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Observations on the occurrence and diversity of zooplankton in the surface water of three tropical ponds at Thiruparankundram near Madurai, Tamilnadu, India

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Abstract
The occurrence and diversity of zooplankton in three freshwater temple ponds at Thiruparankundram near Madurai as observed for a period of three years from September 2009 to August 2012 are reported. A total of 17 zooplankton species were encountered in the three temple ponds and were composed of rotifera (8), cladocera (4), copepoda (4) and ostracoda (1). However, only 11 species such as *Brachionus calyciflorus, Brachionus angularis, Brachionus quadridentata, Brachionus diversicornis, Brachionus plicatilis, Alona rectangula rectangula, Moina brachiata, Moina micrura Mesocyclops thermocyclopoides*, *Mesocyclops aspericornis,* and *Stenocypris major* were observed in all the temple ponds. The variation in the occurrence and diversity of zooplankton was found to be influenced by the seasonal changes and altitudinal variations.

Keywords: Zooplankton occurrence, Diversity, Altitudinal variation, Temple ponds.

1. Introduction
Biodiversity is also considered to mean the variability among the living organisms from all sources including terrestrial, marine and other aquatic ecosystem and ecological complex of which they are part [1]. Information on species diversity, richness, evenness and dominance evaluation on the biological components of the ecosystem is essential to understand detrimental changes in environs [2]. The zooplankton in Indian water bodies consists of diverse assemblage of major taxonomic groups. Many of these forms have different environmental and physiological assemblage. The number, type and distribution of these organisms present in any aquatic habitat provide a clue on the environmental condition prevailing in that particular habitat. It is seen that many environmental factors interact to provide conditions for the growth of zooplankton both spatially and seasonally [3]. The objective of the study is the observation of the occurrence and seasonal changes in the diversity of zooplankton in the surface water of the three ponds that are located at different altitudes with the focus on the effect of human interference on the observations for a period of three years from September 2009 to August 2012 in the three tropical temple ponds in Thiruparankundram near Madurai in the state of Tamilnadu, India.

2. Study Area
Thiruparankundram, is a town located about six kilometers south-east of Madurai in the state of Tamilnadu, India. It is a historical holy place known for the famous temple of Lord Subramanya situated at the base of the hillock and has a heavy inflow of pilgrims regularly for worship from all over the state and tourists from other states of India and abroad. There are three ponds associated with this temple, one on the top of the hillock named Kasi theertham, the second one within the temple, Lakshmi theertham and the third one outside the temple, Saravana poigai. Geographically, these ponds are associated with a hillock located at 9°54'N; 78°7'E from the base at 131MSL measuring a total height of 1056 feet. All the three ponds receive rain water that drains from hillock and forms the only source of water for these ponds. The ponds are used by pilgrims for bathing, washing and some recreational activities. Interestingly, these three ponds which are at the same geographical location and fed by rain water during the monsoon showers differ in their size, altitude and human impact. This provides a unique opportunity to study their influence on occurrence of zooplankton diversity in these ponds.

3. Materials and Methods

Zooplankton samples were collected every month and were analyzed quantitatively in order to assess the diversity during the study period. The plankton concentrate was obtained by filtering 100 liters of surface water through a standard zooplankton net. The collected samples were washed into a sample jar with one litre water, filtered again through a 40 µm Nitex and preserved again in the laboratory in 4% formaldehyde solution which is commonly practiced. The preserved zooplankton samples were kept stored at low temperature, below 20°C until analysis [4]. Identification of the zooplankton in the respective samples was done separately with the help of the available standard reference materials [4, 5, 6]. Enumeration of zooplankton is usually done in gridded trays to prevent duplication of counts [7]. In the present study, a high quality compound microscope (Olympus) was used for this quantification and the quantitative analysis of zooplankton was done by using Sedgwick-Rafter cell. The enumeration was repeated for 3 times and the total number of respective zooplankton species was taken by averaging all the counts rounded off the nearest whole number. The percentage composition of zooplankton species in three temple pond during the entire study period of three years are represented in fig.1-3.

