Environment and Ecology 39 (2) : 299—308, April—June 2021
ISSN 0970-0420

An Overview of Periphytic Organisms ; Species Composition, Substrate Specificity and Seasonal Preference Along Different Stretches of River Periyar, Kerala, India

Blessy John, R. Sunil Kumar

Received 27 November 2020, Accepted 12 March 2021, Published on 5 April 2021

ABSTRACT

Species composition, seasonal preference and substrate specificity of periphytic organisms were studied for one year (June 2016 – May 2017) from different substrates of selected stations of river Periyar. Taxonomic studies revealed a total of 156 species of phytoperiphyton and 135 species of zooperiphyton. Bacillariophyceae dominated the phytoperiphytic group while rotifers dominated the zooperiphyton. Most of the phytoperiphytic and zooperiphytic organisms prefer the pre-monsoon period for their development and subsequent succession. Rotifers, crustaceans, protists and entire phytoperiphytic organisms preferred leaf as their suitable substrate for colonization and development while nematodes preferred log. Canonical correspondence analysis revealed the importance of dissolved oxygen, temperature, pH and phosphate in the distribution and abundance of periphytic organisms.

Keywords Bacillariophyceae, Canonical correspondence analysis, Periphyton, Periyar, Rotifers.

Blessy John*, R. Sunil Kumar
Post Graduate and Research Department of Zoology,
Catholicate College, (Affiliated to Mahatma Gandhi University),
Pathanamthitta 689645, Kerala, India
Email:bessyjohn87@gmail.com
*Corresponding author

INTRODUCTION

Periphyton is a complex assemblage of algae, bacteria, fungus, protozoans, micro invertebrates and detritus attached to the submerged surfaces of aquatic ecosystems (Azim *et al*. 2002). It forms a biofilm over submerged objects and provides a suitable niche for the organisms to colonize and exploit. Biodiversity and speciation of aquatic organisms increase through their interspecific and intraspecific competitions among the periphytic biotope. Periphyton micro-ecosystem acts as solar-powered biogeochemical reactors and plays a significant role in primary production, food web interactions and nutrient fluxes (Wu 2017). Periphytons are ecologically significant and have high economic value. They serve as an important food source for tadpoles, invertebrates and fishes. Periphyton acts as good bio-indicators as they are easily exposed to contaminants and can readily absorb these contaminants into their tissues. They play a crucial role in the re-establishment of vegetation after loss by flood, grazing and external stress (Osagie 2010). Periphyton

