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D. Manoharan
TVS Lakshmi School, Madurai, Tamil Nadu, India, 625020.

L. Isaiarasu
PG and Research Dept. of Zoology, Ayya Nadar Janaki Ammal College, Sivakasi, Tamil Nadu, India.

R. Sureshkumar
PG and Research Department of Zoology, Raja Doraisingam Govt. Arts College, Sivagangai, Tamil Nadu, India.

Correspondence:
R. Sureshkumar
PG and Research Department of Zoology, Raja Doraisingam Govt. Arts College, Sivagangai, Tamil Nadu, India.

Cluster analysis of physical, chemical and nutrient parameters of three freshwater temple ponds at Thirupparankundram near Madurai, Tamil Nadu, India

D. Manoharan, L. Isaiarasu and R. Sureshkumar

Abstract
In the present investigation, the physical, chemical and nutrient parameters of three freshwater temple ponds at Thirupparankundram, Madurai. Tamil Nadu, India was studied. The observations were made on the monthly changes in 15 surface water parameters for a period of three years from September 2009 to August 2012. Most of the parameters were within the permissible limits. The physical, chemical and nutrient parameters also seem to show a clear clustering among the various parameters. This relationship was found to be influenced by the seasonal changes and altitudinal variations.

Keywords: Physical, chemical and nutrient parameters, Cluster analysis, Seasonal changes and altitudinal variation, Temple ponds.

1. Introduction
Water is the principal need of life on earth, the requirement of water in all lives, from microorganism to man is a serious problem today because all water resources have reached a point of crises due to unplanned urbanization and industrialization [12]. Freshwaters of the world are collectively experiencing markedly accelerating rates of qualitative and quantitative degradation [4]. The physico-chemical characteristics of the aquatic environment directly influence the life inhabiting it. Fluctuations in physical, chemical and nutrient constituents often create an adverse environment to organisms, limiting their growth and interfering with the physiological processes, which reduce their ability to compete with other populations within the environment, ultimately changing the community structure [8]. The specific objective of the study is the observation of the seasonal changes in the physical, chemical and nutrient parameters in the surface waters of the three ponds that are located at different altitudes with the focus on the effect of human interference on their water quality and identifying the clustering among them based on the observations for a period of three years from September 2009 to August 2012.

2. Study area
Thirupparankundram, is a town located about six kilometers south-east of Madurai. 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 namely 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 which drains out from hillock and this is the only source of water in these ponds. The ponds are used for various human (including pilgrims) activities such as, 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 the physical, chemical and nutritional parameters of the ponds.

3. Materials and methods

Sampling of water was done for every month and analyzed on the day of sampling. Samples were collected between 6 am and 8 am on all day with the view of ensuring uniformity. The water samples were transported to the laboratory and analyzed for various physical, chemical and nutrient parameters following standard methods [1, 9, 13, 14] The month wise analysis of the rainfall data for this region enabled the recognition of three distinct seasons for the interpretation of the observations in the present study as Monsoon (September-December), Post-monsoon (January-April) and Pre-monsoon (May-August).

4. Cluster Analysis

Cluster analysis is useful to classify the variables into groups. It is a method for combining similar objects into groups or cluster, which are displayed in a tree-like diagram, called dendrogram. A dendrogram represents the amalgamation (grouping) of variables into clusters. Cluster analysis is used commonly by biologists and appears to be a handy tool in determining important factors that control biological activity in pond waters. Each cluster consists of all the objects having the similar property where the property is formulated using the attributes and values of the given many-valued context. Subsets described in this form occur as extents and contingents of formal contexts derived from many-valued contexts by conceptual scaling [5]. In the present study the cluster analysis by using algorithm single linkage, Bray-Curtis similarity measure was applied to test the similarity between physical, chemical and nutrient parameters and this was done by using the software PAST in a computer.

5. Result and Discussion

Cluster analysis of physical, chemical and nutrient parameters in Kasi theertham during monsoon season, in an algorithm single linkage with the Bray–Curtis similarity measure revealed a first group of cluster between air and water temperature. The second group of clusters involved alkalinity, calcium hardness and salinity; pH, free CO_2 and nitrate; dissolved oxygen, chlorides and sulphate.

