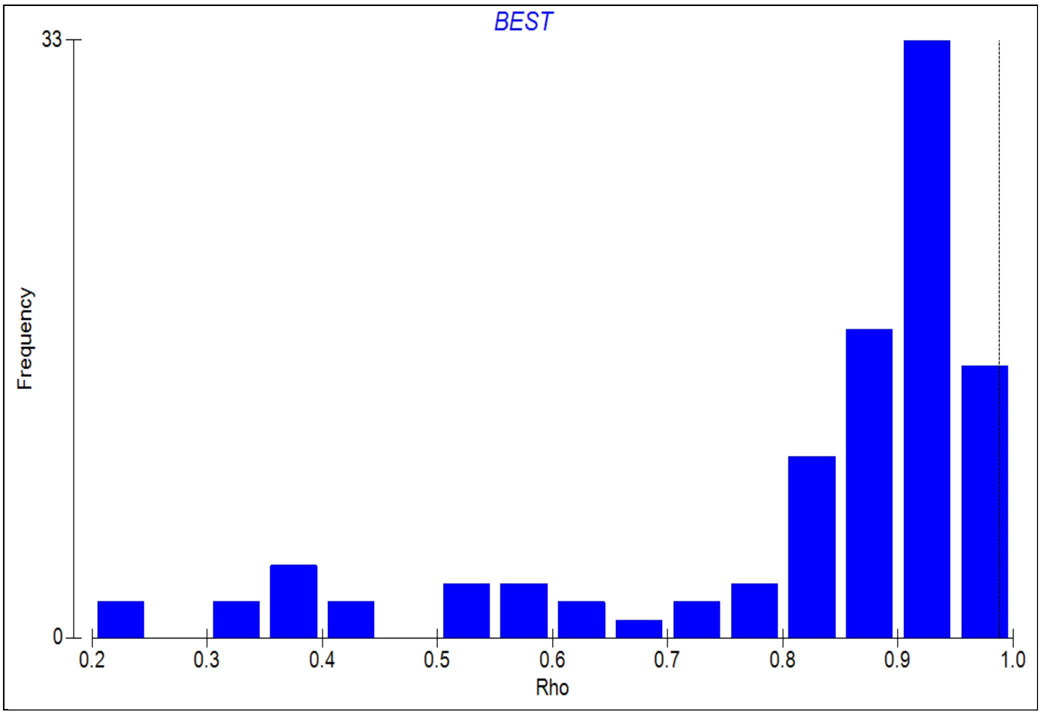

Fig. 8.8. Histogram showing the BEST results for oligochaete abundance (Rho 0.998) in paddy phase in Maranchery Kole wetland.

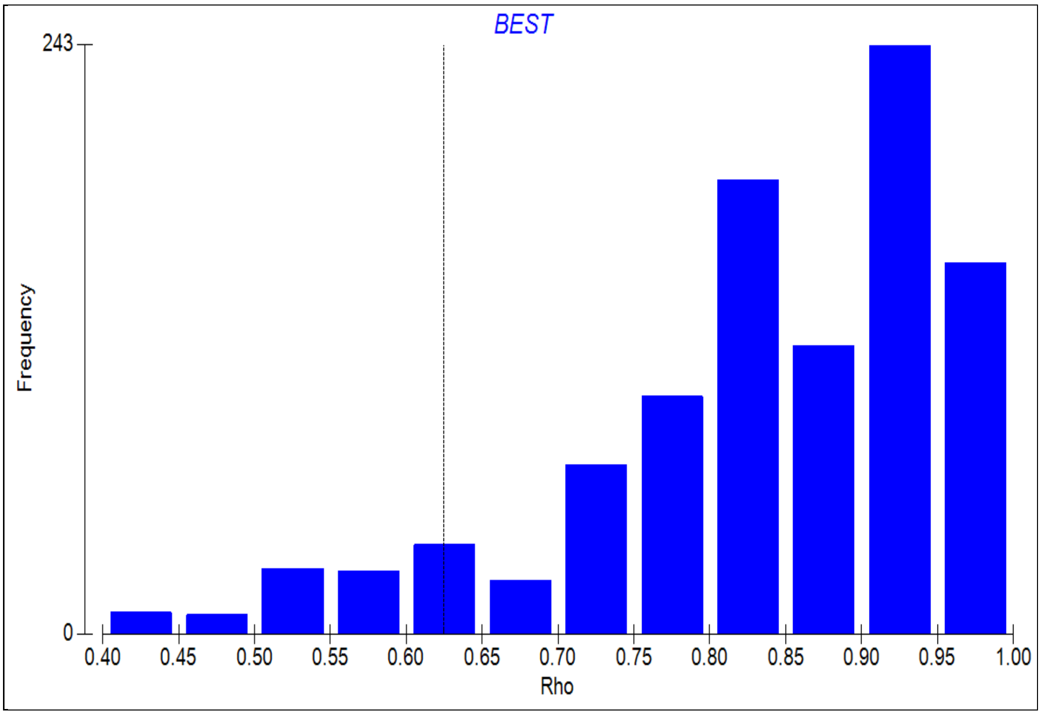

Fig. 8.9. Histogram showing the BEST results for oligochaete abundance (Rho 0.624) in channel phase in Maranchery Kole wetland.