Diversity indices enable the understanding of both species abundance and their relationship in their communities in nature. These are mathematical expressions describing the basic components of the community structure such as Species Richness (Total number of species), Species Evenness (Uniformity in distribution among species) and Species Abundance (Relative number of organisms of a species in the community). These indices also reveal the responses of the organisms in the community towards the quality of its environment. Over the years, number of indices has been proposed for characterizing species richness and evenness. They are termed as richness indices and evenness indices respectively. The indices that combine both these richness and evenness into a single value are called diversity indices. The most common indices used in ecological studies are Margalef's index-R_1.; Mechinick's index-R_2 (Richness indices), Simpon's index-λ ; Shannon-Weiner index-H'; Hill's index 1-N_1 ; Hill's index 2-N_2 (Diversity indices), Pielou index-E_1; Sheldon index- E_2; Heip index-E_3 ; Hill index-E_4, Alatato index-E_5 (Evenness indices) and which were worked out with the help of the software 'SPDIVERS BAS' package in a computer [8].

4. Results and Discussion

Occurrence of zooplankton species is of great significance in freshwater habitats. The abundance and diversity of zooplankton vary according to limnological features and the trophic status of freshwater bodies [9]. A total number of 42 species (23 species of Rotifers, 15 species of Branchiopods, 3 species of Copepods and 1 species of Ostrachopods) of zooplanktons belonging to 19 genera, 12 families, 7 orders and 4 classes were recorded in Sultanpur National Park, Gurgaon, India [10]. In the present study, a total of 17 zooplankton species were encountered in the three temple ponds during the study period with their taxonomical distribution as rotifer (8), cladocera (4), copepoda (4) and ostracoda (1). The maximum number of 17 species was recorded in Saravana poigai, while, in Lakshmi theertham and Kasi theertham the number of species recorded were only 16 and 11 respectively. Of the 17 species, *Brachionus calyciflorus, Brachionus angularis, Brachionus quadridentata, Brachionus diversicornis, Brachionus plicatilis, Alona rectangula rectangula, Moina brachiata, Moina micrura Mesocyclops thermocyclopoides*, *Mesocyclops aspericornis,* and *Stenocypris major* were observed in all the three ponds. The seasonal abundance of zooplankton observed during the entire period of three years was as post-monsoon (1101) > monsoon (723) > pre-monsoon (457) in Kasi theertham; post-monsoon (1557) > pre-monsoon (1377) > monsoon (838) in Lakshmi theertham and as post-monsoon (1840) > pre-monsoon (1327) > monsoon (894) in Saravana poigai, The observations reveled that higher number of zooplankton were registered only during post-monsoon season in all the three ponds. The dominance hierarchy of various zooplankton groups was as copepoda > cladocera > rotifera > ostracoda in Kasi theertham (monsoon and pre-monsoon season) and Lakshmi theertham (pre-monsoon season); as cladocera > copepoda > rotifera > ostracoda in Lakshmi theertham (monsoon) and Kasi theertham (post-monsoon); as rotifera > copepoda > cladocera > ostracoda in Saravana poigai (monsoon) and Lakshmi theertham (post-monsoon); as copepoda > rotifera > cladocera > ostracoda in Lakshmi theertham (post-monsoon) and as rotifera > copepoda > cladocera > ostracoda in Saravana poigai (monsoon, post-monsoon and pre-monsoon). The overall percentage composition of the zooplankton species that occurred during the entire study period of three years in the three temple ponds revealed that in Kasi theertham, the copepoda were the most abundant of the four zooplankton groups comprising 47% of the total number of organisms, followed by the cladocera and rotifera at 45% and 7% respectively. In Lakshmi theertham, the cladocera was the most abundant of the four zooplankton groups comprising 42% of the total number of organisms, followed by the copepoda and rotifera at 29% and 28% respectively. In Saravana poigai, the rotifera were the most abundant of the four zooplankton groups comprising 49% of the total number of organisms, followed by the copepoda and cladocera at 28% and 22% respectively. The ostracoda was the least abundant species with about 1% in all the three ponds. These variations in the percentage of individuals may be due to the altitudinal difference in the locations of the pond (Fig.1). Biodiversity studies have been achieving tremendous importance in present day research, where collection of base line data related to flora and fauna is important. Species diversity is a basic measure of community structure and organization forming the most important parameter to understand the health status of the ecosystem. The diversity indices give a measure of the way in which the individuals in the community are distributed [11]. During the present study, in Kasi theertham, the Margalef index for species richness was low (1.84 to 2.01) in the monsoon seasons and high (2.27 to 2.50) in pre-monsoon seasons. But, the values of another richness index, the Menhinick index was lesser (1.05) in post-monsoon and higher (1.62) in pre-monsoon season. In Lakshmi theertham, the Margalef index for species richness was high (3.20 to 3.86) in the monsoon seasons and low (3.06 to 3.18) in pre-monsoon seasons. But, the values of another richness index, the Menhinick index was lesser (1.13) in post-monsoon and higher (1.86) in monsoon season. In Saravana poigai, the Margalef index for species richness was low (3.04 to 3.11) in the post-monsoon seasons and high (3.15 to 3.52) in monsoon seasons. But, the values of another richness index, the Menhinick index was lesser (1.28 to 1.37) in post-monsoon and higher (1.69 to 1.90) in monsoon season. The species richness was observed to show significant seasonal variations in Lotus Lake at Maharashtra, India [12]. Its maximum species