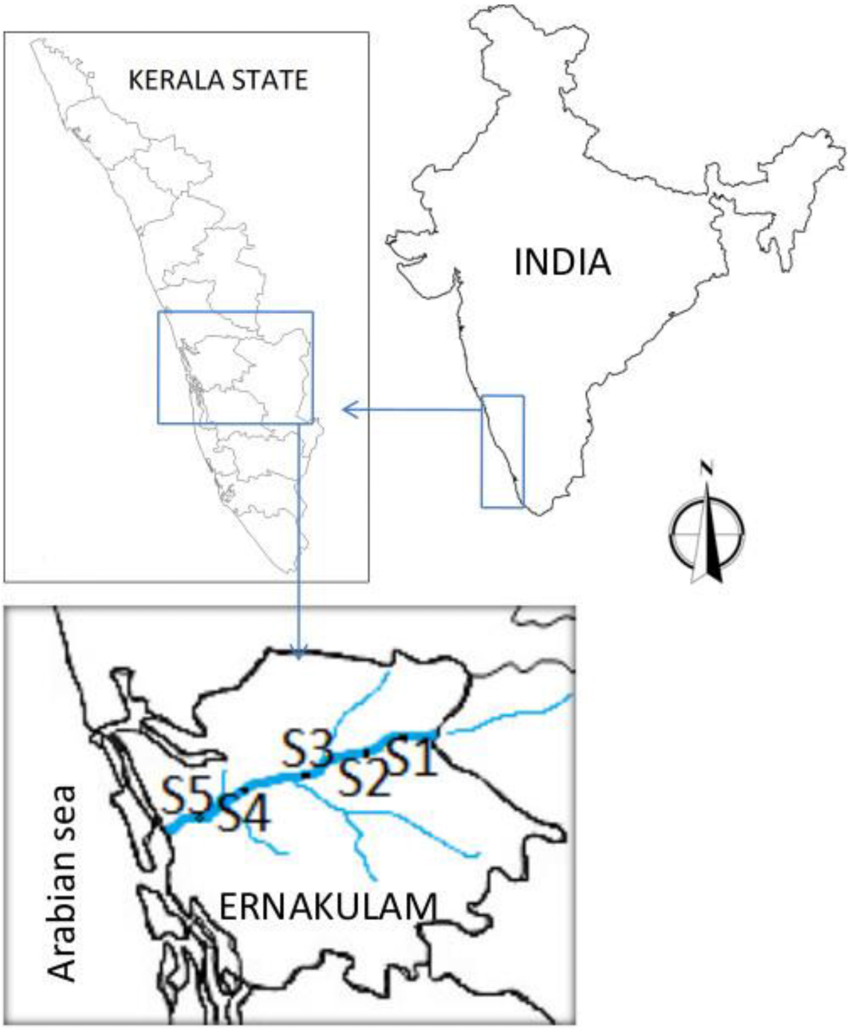

Fig. 1. Map showing the selected stations along Periyar River.

assemblages comprise both phytoperiphyton and zooperiphyton. Phytoperiphyton generally includes different classes of algae such as Bacillariophyceae, Cyanophyceae, Zygnematophyceae, Chlorophyceae and Euglenoidea. Zooperiphyton mostly comprises rotifers, protists, nematodes, different forms of crustaceans and insect larvae.

Study area

Periyar a perennial river of Kerala originates from Sivagiri peaks of Western Ghats and has a total length of 244 km. Periyar River is known as 'Lifeline of Kerala' forms the backbone to the economy of Kerala by providing water for drinking, domestic needs, irrigation, aesthetic purposes and electrical power generation. Five sampling stations were selected along different regions of river Periyar to assess the periphytic composition (Fig. 1). Station 1 (S1): Pooyamkutty ($10^0$3'29.59"N, $76^0$46'33.88"E); Station 2 (S2): Kuttampuzha ($10^0$8'37.11"N, $76^0$43'16.41"E); Station 3 (S3): Thattekadu (10°08′N, 76°41′E); Station 4 (S4): Aluva (10° 6'56.83"N, 76°21'17.38"E) and Station 5 (S5): Varappuzha (10° 4'10.31"N, 76°16’48.28”E).

Sampling procedure

Monthly samples were collected for one year (June 2016 – May 2017) from five selected stations of river Periyar. Five different substrata such as log, leaf, root, rock and wall were chosen from each station and 5 cm^2 surface areas were scrapped from the selected substrate using a scalpel, brush or blade. The scrapped contents were washed out into a tray using distilled water and then transferred to a sampling bottle via a funnel. The samples were preserved with 4% of formalin and made upto10 ml using distilled water (Biggs 1996). One ml of the preserved sample was placed on a Sedgwick rafter counting chamber for enumeration. The counting chamber was then examined under an inverted microscope (Carl Zeiss Primovert, Germany) equipped with phase contrast. The results were expressed in the number of individuals/cm^2. Measurements and photographs of periphytic organisms were taken and identified using standard books, keys and literature.

Physico-chemical parameters such as temperature, pH, dissolved oxygen (DO) and conductivity were determined on-site using a multi-parameter probe (Eutec cyberscan-650). Water samples were brought to the lab under 4^0C in dark conditions for the determination of remaining water quality parameters. The concentration of nitrate, phosphate, sulfate and chloride was determined using standard methods.

Statistical analysis

Statistical analysis was carried out using the software PAST version 318. Environmental data and periphytic species data were subjected to normality tests using Monte-Carlo 999 permutation test. Canonical Correspondence Analysis (CCA) was performed to extract those environmental variables that play a significant role in the distribution and abundance of periphytic organisms. Environmental variables were subjected to Pearson’s (Linear r) correlation to identify the significant variables ($p<0.05$) and were standardized using the formula (X-mean)/SD. To down weigh the contribution of abundant species, periphytic species data were square-foot transformed prior to analysis.

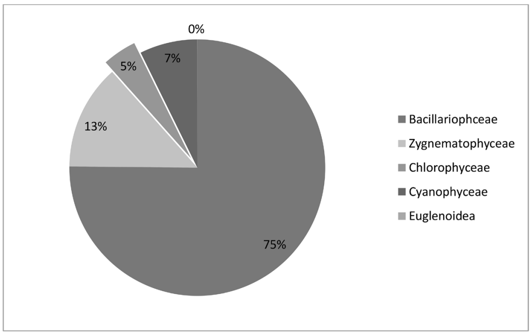

Fig. 2. Percentage composition of phytoperiphyton from river Periyar.