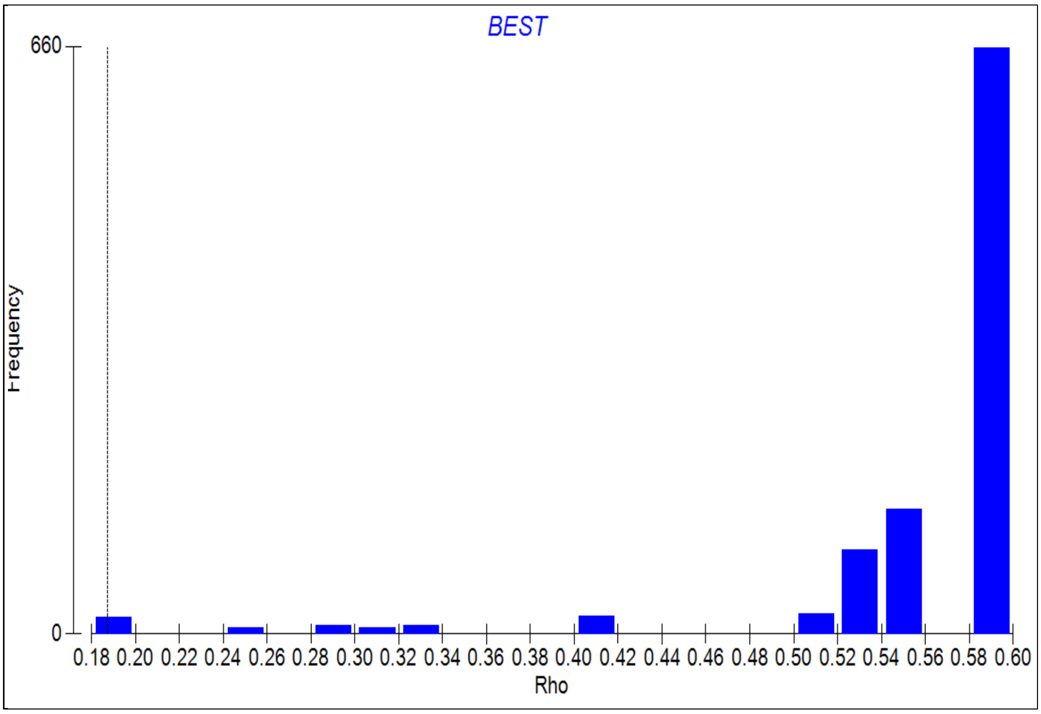

Fig. 8.10. Histogram showing the BEST results for oligochaete abundance (Rho 0.187) in stable phase in Maranchery Kole wetland.

Chapter - 9

SUMMARY AND CONCLUSION

Wetlands are one of the most productive and diverse ecosystems in the world, their functions ranges from providing livelihood to the local people to climate regulation on a global scale. The variety of characteristics in each wetlands make them unique from others which makes the application of a general rule difficult in them. Kole wetlands, a part of Vembanadu Kole wetlands, spreading over Thrissur and Malappuram districts of Kerala are unique as they are saucer shaped low lying tracts below mean sea level, submerged for almost half of the year and under paddy cultivation for the other half. The shift from water body to paddy field involves a series of processes. This series of processes is expected to cause disturbance to the inhabiting organisms. Due to their sedentary life style, benthic organisms are prone to the disturbances than the mobile organisms. They are an also important link in the food chain, providing nourishment to fish and birds. They are considered to be good predictors of changes in the ecosystem.

The study area is a typical kole wetland, where paddy cultivation (*Punja*) is practised from January to May every year. 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. This study tried to explore the difference in benthic community among the above phases and compared it to a part of the wetland, which remained stable throughout the study period.

Depth was the most variable physical parameter in this study. Though the variation seems less, as the water body was shallow, it caused profound changes in the system. Water and sediment pH remained neutral mostly or was otherwise acidic. Eh remained reduced throughout the study period. Organic matter was high indicating the constant and eternal supply of detritus, irrespective of phases. Due to the different phases, the moisture content was expected to differ in Maranchery wetlands, but it remained comparatively high, possibly due to high organic matter. Apart from the general parameters affecting nutrient distribution in wetlands, the cattle and bird excreta was also suspected to impact the nutrient levels, though it was not measured. The sediments observed in Maranchery wetlands were clayey silt, sandy silt, clayey sand, sandy, silty clay and silty sandy during the study period.

The numerical abundance and biomass of benthos varied significantly in different phases. Wet phases were characterized by more abundance as the increased habitable area increases the abundance obviously. Dry and paddy phases showed a reduced abundance. The reduced numerical abundance in the dry phase was attributed to habitat desiccation resulting in reduced numerical abundance due to reduced habitable area directly, and indirectly by increased competition for limited space and other abundance dependent effects. Also the chance of predation from birds and other invertebrates were more due to the shallow nature of the water body resulting in less numerical abundance. In the paddy phase, unlike the bottom of the water bodies bottom of the paddy field was compartmented by paddy root structures providing insufficient space for the proper development of benthic fauna resulting in less available habitable area for benthos resulting in less abundance as in dry phase.

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 a flight mode of dispersal instead of the crawl mode of dispersal in oligochaetes. The paddy plants provided a protected habitat niche for the insect to thrive. An unusual numerical abundance of benthos was observed in May 2011 in channels, due to the result of some specific, localized conditions ensuring the most favourable environment for the benthic fauna there. The variations in biomass was accounted for the presence or absence of molluscs and pisces in the samples. Due to reduced body size of oligochaetes, their contribution to the biomass was very less.

The benthic fauna in Maranchery wetlands belonged to 4 phyla (Annelida, Arthropoda, Mollusca and Chordata), and 7 classes (Oligochaeta, Insecta, Gastropoda, Bivalvia, Pisces, Crustacea, and Hirudinea). Twenty seven species of oligochaetes were recorded, 23 species belonged to the family Naididae, 3 belonged to the family Tubificidae and 1 belonged to Lumbriculidae. The family Tubificidae consisted of the species *Aulodrilus pluriseta, Aulodrilus pigueti, Aulodrilus sp.,* Naididae family was made up of the species *Dero digitata, Dero dorsalis, Dero zeylanica, Dero nivea, Branchiodrilus semperi, Branchiodrilus hortensis, Pristina breviseta, Pristinella minuta, Pristinella menoni, Pristinella jenkinae, Pristinella acuminata, Nais andhrensis, Nais pardalis, Aulophorus carteri, Aulophorus furcatus, Aulophorus hymnae, Allonais inaequalis, Allonais paraguayensis paraguayensis, Allonais gwaliorensis, Haemonais waldvogeli, Stephensoniana trivandrana, Nais sp., Haemonais sp*., The only one species represented in the family Lumbriculidae was *Lumbriculus variegates.* The species *Nais pardalis, Allonais inaequalis, Dero digitata, Aulophorus carteri, Aulophorus furcatus, Nais sp., Dero zeylanica Haemonais sp*., *Nais andhrensis, Allonais paraguayensis paraguayensis* and *Dero nivea,* made sparse appearance contributing a lesser share in abundance.