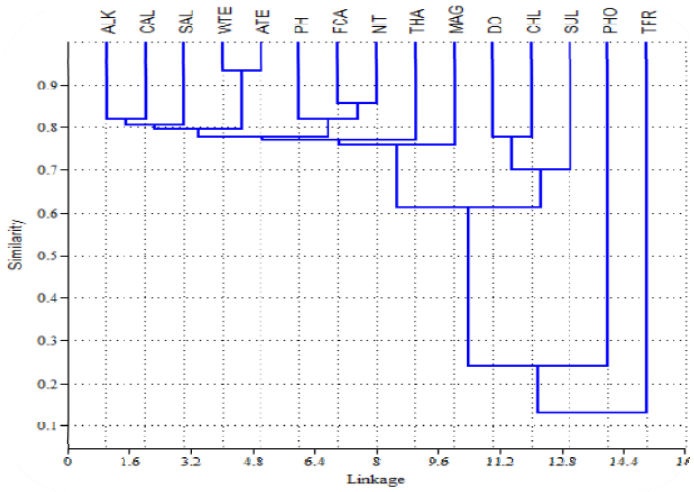

Fig 1: Cluster analysis of physical, chemical and nutrient parameters in Kasi theertham during monsoon by Bray–Curtis similarity index (single linkage method).

Third group of clusters was shown by total harness and magnesium hardness. During the post-monsoon season it was revealed that first group of clusters involved salinity and magnesium; pH and chloride; dissolved oxygen and sulphate. Second group of clusters was shown by water temperature, nitrate and air temperature. Third group of clusters was shown by alkalinity, total hardness, calcium hardness, free carbon di-oxide. During the pre-monsoon season it revealed that first group of clusters involved calcium hardness and nitrate. Second group of similarity was observed in alkalinity, air temperature and water temperature; dissolved oxygen, sulphate and chloride. The third group of similarity cluster was between magnesium, free carbon di-oxide, salinity, pH, and total hardness. In all the three seasons above mentioned the two parameters, total filterable residue and phosphate showed dissimilarity with other parameters (Fig. 1 to 3).

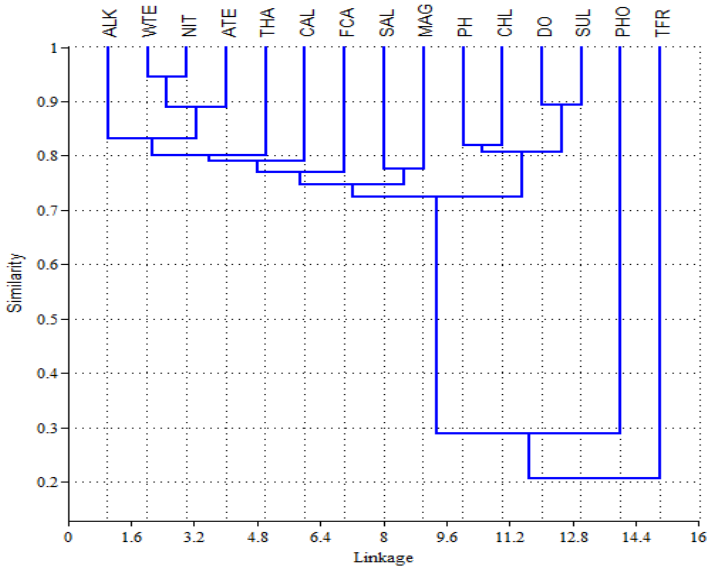

Fig 2: Cluster analysis of physical, chemical and nutrient parameters in Kasi theertham during post-monsoon by Bray–Curtis similarity index (single linkage method).

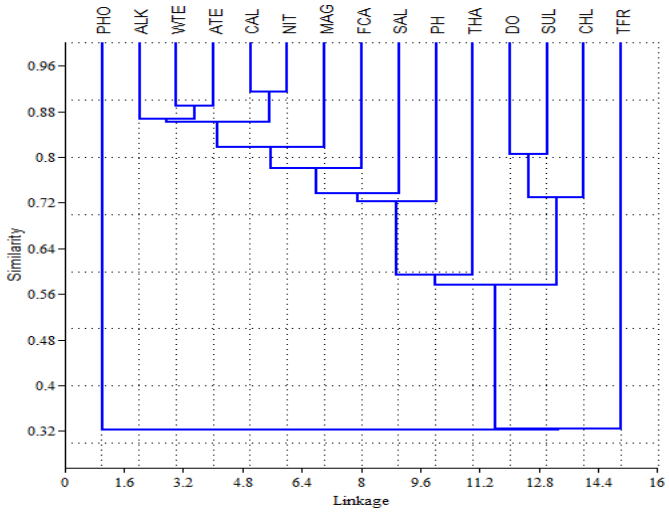

Fig 3: Cluster analysis of physical, chemical and nutrient parameters in Kasi theertham during pre-monsoon by Bray–Curtis similarity index (single linkage method).