RESULTS AND DISCUSSION

Periphytons inhabit all sorts of aquatic ecosystems like lakes, ponds, streams, rivers and cascades. Rivers are continuously moving and any object in the river can reach the sea within a few days. Understanding of attached forms like periphyton becomes more efficient in lotic ecosystems compared to planktonic forms. These periphytic organisms play a considerable role in aquatic food chains as they occur in a sufficient amount in lotic habitats. Distribution and abundance of periphytic organisms were affected by multiple interactions of several factors like temperature, light, grazing, water currents, water chemistry and substrate type. Even though periphytic organisms were ecologically and economically significant little is known about the periphyton community of river Periyar. The present study came out with some interesting information regarding species composition, substrate specificity and seasonal abundance of periphytic organisms.

Species composition of periphyton

Taxonomic studies regarding periphytic assemblages of river Periyar revealed a total of 291 species of organisms. Of these156 species belongs to phytoperiphyton and 135 species belong to zooperiphyton. Among phytoperiphyton, 5 groups namely Bacillariophyceae, Zygnematophyceae, Chlorophyceae,

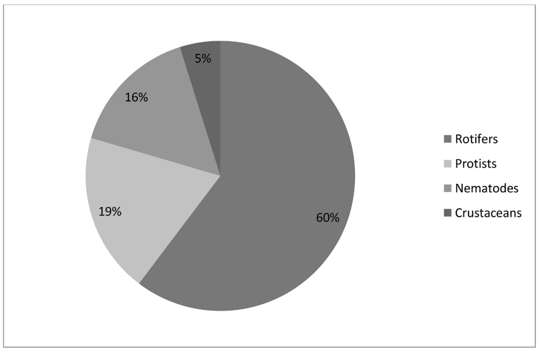

Fig. 3. Percentage composition of zooperiphyton from river Periyar.

Cyanophyceae and Euglenoidae were identified. Zooperiphyton comprises 4 groups namely Rotifers, Protists, Nematodes and Crustaceans.

Percentage composition analysis of phytoperiphyton follows the order Bacillariophyceae > Zygnematophyceae > Cyanophyceae > Chlorophyceae>Euglenoidea (Fig. 2). Bacillariophyceae was the most represented class with 75% of total phytoperiphyton followed by Zygnematophyceae (13%). Euglenoidea was the least represented group and was insignificant. Bacillariphyceae are considered as efficient and pioneering colonizers due to their specialized fixation structures and modifications (Biggs 1996). Dominance and abundance of diatoms in tropical ecosystems mainly due to its competitive ability towards adverse environmental conditions were reported by Forbes and Forbes (1994). They are photoautotrophs and play an important role in the aquatic food chain at the basal level. A vast variety of diatoms are found associated with aquatic ecosystems and can attach to the substratum by means of adherent pads, gelatinous stalks, or branching chains. Since they are primary colonizers they get sufficient light and better nutrients for their quick development. All these factors mark the dominance of Bacillariophyceae resulted from the present study. Periphytic algal studies from the Ganga River (Srivastava *et al.* 2019) and Nemunas-River (Satkauskiene and Glasaite 2013) well agree with the dominance of class Bacillariophyceae in the present study. The dominance of diatoms from different aquatic ecosystems was also reported by Oterler (2016), Kanavillil and Kurisseryl (2013).

Percentage composition analysis of zooperiphyton follows the order Rotifers >Protists> Nematodes > Crustaceans. Rotifers were the maximum represented group of zooperiphyton with 60% of abundance. The least represented group was Crustacea with only 5% of total zooperiphyton (Fig. 3). Considering zooperiphytic groups, rotifers dominated all other