The class Insecta was represented by Diptera (true flies), Coleoptera (beetles), Trichoptera (Caddisflies), Hemiptera (True bugs), Odonata (Dragon flies and Damsel flies), Ephemeroptera (May flies) and Megaloptera (Alder flies). The most abundant insects family was Diptera (Chironomidae, Chaoboridae, Ceratopogonidae, Empedidae, Tipulidae) followed by Odonata (Zygoptera, Libellulidae, Coenegrionidae), Trichoptera (Gyrinidae, Hydrophilidae, Limnephilidae, Dryopidae, Dysticidae), Ephemeroptera (Leptophlebidae, Baetidae), Heteroptera (Aphelecherinidae), Megaloptera (Cory dalidae).

The transformation from one phase to another in the wet, dry, paddy and channel phases were through a series of steps which made the substrate dry resulting in habitat loss and habitat fragmentation for aquatic organisms for some period. Aquatic organisms which are adapted to live in water are known to get affected by this habitat loss and habitat fragmentation. Though the physical structure of the study area varied dramatically in the phases such a shift in species composition of the benthic fauna was absent. The organisms existed in Maranchery Kole wetland were capable of surviving the dry periods. Oligochaetes survived by the strategies such as diapausing eggs, resistant cysts enclosing young, adults or fragments of individuals. The insects such as Diptera survived by diapausing eggs, resistant late instar larvae, sometimes in cocoons of silk or mucus. The survival mechanism for Ephemeroptera was diapausing eggs. Odonata formed resistant nymphs or recolonised adult. In the case of Hemiptera, recolonising adults was the survival strategy. Trichoptera survived by diapausing egg, resistant gelatinous egg mass, recolonizing adults or saved larvae deep in substrate. Coleoptera survived by forming semi-terrestrial pupae, burrowing or recolonising adults. Both diapausing eggs and adult stages made Bivalves to cope with the dry condition, Gastropoda formed a protective apiphragm of dried mucus across shell opening in the case of adults and young survived in moist air/soil under algal mats on pond/stream bed. Hirudinae survived as dehydrated individuals or by constructing small, mucus-lined cells. So the above properties of the benthic fauna in Maranchery Kole wetland ensured their presence in the wetland from inactive/dormant forms, once the wetland was wet.

There are studies which states that in temperory 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. 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 composition.

Irrespective of the difference in the physical structure, the diversity indices remained similar between the phases even a marginal increase in species diversity was observed in dry phase and paddy phase which were characterized by a significantly reduced numerical abundance. Due to the reduced habitable area due to the dry substratum in the dry phase and paddy plantation in the paddy phase, the utilization of the available habitable areas as a refuge by benthos ensured a fairly high diversity and richness in those phases.

In the dry phase, while considering the oligochaetes, the co occurrence of tubificids which are k strategists and naidids which are r strategists would have resulted in a higher diversity where a glimpse of Connel's Intermediate Disturbance Hypothesis was reflected even though a clear demarcation in species diversity or a clear distinction in k and r species and between the dry phase (disturbed phase) and wet, stable phases (undisturbed phases) was not evident. IDH theory states that at intermediate levels of disturbance, diversity is maximized because both competitive k selected and opportunistic r selected species can coexist. In paddy phase also where there was a disturbance factor due to the reduced water level and the growth of paddy (which could be considered as an exotic plant to the natural wetland), a marginal increase in diversity was there but Tubificidae (A*ulodrilus pluriseta* and A*ulodrilus sp*.) showed a clear domination.

When the relationship between the environmental factors and benthic organisms were concerned, a week correlation was observed with many of the environmental parameters. Though such relationship between benthos and the environmental parameters are clearly evident conventional studies, the heterogenous nature of the study area especially the phase changes in a short time span would have made the absence of a correlation. In spite of the physico chemical parameters analyzed in the study, the other unmeasured factors would have determined the abundance structure such as area of the habitable patch, hydrological stability, length of hydroperiod, habitat duration, life history strategy, macrophyte structure, proximity and size of the neighbouring habitat, intensity of disturbance etc. which are known to play a key role. Further the most abundant organism in Maranchery Kole wetlands were oligochaetes. A niche specialization is absent in aquatic oligochaetes and are adapted to live in a wide range of conditions where literature cites that even the usual distinction between lacustrine and palustrine species is less obvious in them. The second abundant taxa were chironomid larvae, which are also known to exist in a wide range of conditions irrespective of any particular environmental preferences. The response of organisms to a stressful environment is determined by the sensitivity of the organisms. This study showed that the varying physical habitat in the wetland during various phases could make a significant variation in the abundance of benthic organism but the composition and community structure of benthos remained similar throughout the phases because the most abundant organisms were oligochaetes and chironomids that were able to tolerate a wide range of stress full environment.

Prediction of total and oligochaete abundance was attempted in the five phases based on multiple regression analysis, but a significant predictive model was absent due to the week correlation between the biota and the environmental parameters measured.

Recently researchers opined that paddy fields could surrogate the loss of natural wetlands due to its biological diversity (Angelini et al. 2008, Nathuhara 2013). But the area under rice cultivation declined from 7.53 lakh hectares in Kerala during 1961 to 2.13 lakh hectares in 2010-2011. Rice cultivation has been the pride of Asian societies, the old saying that the rice farmer is fit to be a king after washing the mud indicates the place he had in ancient society (Edirisinghe et al. 2006). But the past glory of rice farming had disappeared due to low social status and poor income associated with it. The farmers and fishermen in Maranchery kole wetland are also of the opinion that paddy cultivation is not profitable. So unless some economic benefits are assured, gradually the area will be reclaimed for other income generating activities eventually resulting in the loss of wetland. This study was initiated in those circumstances to survey the existing biodiversity of the Maranchery wetland. Based on the results of this study some management options and future outlook are suggested here.

- ✓ 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 here caused stress to the benthic organisms.The global climate change with its probable regional impacts also had its bearing during the dry period. Even in this scenario, the benthic communities through its survival strategies and adaptations maintained the productivity and health of the kole wetland. So the Marancherry wetland should be conserved for long term agrarian livelihood conservation objectives of the state.

- ✓ The considerably higher biological productivityand diversity in terms of the benthic fauna, the true bioturbators, in Maranchery Kole wetland were suitable for enhanced fish farming operations to propagate the native resources. A structured paddy cum fish farming practice (integrated) has to be encouraged depending on the different seasonal phases. The Kerala State Biodiversity Board and other Governmental and non Governmental organizations should initiate effective action in this direction.