richness occurred in summer (5.75/l) and minimum in post-monsoon (4.08/l) while it was (4.58/l) and (5.41/l) in the winter and monsoon respectively. Evenness is the relative abundance with which each species is represented in an area.

Evenness indices indicate whether all species in a community are equally abundant and when it is so evenness indices should be more and decrease towards zero as the relative abundance of the species diverges away from evenness. The values for these indices will be high where all the species are represented by the same number of individuals has high species evenness. In the present study, in Kasi theertham, The mean value of evenness indices ranged between (0.84 to 0.86) in monsoon; (0.87 to 0.89) in post-monsoon and (0.90 to 0.92) in pre-monsoon for E1; (0.71 to 0.75) in monsoon; (0.75-0.77) in post-monsoon and (0.79 to 0.85) in pre-monsoon for E2; (0.67) in monsoon; (0.73 to 0.75) in post-monsoon and (0.77 to 0.83) in pre-monsoon for E3; (0.93 to 1.00) in monsoon ; (0.88 to 0.89) in post-monsoon; (1.00 to 1.09) in pre-monsoon for E4 and finally between (0.93 to 1.00) in monsoon; (0.87 to 0.88) in post-monsoon and (1.00 to 1.09) in pre-monsoon for E5 respectively (Fig.2a-c). In Lakshmi theertham, The mean value of evenness indices ranged between (0.91 to 0.93) in monsoon; (0.90 to 0.91) in post-monsoon; (0.90 to 0.93) in pre-monsoon for E1; (0.80 to 0.82) in monsoon; (0.76 to 0.78) in post-monsoon; (0.77 to 0.82) in pre-monsoon season for E2; (0.78 to 0.81) in monsoon; (0.74 to 0.77) in post-monsoon 10 and; (0.76 to 0.80) in pre-monsoon season for E3; (0.97 to 1.02) in monsoon; (0.89 to 0.92) in post-monsoon; (0.92 to 0.97) in pre-monsoon for E4 and finally between (0.97 to 0.98) in monsoon; (0.88 to 0.92) in post-monsoon and (0.92 to 0.97) in pre-monsoon for E5 respectively (Fig.3a-c). In Saravana poigai, The mean value of evenness indices ranged between (0.91 to 0.92) in monsoon; (0.94 to 0.96) in post-monsoon and (0.94 to 0.95) in pre-monsoon for E1; (0.78 to 0.82) in monsoon; (0.84-0.89) in post-monsoon and (0.85 to 0.88) in pre-monsoon for E2; (0.76 to 0.80) in monsoon; (0.84 to 0.88) in post-monsoon and (0.84 to 0.87) in pre-monsoon for E3; (0.95 to 1.01) in monsoon; (0.96 to 1.02) in post-monsoon; (0.99 to 1.03) in pre-monsoon for E4 and finally between (0.95 to 1.01) in monsoon; (0.96 to 1.03) in post-monsoon and (0.99 to 1.04) in pre-monsoon for E5 respectively (Fig.4a-c). It is observed that in the freshwater habitats the ecological type of macrophytes often serves as a nutritional source for their inhabiting organisms [13]. Accordingly, the evenness was observed to be relatively high during the rainy season indicating a reduction in the plankton diversity [14]. Similar observations were made in Kottakudi and Nari Backwaters, South East of Tamilnadu [15]. The mean values of the evenness index to range between E1 from 0.85 to 0.95 and E2 from 0.75 to 0.88 at Chinnappar kovil pond, E1 from 0.88 to 0.96 and E2 from 0.53 to 0.88 at Nallanchettipatti and E1 from 0.47 to 0.78 and E2 from 0.44 to 0.76 at Kadabamkulam pond in this region [16]. The evenness indices E1 to E5 from 0.73 to 1.63 in a seasonal tropical pond in Sivakasi were recorded [17]. The highest evenness during January and February being 0.99 in both the months while the richness being 3.28, 3.22 and 3.07 in the months of December, January and February respectively in Jamunabundh perennial pond located at Bishnupur was reported [18].