In Lakshmi theertham during monsoon season, there were 2 major single linkage clusters. The Bray-Curtis primary similarity was noticed between alkalinity and calcium; pH and chloride. The second group of clusters involved dissolved oxygen, sulphate and phosphate. The third group of clusters

involved salinity, nitrate, water temperature and air temperature. The fourth group of clusters was seen between magnesium hardness and free carbon di-oxide. The total filterable residue did not show any close alignment with other parameters. During the post-monsoon season the first group of clusters involved nitrate and air temperature; water temperature and salinity; alkalinity and calcium hardness. The second group of clusters involved pH, dissolved oxygen, sulphate and phosphate. Third group of clusters was shown by free carbon di-oxide, magnesium and chloride. During the pre-monsoon season the first group of clusters involved alkalinity and calcium hardness; phosphate and sulphate. The second group of clusters was noticed among pH, dissolved oxygen and chloride. The third group of clusters was shown by free carbon di-oxide, salinity, nitrate, air temperature, magnesium hardness and water temperature. Two parameters *i.e.*, total hardness and total filterable residue did not show any close alignment with other parameters (Fig. 4 to 6).

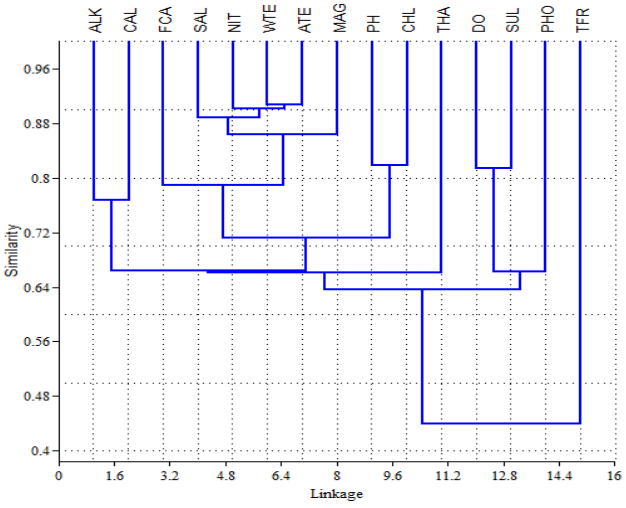

Fig 4: Cluster analysis of physical, chemical and nutrient parameters in Lakshmi theertham during monsoon by Bray–Curtis similarity index (single linkage method).

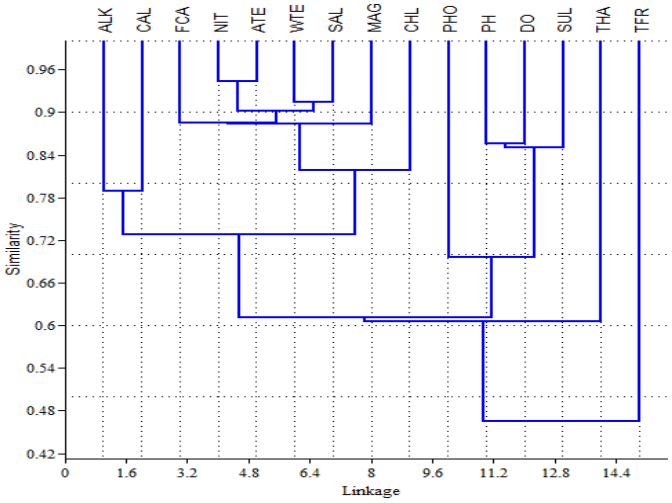

Fig 5: Cluster analysis of physical, chemical and nutrient parameters in Lakshmi theertham during post-monsoon by Bray–Curtis similarity index (single linkage method).

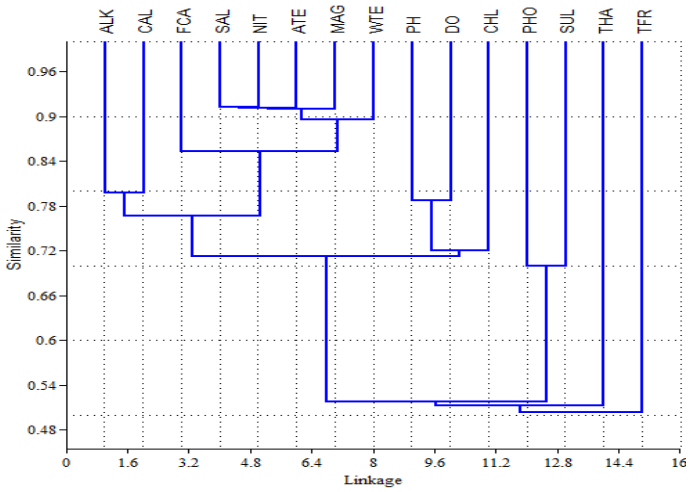

Fig 6: Cluster analysis of physical, chemical and nutrient parameters in Lakshmi theertham during pre-monsoon by Bray–Curtis similarity index (single linkage method).