- ✓ As oligochaetes, promote nutrient mineralization and suppress weed germination, healthy oligochaete community is sufficient to meet the nutrient needs for the paddy fields thus the usage of chemical fertilizers and weedicides can be reduced. Reduced usage of agrochemicals, promoting organic farming can reduce the cost, thus paddy production can be more economical.
- ✓ Rice bioparks can be established, intended to convert every part of the rice biomass into valuable products that helps the farmer obtain a better profit so as to retain them in rice cultivation. The scenic beauty of kole wetlands especially due to the presence of numerous native and migratory birds could be explored for tourism purposes without disturbing the system.
- ✓ Kole wetlands are unique treasures of biodiversity and agronomic practices of the country. So the Maranchery wetland should be conserved as a model Kole land of the Government to illustrate and propagate different farming operations. The long-term solution of conserving wetlands lies in realising the values and fragility of these systems and transmits information effectively beyond scientific circles.

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ANNEXURE

Annexure 1. Numerical abundance of macrobenthos (ind./m^2)in Maranchery Kole wetlands during the study period.

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
November 2009							
Station 1	44	22	-	-	-	-	67
Station 2	22	44	-	-	-	-	67
Station 3	200	-	-	-	-	-	200
Station 4	111	67	-	-	-	-	178
Station 5	111	-	-	-	-	-	111
Station 6	44	-	-	-	-	-	44
Station 7	-	-	-	-	-	-	-
Station 8	311	-	-	-	-	-	311
December 2009							
Station 1	133	44	-	-	-	-	178
Station 2	2044	111	-	-	-	-	2155
Station 3	333	22	-	-	-	-	356
Station 4	-	289	-	-	-	-	289
Station 5	67	-	-	-	-	-	67
Station 6	111	-	-	-	-	-	111
Station 7	-	22	-	-	-	-	22
Station 8	133	67	-	-	-	-	200
January 2010							
Station 1	156	422	-	-	-	-	578
Station 2	67	44	-	-	-	-	111
Station 3	-	289	-	-	-	-	289
Station 4	22	778	-	-	-	-	800
Station 5	133	-	-	-	-	-	133
Station 6	578	-	-	-	-	-	578
Station 7	622	-	-	-	-	-	622
Station 8	222	44	-	-	-	-	267
February 2010							
Station 1	44	67	-	22	-	-	133
Station 2	22	89	22	-	-	-	133

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 3	89	244	-	-	-	-	333
Station 4	267	156	-	-	-	-	422
Station 5	89	67	-	-	-	-	156
Station 6	67	22	-	-	-	-	89
Station 7	22	156	-	22	-	-	200
Station 8	444	44	-	-	-	-	489
March 2010							
Station 1	-	22	-	-	-	-	22
Station 2	-	222	-	-	-	-	222
Station 3	44	89	-	-	-	-	133
Station 4	22	156	-	-	-	-	178
Station 5	22	-	-	-	-	-	22
Station 6	178	67	-	-	-	-	244
Station 7	156	-	-	-	-	-	156
Station 8	289	-	-	-	-	-	289
April 2010							
Station 1	-	111	-	-	-	-	111
Station 2	-	178	44	-	-	-	222
Station 3	156	67	-	-	-	-	222
Station 4	156	111	-	-	-	-	267
Station 5	22	89	-	-	-	-	111
Station 6	44	89	-	-	-	-	133
Station 7	400	89	-	-	-	-	489
Station 8	111	-	-	-	-	-	111
May 2010							
Station 1	44	22	-	-	-	-	67
Station 2	-	133	-	-	-	-	133
Station 3	-	133	-	-	-	-	133
Station 4	-	89	-	-	-	-	89
Station 5	-	111	-	-	-	-	111
Station 6	244	89	-	-	-	-	333
Station 7	1911	-	-	-	-	-	1911
Station 8	444	-	-	-	-	-	444
June 2010							
Station 1	44	89	-	-	-	-	133
Station 2	44	-	-	-	-	-	44
Station 3	22	-	-	-	-	-	22
Station 4	222	111	-	-	-	-	333
Station 5	-	156	-	-	-	-	156
Station 6	111	111	-	-	-	-	222
Station 7	-	-	22	-	-	-	22

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 8	356	-	-	-	-	-	356
July 2010							
Station 1	-	44	-	-	-	-	44
Station 2	22	267	-	-	-	-	289
Station 3	200	-	-	-	-	-	200
Station 4	44	-	-	-	-	-	44
Station 5	444	200	-	-	-	-	644
Station 6	289	-	-	-	-	-	289
Station 7	244	-	-	-	-	-	244
Station 8	289	-	-	-	-	-	289
August 2010							
Station 1	67	44	-	-	-	-	111
Station 2	89	44	-	-	-	-	133
Station 3	89	133	-	-	-	-	222
Station 4	267	-	-	-	-	-	267
Station 5	133	22	-	-	-	-	156
Station 6	111	44	-	-	-	-	156
Station 7	378	-	-	-	-	-	378
Station 8	22	111	-	-	-	-	133
September 2010							
Station 1	89	822	-	-	-	-	911
Station 2	111	267	-	-	-	-	378
Station 3	1889	111	-	-	-	-	2000
Station 4	22	89	-	-	-	-	111
Station 5	200	89	-	-	-	-	289
Station 6	-	156	-	-	-	-	156
Station 7	511	-	-	-	-	-	511
Station 8	333	-	-	-	-	-	333
October 2010							
Station 1	244	44	-	-	-	-	289
Station 2	89	-	-	-	-	-	89
Station 3	444	-	-	-	-	-	444
Station 4	867	-	-	-	-	-	867
Station 5	-	89	-	-	-	-	89
Station 6	955	-	-	-	-	-	955
Station 7	222	67	-	-	-	-	289
Station 8	489	-	-	-	-	-	489
November 2010							
Station 1	111	89	-	-	22.22	-	222
Station 2	22	67	-	-	-	-	89
Station 3	111	133	-	-	-	-	244