The species diversity is the number of different species on a particular area (species richness) weighed by some measure of abundance such as number of individuals or biomass. The zooplankton Shannon diversity index if it is less than one, then it shows poor diversity. The diversity index is a measure of biodiversity which quantifies how equal the populations are numerically. The values range between 0-1. The less is the variation in populations between species, the higher evenness there will be. When there is poly-modal pattern of monthly fluctuation, variation among the values will be less. Higher values were found during warmer months with the peak occurring during April 2003 (1.297) and June 2003 (1.057). Such a peak of abundance was also during winter season *i.e.,* during December 2003 (0.945) in a freshwater body of Aligarh region in Uttar Pradesh [19]. The overall zooplankton diversity index is between 0.61 and 0.76, reported in Safilguda tank, indicates less diversity of planktonic community in the tank, and also it has been evidenced with Simpson diversity index was from 0.26 to 0.18 [20]. In the present study the diversity indices worked out revealed similar trends. For example, in Kasi theertham, low value of Simpson's index (0.13 to 0.15) in post-monsoon and high values (0.11 to 2.28) in pre-monsoon are recorded. The Shannon's index value was low (1.75 to 1.88) in monsoon and high (1.99 to 2.11) in post-monsoon. N1 ranged from 0.1 to 0.21 and N2 value ranged from 4.68 to 9.79 in tropical pond at Sivakasi [17]. Hill's index 1 was low (5.79 to 6.57) in monsoon and high (7.40 to 8.32) in post-monsoon. Hill's index 2 was low (5.52 to 6.95) in monsoon and high (8.29 to 8.74) pre-monsoon. In Lakshmi theertham, low values of Simpson's index (4.65 to 7.00) were noticed in post-monsoon and high values (7.99 to 8.90) were recorded in pre-monsoon. The Shannon index values were low (2.45 to 2.46) in monsoon and high (2.44 to 2.51) in pre-monsoon season. Hill's index 1 was low (5.79) in monsoon and high (8.32) in post-monsoon. Hill's index 2 was low (11.57 to 12.06) in post-monsoon and high (11.97 to 12.92) in pre-monsoon. In Saravana poigai, the low value of Simpson's index (4.68 to 7.10) was in pre-monsoon and high value (6.72 to 7.98) was in monsoon. The Shannon index values were low (2.42 to 2.53) in monsoon and high (2.64 to 2.69) in post-monsoon. Hill's index 1 was low (11.32 to 12.69) in monsoon and high (13.99 to 14.73) in post-monsoon. Hill's index 2 was low (10.88 to 12.87) in monsoon and high (14.06 to 15.16) pre-monsoon. The Simpson's index for the zooplankton recorded to range from 0-1 in a tropical pond in Sivakasi [17]. The biodiversity of zooplanktons was higher during monsoon and winter season while minimum values were recorded during the summer period. It was considered that the ascended values of zooplanktons diversity during rainy season may be attributed to inflow of waste water while its increased values during the summer period may be due to accumulation of organic wastes and reduced fish predation in the pond. Further, in the present study, reduction in the number of genera noticed in Kasi theertham might be due to fewer nutrients in the high altitude pond which consequently result in less productivity or due to the depletion of important physical, chemical and nutrient factors. The high biodiversity of zooplankton with presence of pollution indicators in the present study revealed that the ponds have been experiencing organic enrichment and may slowly progress towards degradation. The local people and pilgrims who use these ponds for bathing and washing seem to add much of the allothonous input in to these ponds. The Saravana poigai which is located at the base of the hillock in the vicinity of the human settlement is fast deteriorating. The Lakshmi theertham that is located inside the temple premises seem to get moderate impact while the Kasi theertham that is almost at the top of the hillock is the least affected by pollution. This was revealed by the quantity of nutrient chemicals added to these ponds during the period of this study.