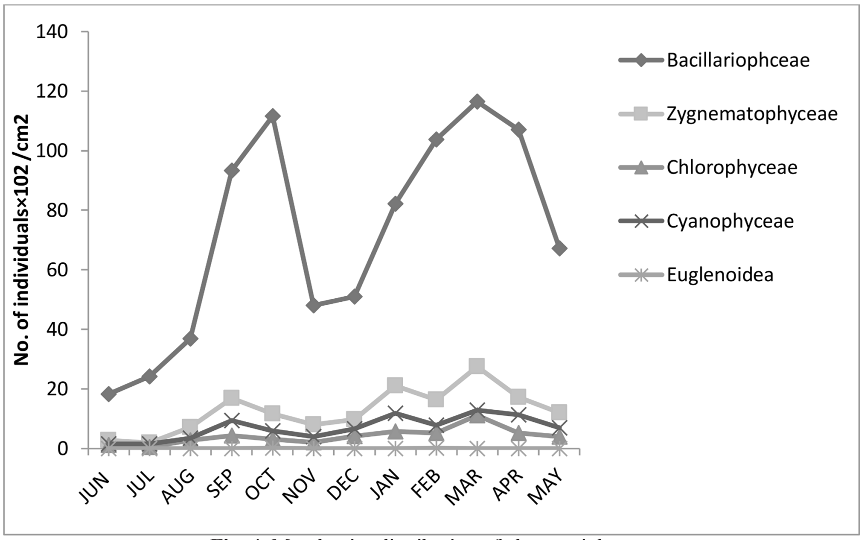

Fig. 4. Month wise distribution of phytoperiphyton.

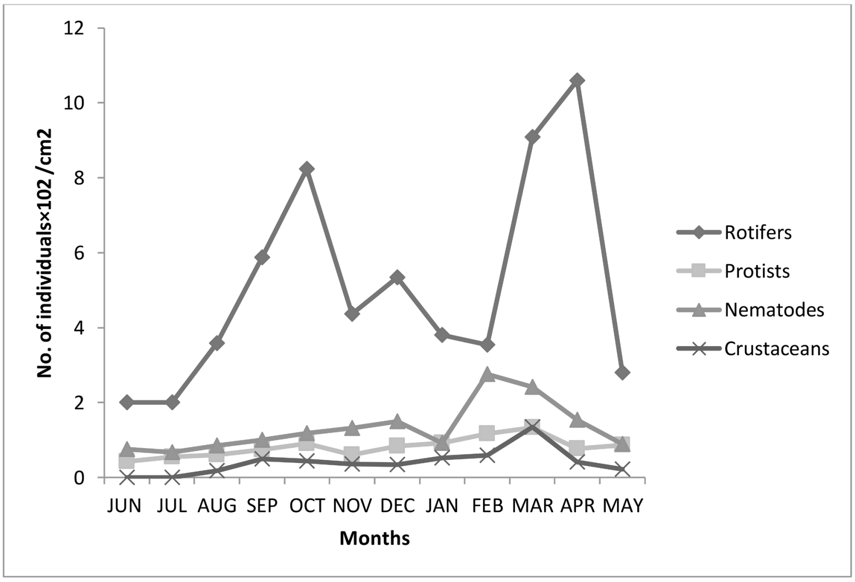

Fig. 5. Month wise distribution of zooperiphyton.

zooperiphytons irrespective of seasonal variations, substrate type and regional differences. Even though rotifers are small-sized organisms they occupy a pivot space in aquatic ecosystems due to its abundance. A high abundance of periphytic rotifers also depends on sufficient food and suitable environmental conditions (Gadhikar and Sawale 2016). Bano *et al.* (2017) documented the abundance of rotifers from his studies on the Narmada River, India. The abundance of rotifers in freshwater ecosystems was also reported by Pawar (2016), Karuthapandi (2013), Kumar *et al.* (2011, 2018).

Month-wise distribution of periphyton

Graphical representation of the month-wise distribution of phytoperiphyton (Fig. 4) illustrates the dominance of Bacillariophyceae irrespective of different seasons. Bacillariphyceae distribution shows two peaks, one in September and the other in March. Bacillaripohyceae abundance varied from a minimum of 18.3×10^2 ind/cm^2 (June 2016) to a maximum of 116.5×10^2 ind/cm^2 (March 2017). Zygnematophyceae was the second abundant group of phytoperiphyton with 3 peaks in September, January and March. The minimum density of Zygnematophyceae was observed in July (1.8×10^2 ind/ cm^2) while the maximum was recorded in March (27.52×10^2 cm^2). Cyanophyceae distribution also showed three peaks in September, January and March. The abundance of Cyanophyceae varies from a minimum of 1.6×10^2 ind/cm^2 (June, July) to a maximum of 12.85×10^2 ind/cm^2 (March). Distribution of class Chlorophyceae showed only a single peak in March. Minimum Chlorophyceae distribution was observed in June (0.5×10^2 ind/cm^2) while the maximum was in March (11.05×10^2ind/ cm^2).