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 4	178	44	-	-	-	22	244
Station 5	1866	-	-	-	-	-	1866
Station 6	178	89	-	-	-	-	267
Station 7	400	22	-	-	-	-	422
Station 8	667	-	-	-	-	-	667
December 2010							
Station 1	67	89	-	-	-	-	156
Station 2	89	-	-	-	-	-	89
Station 3	133	-	-	-	-	-	133
Station 4	-	44	-	-	-	-	44
Station 5	-	-	-	-	-	-	-
Station 6	267	-	-	-	-	-	267
Station 7	-	-	-	-	-	-	-
Station 8	133	-	-	-	-	-	133
January 2011							
Station 1	22	267	44	-	-	-	333
Station 2	178	333	-	-	-	-	511
Station 3	578	222	-	-	-	-	800
Station 4	800	89	-	-	-	-	889
Station 5	311	200	-	-	-	-	511
Station 6	-	111	-	-	-	-	111
Station 7	-	22	-	-	-	-	22
Station 8	-	200	-	-	-	-	200
February 2011							
Station 1	22	222	-	-	-	-	244
Station 2	-	222	-	22	-	-	244
Station 3	22	22	-	-	-	-	44
Station 4	711	244	22	-	-	-	978
Station 5	22	111	-	-	-	-	133
Station 6	44	22	-	-	44.44	-	111
Station 7	-	644	-	-	-	-	644
Station 8	-	44	-	-	-	-	44
March 2011							
Station 1	-	111	-	-	-	-	111
Station 2	267	89	-	-	-	-	356
Station 3	44	178	-	-	-	-	222
Station 4	111	133	-	-	-	-	244
Station 5	44	1089	-	-	-	-	1133
Station 6	1045	67	22	-	-	-	1134
Station 7	644	489	-	-	-	-	1133
Station 8	111	-	-	-	-	-	111

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
April 2011							
Station 1	67	111	-	-	-	-	178
Station 2	267	-	-	-	-	-	267
Station 3	-	267	-	-	-	-	267
Station 4	244	111	-	-	22	-	377
Station 5	-	178	-	-	-	-	178
Station 6	-	89	-	-	-	-	89
Station 7	44	67	-	-	-	-	111
Station 8	-	-	-	-	-	-	-
May 2011							
Station 1	44	22	-	-	-	-	67
Station 2	22	333	-	-	-	-	356
Station 3	-	133	-	-	-	-	133
Station 4	4400	3466	-	-	-	-	7866
Station 5	2266	178	44	-	-	-	2444
Station 6	89	-	-	-	-	-	89
Station 7	22	44	-	-	-	-	67
Station 8	-	156	-	-	-	-	156
June 2011							
Station 1	-	-	-	-	-	-	-
Station 2	-	-	-	-	-	-	-
Station 3	44	-	-	-	-	-	44
Station 4	178	-	-	-	-	-	178
Station 5	-	89	-	-	-	-	89
Station 6	67	-	-	-	-	-	67
Station 7	22	22	-	-	-	-	44
Station 8	22	22	-	-	-	-	44
July 2011							
Station 1	-	133	-	-	-	-	133
Station 2	267	-	-	-	-	-	267
Station 3	111	222	-	-	-	-	333
Station 4	400	-	-	-	-	-	400
Station 5	-	44	-	-	-	-	44
Station 6	22	89	-	-	-	-	111
Station 7	267	111	-	-	-	-	378
Station 8	-	22	-	-	-	-	22
August 2011							
Station 1	422	-	-	-	-	-	422
Station 2	267	-	-	-	-	-	267
Station 3	356	-	-	-	-	-	356
Station 4	244	22	-	-	-	-	267

	Oligochaetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 5	-	67	-	-	-	-	67
Station 6	-	-	-	-	-	-	-
Station 7	178	133	-	-	-	-	311
Station 8	111	22	-	-	-	-	133
September 2011							
Station 1	156	-	-	-	-	-	156
Station 2	-	-	-	-	-	-	-
Station 3	289	-	-	-	-	-	289
Station 4	333	-	-	-	-	-	333
Station 5	244	-	-	-	-	-	244
Station 6	378	-	-	-	-	-	378
Station 7	-	22	-	-	-	-	22
Station 8	-	89	-	-	-	-	89
October 2011							
Station 1	67	44	-	-	-	-	111
Station 2	222	-	-	-	-	-	222
Station 3	200	-	-	-	-	-	200
Station 4	156	-	-	-	-	-	156
Station 5	178	-	-	-	-	-	178
Station 6	156	-	-	-	-	-	156
Station 7	178	-	-	-	-	-	178
Station 8	178	200	-	-	-	-	378

Annexure 2. Biomass of macrobenthos (mg/m^2) in Maranchery Kole wetlands during the study period.

	Oligochatetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
November 2009							
Station 1	0.04	1.33	-	-	-	-	1.38
Station 2	0.02	3.11	-	-	-	-	3.13
Station 3	0.29	-	-	-	-	-	0.29
Station 4	0.02	3.33	-	-	-	-	3.36
Station 5	0.07	-	-	-	-	-	0.07
Station 6	0.11	-	-	-	-	-	0.11
Station 7	-	-	-	-	-	-	-
Station 8	1.91	-	-	-	-	-	1.91
December 2009							
Station 1	0.22	2.00	-	-	-	-	2.22
Station 2	7.55	10.22	-	-	-	-	17.78
Station 3	7.33	1.78	-	-	-	-	9.11
Station 4	-	0.89	-	-	-	-	0.89
Station 5	11.78	-	-	-	-	-	11.78
Station 6	0.11	-	-	-	-	-	0.11
Station 7	-	5.56	-	-	-	-	5.56
Station 8	2.93	3.78	-	-	-	-	6.71
January 2010							
Station 1	0.22	2.44	-	-	-	-	11.78
Station 2	2.44	22.44	-	-	-	-	24.89
Station 3	-	1.11	-	-	-	-	1.11
Station 4	38.00	-	-	-	-	-	38.00
Station 5	0.44	-	-	-	-	-	0.44
Station 6	4.67	-	-	-	-	-	4.67
Station 7	13.11	12.44	-	7.6	-	-	25.55
Station 8	4.00	3.33	-	-	-	-	7.33
February 2010							
Station 1	5.33	5.33	-	-	-	-	10.66
Station 2	0.02	3.33	87.99	-	-	-	91.35
Station 3	0.18	12.67	-	-	-	-	12.84
Station 4	10.67	1.56	-	-	-	-	12.22
Station 5	20.00	5.56	-	-	-	-	25.55
Station 6	0.67	1.78	-	-	-	-	2.44
Station 7	0.04	5.56	-	-	-	-	5.60
Station 8	9.33	4.44	-	-	-	-	13.78
March 2010							
Station 1	-	1.11	-	-	-	-	1.11
Station 2	-	24.44	-	-	-	-	24.44
Station 3	0.09	5.78	-	-	-	-	5.87
Station 4	0.02	10.67	-	-	-	-	10.69

	Oligochatetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 5	0.02	1.11	-	-	-	-	1.13
Station 6	0.44	4.00	-	-	-	-	4.44
Station 7	0.89	4.00	-	-	-	-	4.89
Station 8	0.11	-	-	-	-	-	0.11
April 2010							
Station 1	-	9.55	-	-	-	-	9.55
Station 2	-	17.78	-	-	-	-	17.78
Station 3	0.067	7.55	-	-	-	-	7.62
Station 4	16.221	3.11	60.66	-	-	-	79.99
Station 5	0.178	4.44	-	-	-	-	4.62
Station 6	0.422	4.89	-	-	-	-	5.31
Station 7	-	5.56	-	-	-	-	5.56
Station 8	19.554	-	-	-	-	-	19.554
May 2010							
Station 1	0.04	10.22	-	-	-	-	10.27
Station 2	-	12.22	-	-	-	-	12.22
Station 3	-	6.67	-	-	-	-	6.67
Station 4	-	3.56	-	-	-	-	3.56
Station 5	-	4.89	-	-	-	-	4.89
Station 6	0.62	0.89	-	-	-	-	1.51
Station 7	1.11	-	-	-	-	-	1.11
Station 8	0.89	-	-	-	-	-	0.89
June 2010							
Station 1	0.02	-	-	-	-	-	0.02
Station 2	15.55	-	-	-	-	-	15.55
Station 3	0.02	16.00	-	-	-	-	16.02
Station 4	10.22	5.11	-	-	-	-	15.33
Station 5	-	7.55	-	-	-	-	7.55
Station 6	0.67	1.33	-	-	-	-	2.00
Station 7	-	-	-	-	-	-	-
Station 8	1.62	-	-	-	-	-	1.62
July 2010							
Station 1	-	2.22	-	-	-	-	2.22
Station 2	33.33	18.22	-	-	-	-	51.55
Station 3	8.00	-	-	-	-	-	8.00
Station 4	0.22	-	-	-	-	-	0.22
Station 5	0.22	14.22	-	-	-	-	14.44
Station 6	0.44	-	-	-	-	-	0.44
Station 7	1.11	-	-	-	-	-	1.11
Station 8	0.16	-	-	-	-	-	0.16
August 2010							
Station 1	0.22	1.78	-	-	-	-	2.00
Station 2	0.44	4.00	-	-	-	-	4.44
Station 3	0.40	11.33	-	-	-	-	11.73

	Oligochatetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 4	2.22	3.56	-	-	-	-	5.78
Station 5	4.00	-	-	-	-	-	4.00
Station 6	0.89	1.33	-	-	-	-	2.22
Station 7	0.09	3.33	-	-	-	-	3.42
Station 8	8.67	8.00	-	-	-	-	16.67
September 2010							
Station 1	35.11	31.33	-	-	-	-	66.44
Station 2	28.00	19.78	-	-	-	-	47.77
Station 3	3.78	1.11	-	-	-	-	4.89
Station 4	1.56	-	-	-	-	-	1.56
Station 5	20.44	5.56	-	-	-	-	26.00
Station 6	6.22	16.00	-	-	-	-	22.22
Station 7	0.67	-	-	-	-	-	0.67
Station 8	2.44	-	-	-	-	-	2.44
October 2010							
Station 1	27.78	2.22	-	-	-	-	30.00
Station 2	0.89	-	-	-	-	-	0.89
Station 3	2.89	-	-	-	-	-	2.89
Station 4	1.56	-	-	-	-	-	1.56
Station 5	-	22.22	-	-	-	-	22.22
Station 6	22.78	-	-	-	-	-	22.78
Station 7	11.55	2.22	-	-	-	-	13.78
Station 8	13.09	-	-	-	-	-	13.09
November 2010							
Station 1	28.89	16.89	-	-	-	-	45.78
Station 2	1.56	4.67	-	-	-	-	6.22
Station 3	101.32	-	-	-	-	-	101.32
Station 4	1.11	54.66	-	-	-	3.88	59.65
Station 5	177.09	-	-	-	-	-	177.09
Station 6	0.27	5.33	-	-	-	-	5.60
Station 7	8.00	4.89	-	-	-	-	12.89
Station 8	3.11	-	-	-	-	-	3.11
December 2010							
Station 1	0.22	4.89	-	-	-	-	5.11
Station 2	6.89	-	-	-	-	-	6.89
Station 3	8.00	-	-	-	-	-	8.00
Station 4	-	7.11	-	-	-	-	7.11
Station 5	0.29	-	-	-	-	-	0.29
Station 6	0.47	-	-	-	-	-	0.47
Station 7	-	-	-	-	-	-	-
Station 8	-	-	-	-	-	-	-
January 2011							
Station 1	16.44	58.22	1334.09	-	-	-	1408.75
Station 2	97.10	32.44	-	-	-	-	129.54

	Oligochatetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 3	4.44	63.33	-	-	-	-	67.77
Station 4	17.33	36.22	-	-	-	-	53.55
Station 5	59.99	128.88	-	-	-	-	188.87
Station 6	-	9.55	-	-	-	-	9.55
Station 7	-	2.22	-	-	-	-	2.22
Station 8	-	3.11	-	-	-	-	3.11
February 2011							
Station 1	0.04	11.33	-	-	-	-	11.38
Station 2	-	28.89	-	3.6	-	-	29.25
Station 3	5.11	1.33	-	-	-	-	6.44
Station 4	20.00	26.22	1920.03	-	-	-	1966.25
Station 5	28.66	11.33	-	-	-	-	40.00
Station 6	69.55	1.11	-	-	5607.22	-	5677.88
Station 7	-	44.44	-	-	-	-	44.44
Station 8	-	2.44	-	-	-	-	2.44
March 2011							
Station 1	-	42.44	-	-	-	-	42.44
Station 2	6.00	5.78	-	-	-	-	11.78
Station 3	4.67	3.33	-	-	-	-	8.00
Station 4	16.67	10.00	-	-	-	-	26.66
Station 5	39.33	19.78	-	-	-	-	59.11
Station 6	8.44	2.00	2523.30	-	-	-	2533.75
Station 7	6.00	3.11	-	-	-	-	9.11
Station 8	-	-	-	-	-	-	-
April 2011							
Station 1	0.44	20.44	-	-	-	-	20.89
Station 2	74.66	-	-	-	-	-	74.66
Station 3	-	6.22	-	-	-	-	6.22
Station 4	8.22	4.22	-	-	-	-	12.44
Station 5	-	16.00	-	-	-	-	16.00
Station 6	0.67	5.56	-	-	-	-	6.22
Station 7	-	6.22	-	-	-	-	10.00
Station 8	-	-	-	-	-	-	-
May 2011							
Station 1	0.67	42.44	-	-	-	-	43.11
Station 2	18.00	5.78	-	-	-	-	23.78
Station 3	-	3.33	-	-	-	-	3.33
Station 4	96.41	10.00	-	-	-	-	106.41
Station 5	65.99	19.78	6066.73	-	-	-	6152.50
Station 6	2.00	-	-	-	-	-	2.00
Station 7	6	3.11	-	-	-	-	9.11
Station 8	-	10.00	-	-	-	-	10.00
June 2011							
Station 1	-	-	-	-	-	-	-