Moreover the seasonal changes observed in the zooplankton occurrence and diversity in these ponds show that the monsoon has great influence on the occurrence. Creation of general awareness among the pilgrims is required for proper conservation of these historical perennial freshwater bodies, which support a rich biodiversity of flora and fauna.

5. Acknowledgement
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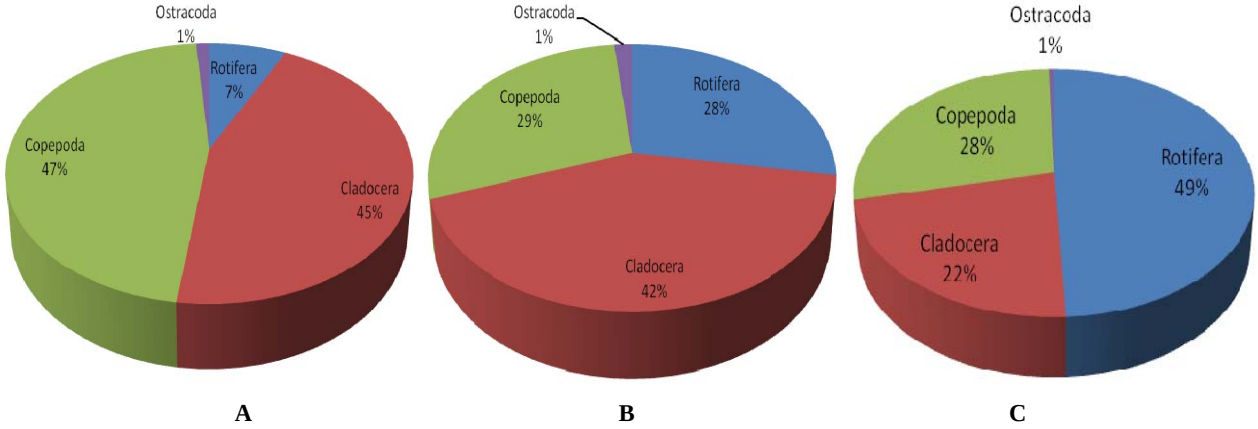

Fig 1: Percentage composition of zooplankton species observed in the three temple ponds, Kasi theertham (A), Lakshmi theertham (B) and Saravanpoigai (C) during the entire study period of three years.

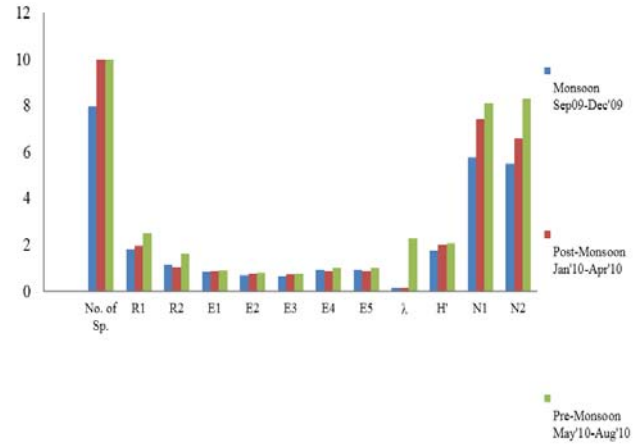

Fig 2a: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Kasi theertham during the year 2009-2010