Seasonal fluctuations in the abundance and diversity of periphytic organisms are mainly due to the differential response of diverse species to varying temperature, light intensity, nutrient levels and grazing pressures. Bacillariophyceae (Jyotsna *et al.* 2014, Hajong and Ramanujam 2018), Zygnemato phyceae (Vidyavati 2007) members show two peaks, one in post-monsoon and the highest peak in pre-monsoon. Cyanophycean (Santhosh *et al.* 2007, Khanna and Indu 2009) and Chlorophycean (Joshi 2010, Joseph 2017) members also exhibit a higher population in the pre-monsoon period. Higher temperature, maximum light intensity, sufficient nutrients in the form of nitrate and phosphate makes pre-monsoon

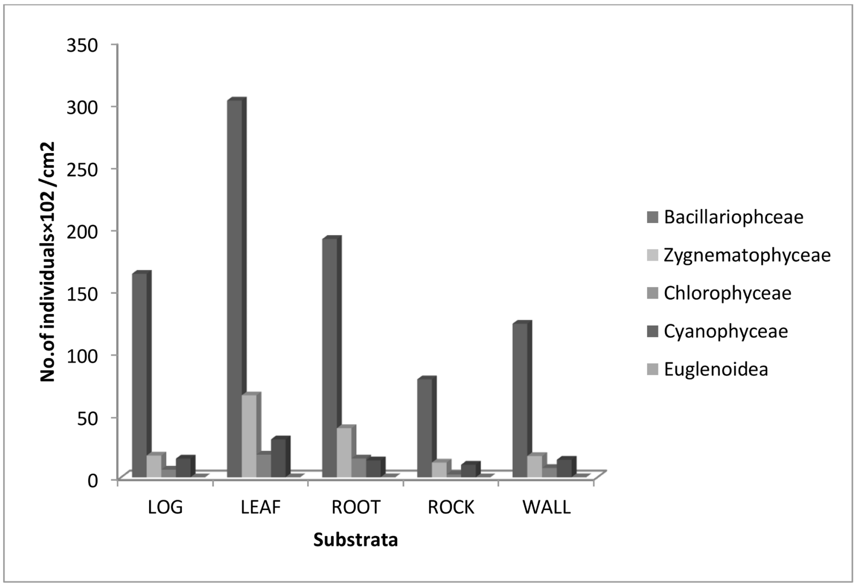

Fig. 6. Phytoperiphytic compositions among selected substrata.

a suitable period for the growth and proliferation of phytoperiphytons.

Graphical representation of the month-wise distribution of zooperiphyton denotes the dominance of rotifer in all the three seasons (Fig. 5). Monthly variation of rotifer abundance shows three peaks in October, December and April. Rotifer density varies from a minimum of 2×10^2 ind/cm^2 (June, July) to a maximum of 10.59×10^2ind/cm^2 (April). Nematode distribution showed a single peak in February. The minimum density of nematode was observed in July

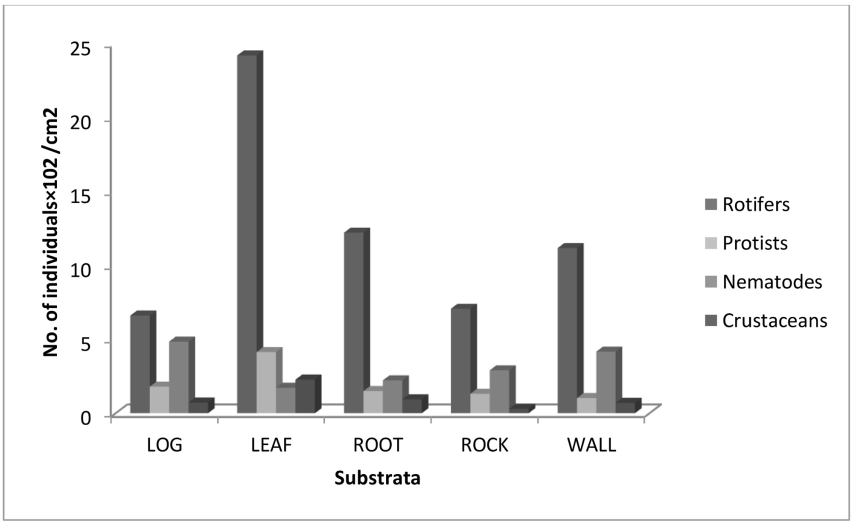

Fig. 7. Zooperiphytic composition among selected substrata.

Table 1. Station wise account of environmental variables recorded from river Periyar.