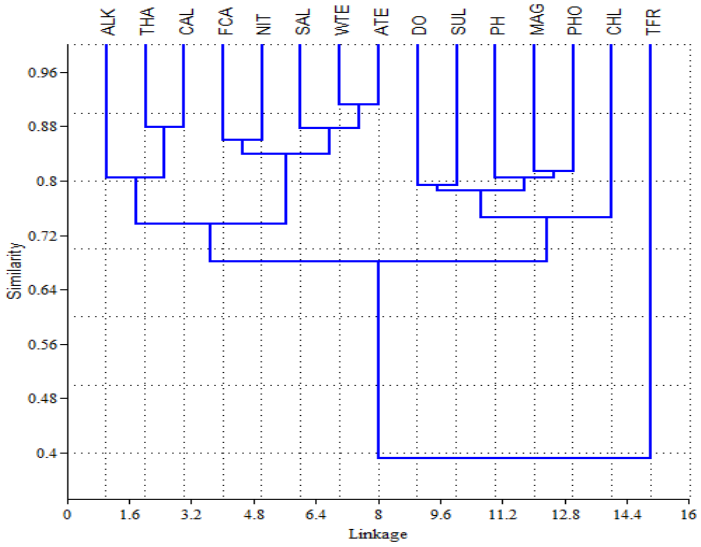

Fig 7: Cluster analysis of physical, chemical and nutrient parameters in Saravana poigai during monsoon by Bray–Curtis similarity index (single linkage method)

In Saravana poigai during monsoon season, the first group of clusters involved free carbon di-oxide and nitrate; dissolved oxygen and sulphate. The second group of cluster involved alkalinity, total hardness and calcium hardness; salinity, water temperature and air temperature; pH, magnesium hardness and phosphate. The chloride and total filterable residue did not show any alignment with other parameters during monsoon season. During the post-monsoon season the first group of clusters involved salinity and air temperature and water temperature and free carbon di-oxide. The second group of clusters was seen among dissolved oxygen, pH, phosphate and sulphate; alkalinity, total hardness and calcium hardness. The magnesium hardness, chloride and nitrate and total filterable residue showed distant relations with other parameters. During the pre-monsoon season the first group of clusters involved salinity, air temperature and water temperature; pH phosphate and sulphate; alkalinity and calcium hardness and total hardness. The second group of the cluster was noticed among nitrate, chloride, free carbon di-oxide and total filterable residue. The dissolved oxygen did not show any close alignment with other parameters (Fig. 7 to 9).

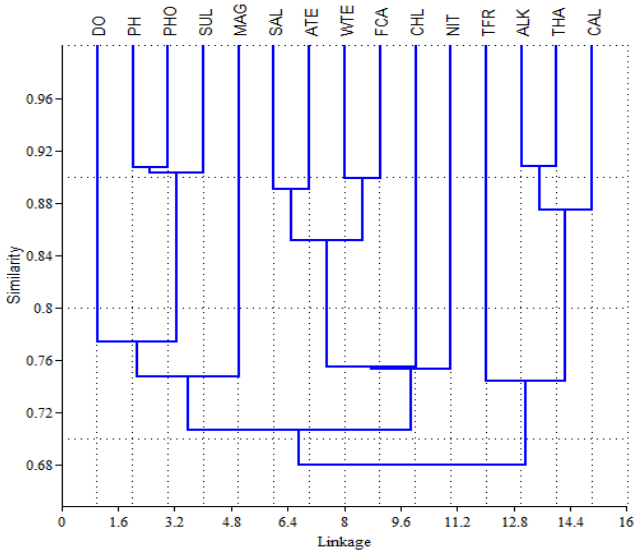

Fig 8: Cluster analysis of physical, chemical and nutrient parameters in Saravana poigai during post-monsoon by Bray–Curtis similarity index (single linkage method)