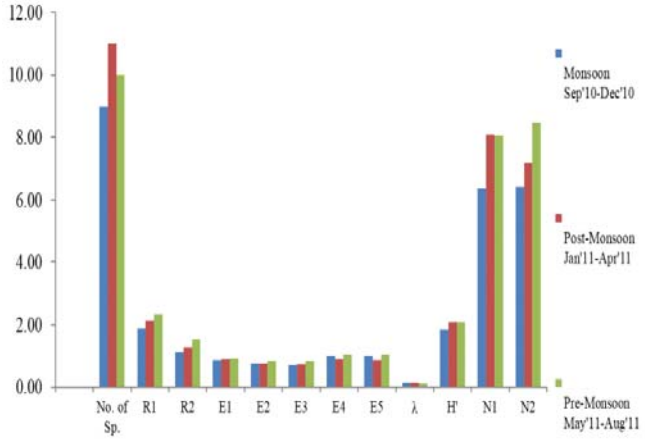

Fig 2b: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Kasi theertham during the year 2010-2011

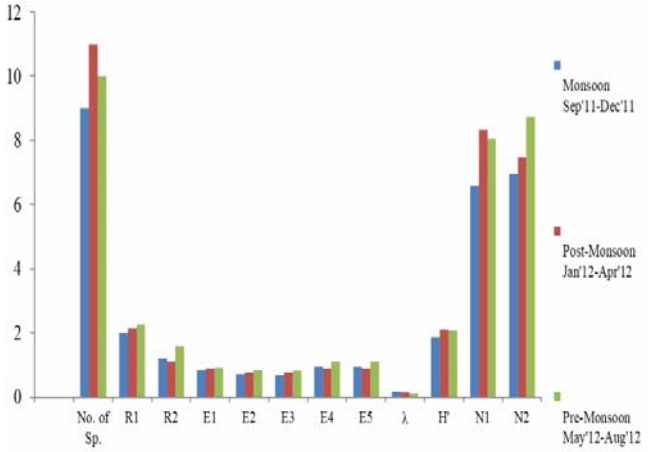

Fig 2c: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Kasi theertham during the year 2011-2012

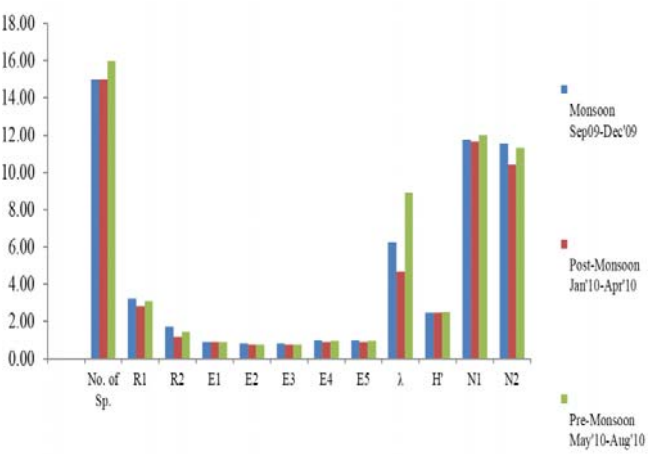

Fig 3a: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Lakshmi theertham during the year 2009-2010

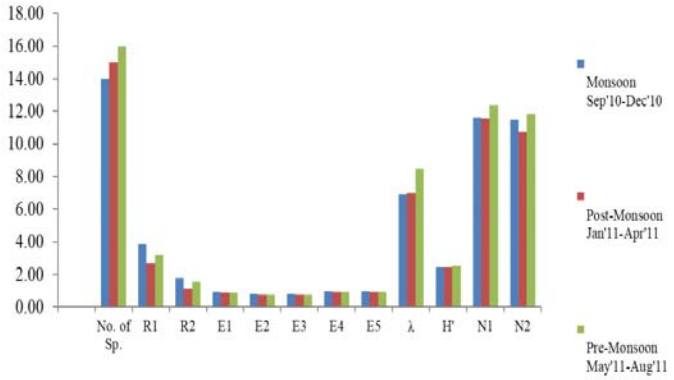

Fig 3b: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Lakshmi theertham during the year 2010-2011