	Oligochatetes	Insects	Molluscs	Crustaceans	Pisces	Hirudinae	Total
Station 2	-	-	-	-	-	-	-
Station 3	28.44	-	-	-	-	-	28.44
Station 4	15.44	-	-	-	-	-	15.44
Station 5	-	0.22	-	-	-	-	0.22
Station 6	3.9	-	-	-	-	-	3.9
Station 7	0.02	1.11	-	-	-	-	1.13
Station 8	0.05	4.89	-	-	-	-	4.94
July 2011							
Station 1	-	0.2222	-	-	-	-	0.2222
Station 2	0.7777	-	-	-	-	-	0.7777
Station 3	0.2222	-	-	-	-	-	0.2222
Station 4	-	31.108	-	-	-	-	31.108
Station 5	7.86588	3.9996	-	-	-	-	11.86548
Station 6	5.555	14.443	-	-	-	-	69.998
Station 7	3.9996	7.3326	-	-	-	-	11.3322
Station 8	-	5.555	-	-	-	-	5.555
August 2011							
Station 1	0.04	-	-	-	-	-	0.04
Station 2	0.47	-	-	-	-	-	0.47
Station 3	0.89	-	-	-	-	-	0.89
Station 4	4.00	2.00	-	-	-	-	6.00
Station 5	-	6.67	-	-	-	-	6.67
Station 6	-	-	-	-	-	-	7.11
Station 7	1.27	4.00	-	-	-	-	5.27
Station 8	0.44	27.78	-	-	-	-	28.22
September 2011							
Station 1	17.55	-	-	-	-	-	17.55
Station 2	-	-	-	-	-	-	-
Station 3	6.00	-	-	-	-	-	6.00
Station 4	1.33	-	-	-	-	-	1.33
Station 5	-	-	-	-	-	-	-
Station 6	4.67	-	-	-	-	-	4.67
Station 7	-	3.11	-	-	-	-	3.11
Station 8	10.00	3.33	-	-	-	-	13.33
October 2011							
Station 1	0.04	2.67	-	-	-	-	2.71
Station 2	0.24	-	-	-	-	-	0.24
Station 3	0.44	-	-	-	-	-	0.44
Station 4	0.89	-	-	-	-	-	0.89
Station 5	4.89	-	-	-	-	-	4.89
Station 6	6.44	-	-	-	-	-	6.44
Station 7	7.78	3.33	-	0.70	-	-	11.81
Station 8	5.33	16.00	-	-	-	-	21.33

Annexure 3. Numerical abundance of oligochaete species (ind./m^2) in Maranchery Kole wetlands during the study period

Station 1

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	67	-	-	-	-	-	-
Nais pardalis	-	22	-	-	-	-	-	-
Allonais inaequalis	-	22	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	22	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	22	-	-	-	-	-
Haemonais waldvogeli	-	-	89	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	22	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	22	-	-	-	-	44	-
Aulodrilus sp.	44	-	-	44	-	-	-	44
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	22	-	-	-	-	-

Station 1

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	22	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	67	22	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	22	222	22	-	-	-
Haemonais waldvogeli	-	22	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	22
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	22	-	-	-	-	-	-
Aulodrilus sp.	-	22	-	-	44	67	-	-
Haemonais sp.	-	-	-	-	-	-	22	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 1

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	89	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	44	-	-	-	156	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	44	-	-	-	-	-	-
Aulodrilus sp.	-	-	-	-	-	-	-	67
Haemonais sp.	-	22	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	222	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 2

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	289	-	-	-	-	-	-
Pristinella menoni	-	1422	-	-	-	-	-	-
Aulophorus hymnae	-	22	-	-	-	-	-	-
Pristinella jenkinae	22	244	-	-	-	-	-	-
Allonais gwaliiorensis	-	44	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	44	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	-	-	-	-	44
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	89	-	-	-	-	-
Aulodrilus sp.	-	-	22	22	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	44	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 2

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	89	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	22	-	-	-	44	-
Branchiodrilus semperi	111	-	-	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	67	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	22	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	67	-	-	89	44	-
Aulodrilus sp.	-	89	22	-	22	-	22	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 2

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	67	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	133	-	-	-
Aulophorus hymnae	-	-	-	-	44	-	-	-
Pristinella jenkinae	-	44	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	44
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	89	-	-	178
Branchiodrilus semperi	-	22	-	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	22	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	-	-	133	-	-
Aulodrilus sp.	133	-	22	-	-	89	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 3

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	67	-	-	-	-	-	-
Pristinella menoni	44	44	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	67	-	-	22	-	-	-
Allonais gwaliiorensis	44	89	-	-	-	22	-	-
Dero dorsalis	-	44	-	-	-	44	-	-
Aulodrilus pigueti	67	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	22	-	89	-	89	-	-
Aulodrilus sp.	-	-	-	-	22	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	22
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 3

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	89	-	22	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	22	-	-	-
Branchiodrilus semperi	2--	67	-	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	22
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	89	22	1844	378	-	289	22	-
Aulodrilus sp.	-	-	67	67	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 3