Stations	Temperature (^0C)	pH	D.O (mg/l)	Conductivity (mS)	Phosphate (mg/l)	Sulfate (mg/l)	Nitrate (mg/l)	Chloride (mg/l)
S1	25.6 ± 0.22	6.4 ± 0.11	8.02 ± 0.13	0.021 ± 0.00	0.586 ± 0.11	0.182 ± 0.05	1.44 ± 0.61	79.14 ± 9.65
S2	26.3 ± 0.33	6.3 ± 0.14	7.8 ± 0.12	0.029 ± 0.01	0.594 ± 0.13	0.235 ± 0.06	1.92 ± 0.86	74.97 ± 9.73
S3	27.4 ± 0.38	6.6 ± 0.12	7.4 ± 0.07	0.024 ± 0.00	0.682 ± 0.13	0.243 ± 0.07	2.26 ± 0.96	83.31 ± 9.40
S4	28.9 ± 0.43	6.2 ± 0.18	6.8 ± 0.13	0.035 ± 0.00	0.99 ± 0.15	0.356 ± 0.11	4.56 ± 0.95	99.97 ± 12.31
S5	29.3 ± 0.43	7.4 ± 0.09	6.3 ± 0.18	39.92 ± 3.84	1.194 ± 0.14	37.38 ± 9.03	3.58 ± 0.41	1255.24±231.9

(0.68×10^2 ind/cm^2) while the maximum was recorded in February (2.76×10^2 ind/ cm^2). Protist density varies from a minimum of 0.43×10^2 ind/cm^2 (June) to a maximum of 1.33×10^2 ind/cm^2 (April). Crustaceans were absent in June and July and were maximum reported in March (1.35×10^2ind/ cm^2).

Seasonal fluctuations of rotifers exhibit two peaks, one in post-monsoon and the other in pre-monsoon (Vanjare and Pai 2013, Jose and Sanalkumar 2012). The pre-monsoon period marks a higher abundance of nematodes (Schroeder *et al*. 2012, Ansari *et al*. 2015, Kothandapani *et al.* 2016, Mihaljevic *et al.* 2015), protists and crustaceans (Singh 2000). In the pre-monsoon period water becomes more stable and higher temperature increases the rate of decomposition of organic materials results in the sufficient production of zooperiphytonfavored food like algae, detritus and bacteria. The pre-monsoon period is also characterized by the increased rate of moulting and brood production of zooperiphytons. All these resulted in a maximum population of zooperiphyton in the pre-monsoon season.

Substrate wise distribution of periphyton

In addition to suitable environmental conditions,

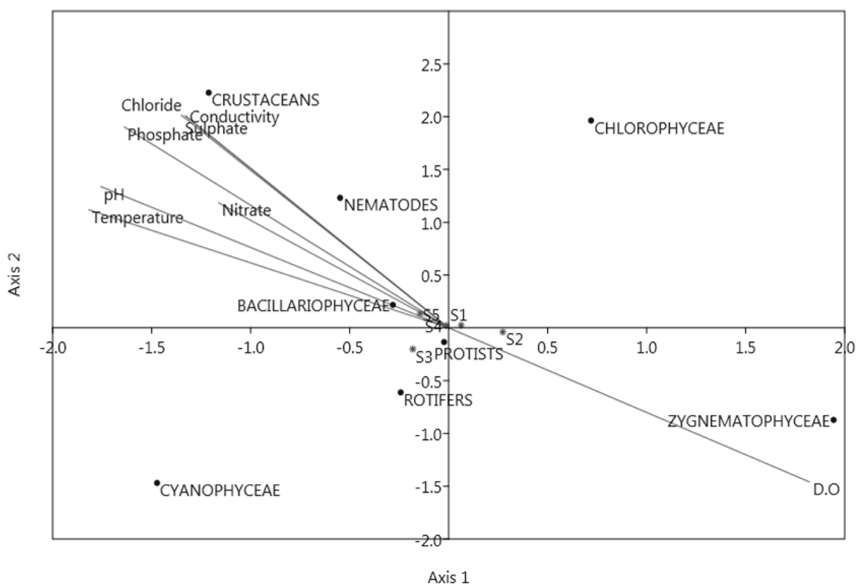

Fig. 8. CCA ordination plot depicting the relationship between environmental variables and periphytic groups. Environment variables were represented by vectors radiating from the origin. Periphytic groups were represented by dots on the plot. Stars denote selected stations (S1-Station 1, S2-Station 2, S3-Station 3, S4-Station 4 and S5-Station 5).

stable and durable substrates are also important for massive periphyton development. Surfaces of submerged rocks, stones, reeds, woods and exposed leaf surfaces act as more persistent substrates (Liboriussen and Jeppesen 2009). Graphical representation of substrate wise distribution of phytoperiphyon clearly states that all classes of phytoperiphyton prefer leaf as their suitable substratum for colonization followed by root and log. Rock was the least preferred substratum by phytoperiphytons (Fig. 6). Periphyton mats are generally developed from planktonic propagules and the exposed surfaces of leaves can readily attach these propagules and facilitate in periphyton development (Kanavillil and Kurisseryl 2013). Large surface area, sufficient nutrient availability, easy attachment and colonization make leaf as a suitable substrate for phytoperiphytons. Phytoperiphytons generally prefer organic substrates than mineral ones (Sharifinia *et al.* 2016) which make rock and wall the least preferred ones.