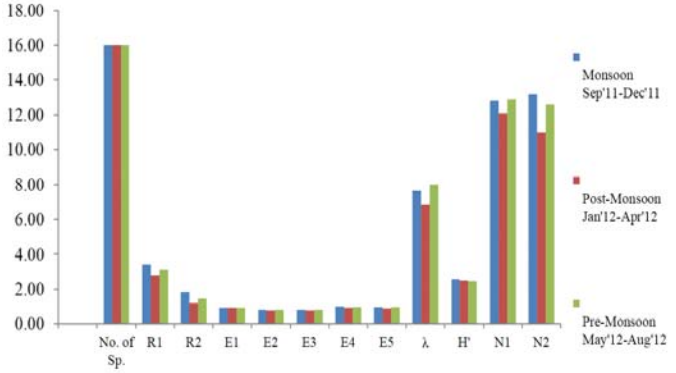

Fig 3c: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Lakshmi theertham during the year 2011-2012

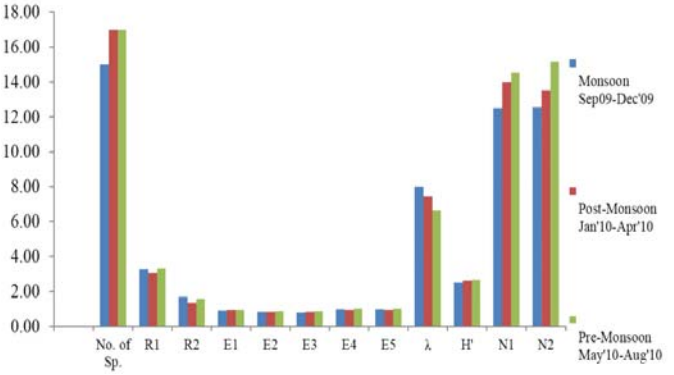

Fig 4a: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Saravana poigai during the year 2009-2010

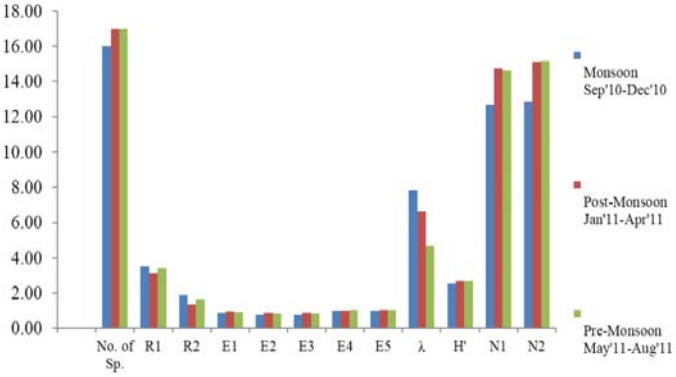

Fig 4b: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Saravana poigai during the year 2010-2011

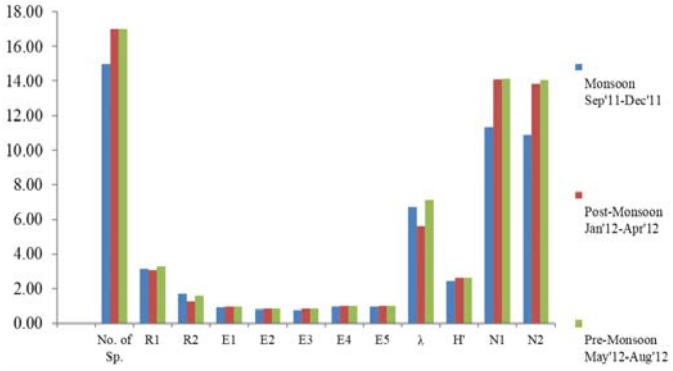

Fig. 4c: Zooplankton Diversity indices, Evenness and Richness of the surface water of the pond, Saravana poigai during the year 2011-2012

R1 -Margalef index, R2-Menhinick index, E1-Pielou evenness index, E2-Sheldon evenness index, E3-Heip evenness index, E4-Hill evenness index, E5-Alatato evenness index, λ-Simpson's index, H'-Shannon's index, N1- Hill's index 1, N2- Hill's index 2.

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