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	44	-	22
Pristinella menoni	-	-	-	-	-	-	244	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	178	-	-
Allonais gwaliiorensis	-	-	-	-	-	89	-	-
Dero dorsalis	-	-	-	-	-	44	22	-
Aulodrilus pigueti	22	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	-	-	-	-	44
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	133
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	22	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	44	-	-	22	400	-	-	-
Aulodrilus sp.	-	-	-	-	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	22	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 4

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	67	-	-	-	22	44	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	44	-	-	89	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	22	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	89
Branchiodrilus semperi	-	-	22	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	22	-	-	-	-
Aulophorus furcatus	-	-	-	44	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	133	-	-	-	222
Aulodrilus sp.	-	-	-	-	-	111	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 4

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	133	-	-	-	22
Pristinella menoni	-	-	-	-	-	-	511	-
Aulophorus hymnae	-	-	-	444	44	-	-	-
Pristinella jenkinae	156	-	-	156	-	-	67	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	44	22
Branchiodrilus semperi	-	89	-	-	-	-	-	67
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	22	-	-	-	-	22
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	178	-	-	133	-	133	333
Aulodrilus sp.	-	-	-	133	-	-	44	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	22
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 4

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	44	444	-	-	-	-	-
Pristinella menoni	-	44	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	111	67	444	-	-	-	-	-
Allonais gwaliiorensis	-	-	489	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	22	-	-	-	-	22
Branchiodrilus semperi	267	-	489	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	111	-	222	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	44	-	-	-	-	-
Aulodrilus pluriseta	-	89	1778	-	-	244	-	133
Aulodrilus sp.	-	-	178	-	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	267	-	-	-	89	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	156	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 5

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	44	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	67	-	-	-	22	-	-	-
Pristinella menoni	-	-	-	-	-	44	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	89	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	22	-	-	-	-
Aulodrilus pigueti	-	44	-	-	-	-	-	89
Branchiodrilus semperi	-	-	22	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	22	-	22	-	-	-	-
Aulophorus furcatus	-	-	-	44	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	133	-	-	-	222
Aulodrilus sp.	-	-	-	-	-	111	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 5

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	133	-	-	-	-
Pristinella menoni	-	-	-	444	44	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	156	-	-	156	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	89	-	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	22	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	178	-	-	133	289	311	22
Aulodrilus sp.	-	-	-	133	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 5

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	22	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	44	-	-	67	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	22	-	222	-	-	-	-	22
Branchiodrilus semperi	44	-	44	-	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	22	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	22	-	1822	-	311	244	-	133
Aulodrilus sp.	-	-	-	-	22	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	89
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 6

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	-
Pristinella menoni	-	89	311	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	244	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	22	-	22	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	244	-	-	44	-	-
Aulodrilus sp.	44	22	-	67	111	-	-	133
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 6

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	22	-	-	-	-
Pristinella minuta	-	111	-	-	-	267	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	44	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	89	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	89	-	-	889	-	-	-	-
Aulodrilus sp.	200	-	-	-	-	-	-	44
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	89	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 6

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	67	22	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	44	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	44	-	-	311	133	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	1044	-	-	-	-	-	-	-
Aulodrilus sp.	-	-	-	-	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 7

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	44	-	111	-
Pristinella menoni	-	-	44	-	-	111	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	178	-
Allonais gwaliiorensis	-	-	22	-	67	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	-	44	156	-	-
Haemonais waldvogeli	-	-	-	-	-	-	22	-
Stephensoniana trivandrana	-	-	-	-	-	133	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	67	-
Dero digitata	-	-	111	-	-	-	-	-
Aulophorus carteri	-	-	178	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	22	-	-	1333	-
Aulodrilus sp.	-	-	244	-	-	-	200	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 7

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	22	222	-	-	-	-	-	-
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	200	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	156	133	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	133	-	222	-	-	-
Branchiodrilus hortensis	-	-	-	-	44	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	378	22	-	-	-	-
Aulodrilus sp.	-	-	-	-	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	156	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

station 7

Station 8

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	22	-	-
Pristinella menoni	67	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	67	-	-	-	-	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	67	-	-	-	44	-	-	44
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	222	-	-	-
Branchiodrilus hortensis	22	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	-	-	156	-	133
Aulodrilus sp.	-	-	-	-	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	22	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	22	-	-	-	-	-	-

Station 8

Species	Months							
	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	22	67	-	-	-	-
Pristinella menoni	-	156	156	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	67	-	-	222	-
Allonais gwaliiorensis	-	-	111	-	111	-	-	-
Dero dorsalis	-	-	-	-	-	44	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	44	44	-	156	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	67	67	-	-	-	133	89
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	222	133	22	-	-	244	-	200
Aulodrilus sp.	89	-	-	111	-	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 8

Species	Months							
	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	-
Pristinella menoni	-	-	-	222	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	-	-	-	67
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	22	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	22	67	-	-	-	-
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	89	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	267	333	-	-	-	-	44
Aulodrilus sp.	-	67	133	133	133	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	156	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-

Station 8

Species	Months							
	Mar '11	Apr '11	May '11	Jun '11	Jul '11	Aug '11	Sep '11	Oct '11
Pristina breviseta	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Allonais inaequalis	-	-	-	-	-	-	-	-
Pristinella minuta	-	-	-	-	-	-	-	22
Pristinella menoni	-	-	-	-	-	-	-	-
Aulophorus hymnae	-	-	-	-	-	-	-	-
Pristinella jenkinae	-	-	-	-	22	-	-	-
Allonais gwaliiorensis	-	-	-	-	-	-	-	-
Dero dorsalis	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Branchiodrilus semperi	-	-	-	-	-	-	-	22
Haemonais waldvogeli	-	-	-	-	-	-	-	-
Stephensoniana trivandrana	-	-	-	-	-	-	-	-
Branchiodrilus hortensis	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-
Aulophorus carteri	-	-	-	-	-	-	-	-
Lumbriculus variegates	-	-	-	-	-	-	-	-
Aulophorus furcatus	-	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-	-
Dero zeylanica	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	1133	-	-	-	133	-
Aulodrilus sp.	-	-	-	-	89	-	-	-
Haemonais sp.	-	-	-	-	-	-	-	-
Pristinella acuminata	-	-	-	-	-	-	-	-
Nais andhrensis	-	-	-	-	-	-	-	-
Allonais paraguayensis paraguayensis	-	-	-	-	-	-	-	-
Dero nivea	-	-	-	-	-	-	-	-