Graphical representation of substrate wise distribution of zooperiphyton illustrates the dominance of rotifers irrespective of substratum differences and was abundantly found from leaf substratum. Protists and Crustaceans also choose leaf as the preferred substratum when nematodes prefer log mostly for colonization and succession (Fig. 7). The availability of sufficient food, enough space and easy attachment makes leaf as a suitable substratum for most of the zooperiphytons (Sharma *et al.* 2013). Nematodes prefer log mostly because of its structural heterogeneity, more stable and durable nature and availability of nematode favored food (Mihaljevic *et al.* 2015, Chauhan 2015).

Canonical correspondence analysis (CCA)

CCA was conducted to assess the relation existing between the eight environmental parameters studied (Table 1) and the periphytic organisms reported. Eigenvalues for axis 1 and 2 itself explain 89.53% of the relationship between the data. In the ordination plot, environmental variables were represented by vectors radiating from the origin and periphytic groups were represented by dots on the space (Fig. 8). Vector for dissolved oxygen (DO) forms an obtuse angle with all other vectors; illustrates that DO is negatively correlated with all other environmental parameters. Vectors for pH and temperature form an acute angle denotes the positive correlation with each other, likely conductivity, chloride, sulfate, phosphate and nitrate were positively correlated with each other.

Axis 1 forms a positive association between DO and periphytic groups like Chlorophyceae and Zygnematophyceae illustrates the importance of DO in the distribution and abundance of these algal groups. Axis 1 forms a negative association between temperature, pH, phosphate and periphytic groups like Nematodes and Crustaceans and Cyanophyceae which signifies the role of temperature, pH and phosphate in the distribution and abundance of these periphytic groups.

CCA plot reveals the influence of certain environmental parameters in the distribution and abundance of periphytic organisms. Zygnematophyceae members are mostly sensitive to eutrophic conditions and are generally seen in oligotrophic waters where turbidity, nitrate and phosphate concentrations were comparatively low and DO is high (Hajong and Ramanujam 2017, Kiran 2016, Gayathri *et al.* 2011). A high concentration of Cyanophycean members is an indication of the nutrient status of the river especially that of nitrate and phosphate (Neelam *et al.* 2009). The positive influence of food and nutrients on the crustacean population was reported by Bano *et al.* (2017) from their studies on the Narmada River, India. Temperature also positively influences on the food availability, moulting rate and brood production of crustacean eggs (Singh 2000). Organic contaminants that undergo bacterial oxidation serve as a potential food source for periphytic nematodes result in their abundance and richness in polluted zones compared to clear zones. Skalskayaa and Gagarina (2019) reported a considerable increase in species richness and abundance of periphytic nematodes from the regions contaminated with organic pollutants of zoogenic and anthropogenic origin. Periphytic groups generally exhibit certain preferences for substrates, environmental conditions and microhabitats. This preference range varies with different species tolerance levels to changing environmental conditions and the availability of sufficient and suitable food.

ACKNOWLEDGMENT

The authors would like to thank Principal, Catholicate College, Pathanamthitta for providing the facility to carry out the research work. The first author would like to thank Mahatma Gandhi University, Kottayam for providing the fellowship under University Junior Research Fellowship (4677/A6/2/JRF2017/Acd).

REFERENCES

Ansari E, Gadhia M, Ujjania NC (2015) Phytoplankton diversity and water quality assessment of ONGC pond, Hazira. *IJRES* 1 (1) : 1—5.

Azim ME, Verdegem MCJ, Khatoon H, Wahab MA, Van Dam AA, Beverdge MCM (2002) A comparison of fertilization, feeding and three periphyton substrates for increasing fish production in freshwater pond aquaculture in Bangladesh. *Aquaculture* 212: 227—243.

Bano Z, Chauhan R, Mahmood S (2017) Distribution of zooplankton in river Narmada at Hoshangabad, Madhya Pradesh, India. *Int J Zool Stud* 2 (6): 96—100.