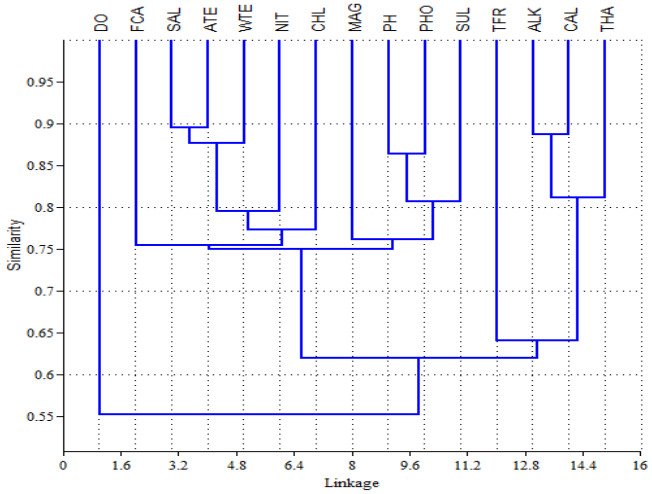

Fig 9: Cluster analysis of physical, chemical and nutrient parameters in Saravana poigai during pre-monsoon by Bray–Curtis similarity index (single linkage method).

The overall analysis of the similarity index of the clusters revealed that the clustering was very close during monsoon and post-monsoon seasons while it was dispersed during pre-monsoon seasons in all the three ponds. Further, it revealed that the clusters were very close in Kasi theertham followed by Lakshmi theertham while it was dispersed in Saravana poigai. The hierarchical cluster analysis showed differences in the amount of physical, chemical and nutrient parameters of monsoon, post-monsoon and pre-monsoon seasons, which in turn, are primarily influenced by the presence or absence of the contents in freshwater pond.

During the study period, in Kasi theertham cluster analysis in an algorithm single linkage with the Bray–Curtis similarity measure was seen with high affinities between the parameters of air and water temperature, during monsoon season. During post-monsoon season, it was between salinity and magnesium; pH and chloride; dissolved oxygen and sulphate. During pre-monsoon season, high affinities were seen between calcium hardness and nitrate. The divergence was observed between the total filterable residue and phosphate during all three seasons in Kasi theertham.

In Lakshmi theertham, high affinities in cluster were observed between the parameters alkalinity and calcium; pH and chloride during monsoon season. During post-monsoon, high affinities in cluster were observed between nitrate and air temperature; water temperature and salinity; alkalinity and calcium hardness. While, during pre-monsoon season, high affinities were seen among the salinity, alkalinity and calcium hardness; phosphate and sulphate. The divergence was observed in total filterable residue in monsoon; total filterable residue and total alkalinity in post-monsoon and pre-monsoon seasons in Lakshmi theertham.

In Saravana poigai, during monsoon season high affinities cluster was seen between the parameters such as, free carbon di-oxide and nitrate; dissolved oxygen and sulphate. During post-monsoon season, the high affinity clusters were seen in between salinity and air temperature; water temperature and free carbon di-oxide. During pre-monsoon season it was between salinity, air temperature and water temperature; pH phosphate and sulphate; alkalinity and calcium hardness and total hardness. The divergence was observed in between total filterable residue and chloride in monsoon; whereas in post-monsoon season divergence was seen in magnesium hardness, chloride, nitrate and total filterable residue. While in pre-monsoon the dissolved oxygen was showed divergence.

The overall analysis of the similarity index of the clusters revealed that the clustering was very close during monsoon and post-monsoon seasons while it was dispersed during pre-monsoon seasons in all the three ponds. Further it revealed that the clusters were very close in Kasi theertham followed by Lakshmi theertham while it was dispersed in Saravana poigai. Such cluster analysis was reported by Bruno *et al.* (2002) who showed the averages of physical and chemical variables at the sampling stations in Everglades National Park. Jung-Hoom *et al.* (2004) [7] used cluster tool to show zooplankton abundance in the East Sea. Rana and Bhat (2005) also represented cluster analysis with a dendrogram to show relationships among cotton cultivators belonging to four cultivated species of cotton. Hamilton *et al.* (2005) [6] employed cluster analysis to show the way clusters and groups of planktonic invertebrates are based on density across 105 ponds. Sharma and Pachualu (2013) [11] showed hierarchical cluster analysis in sub-tropical reservoir of Mizoram, the differences in monthly groupings between two years which, in turn, is primarily influenced by the occurrence or absence of different members of the species-rich rotifera and rhizopoda.

In the present study, the cluster dendrogram representation clearly revealed that the seasonal variations and the use of the pond water by human for bathing and washing may influence the clustering of various parameters. Such variations in the physical, chemical and nutrient characteristics also seemed to influence the occurrence of zooplankton species which was not homogenous in all the ponds of the study area, and there was a clear cut seasonal variation among zooplankton species. All these are attributed to the altitudinal differences in the location of these ponds that influence the changes in physical, chemical and nutrient parameters of these ponds by curtailing the human interferences.

6. Acknowledgement

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