Biggs BJF(1996) Patterns in benthic algae of streams, Algal Ecology. Academic Press, pp 31—56.

Chauhan (2015) Ecology of periphytic communities in lakes Nainital and Bhimtal. A thesis submitted to Kauman University.

Forbes VE, Forbes TL (1994) Ecotoxicology in theory and practice. Chapman and Hall, London.

Gadhikar YA, Sawale SP (2016) Seasonal abundance and diversity of rotifers of Shahanoor dam, Amravati District, India. *Universal J Environm Res Technol* 6 (2): 82—90.

Gayathri N, Rajashekhar M, Fatima K, Vijayakumar K, Ratandeep, Baburrao M (2011) Hydrochemistry and plankton diversity of Tungabhadra reservoir Bellary District, Karnataka. *Int J Zool Res* 1(1) : 1—7.

Hajong P, Ramanujam P (2017) Effect of anthropogenic activities on algal community in Ganol River, West Garo Hills.*Bull Environ Pharmacol Life Sci* 6 (9) : 109—120.

Hajong P, Ramanujam P (2018) Seasonal variation in algal diversity and productivity in Dachi Lake, Meghalaya. *J Algal Biomass Utilization* 9 (2) : 9—24.

Jose R, Sanalkumar MJ (2012) Seasonal variations in the zooplankton diversity of river Achenkovil. *Int J Scient Res Publ* 2 (11) : 1—5.

Joseph J (2017) Diversity and distribution of phytoplankton in an artificial pond. *Int J Adv Res Biol Sci* 4 (5) : 114—122.

Joshi KK (2010) Studies on the periphytic algae in Pokkali and Prawn fields of N. Paravoor and Vypeen Island. PhD thesis. Mahatma Gandhi University, Kottayam.

Jyotsna N, Rangaiah SG, Rao MNG (2014) A contribution to the seasonal distribution and biodiversity of freshwater phytoplankton of Karagam Lake, Srikakulam, Andhra Pradesh, India. *Int J Environ* 4 (1): 82-100.

Kanavillil N, Kurisseryl S (2013) Temporal variation of periphyton communities: A 3- year study from northwest lake Simcoe, Ontario, Canada. Inland Waters 3(4): 437-486. https://doi.org/10.5268/IW-3.4.525

Karuthapandi M (2013) Studies on zooplankton community structure, composition and dynamics in few freshwater lakes. PhD thesis. Manonmaniam Sundaranar University.

Khanna V, Indu Y (2009) Planktonic diversity in the holy lake of Pushkar, Ajmar.*Nat Environ Poll Tech* 8 (2): 339—342.

Kiran BR (2016) Distribution and occurrence of desmids in Bhadra reservoir Karnataka. *Int J Res Environm Sci* 2 (3) : 16—23.

Kothandapani S, Sukumaran M, Muthukumaravel K (2016) Seasonal variations of zooplankton diversity in Muthupet estuary, Southeast coast of India. *Int J Zool Appl Biosci* 1 (5) : 213—220.

Kumar GE, Thanzeeha KV, Sasikala K, Pradeepkumar G, Sivadasan KK, Jaleel AV (2018) A preliminary study on the diversity of planktonic algae of Kaanam River, Kerala, India. *Phykos* 48 (2) : 13—16.

Kumar P, Wanganeo A, Wanganeo R, Sonaullah F (2011) Seasonal variations in zooplankton diversity of railway pond, Sasaram, Bihar. *Int J Environm Sci* 2 (2) : In press.

Liboriussen L, Jeppesen E (2009) Periphyton biomass, potential production and respiration in a shallow lake during winter and spring. *Hydrobiologia* 632 : 201—210.

Mihaljevic M, Pfeiffer TZ, Vidakovic J, Poljaric OS, Stevic F (2015) The importance of microphytic composition on coarse woody debris for nematode colonization: A case study in a fluvial floodplain environment. Biodiversity and conservation DOI 10.1007/s10531-015-0889-5

Neelam V, Avinash B,Dwivedi SN (2009) Planktonic biodiversity of Bhoj wetl and. *Bhopal J Appl Sci Environ Manag* 13 (4): 103—111.

Osagie E (2010) Composition, occurrences and checklist of periphyton algae of some water bodies around Benin City, Edo State, Nigeria. *Ethopian J Environm Stud Manag* 3 (2) : 1—10.

Oterler B (2016) Longitudinal and seasonal succession of algal periphyton colonization in Lowland River. Peer J Prints https://doi.org/10.7287/peerj.preprints.1953v1

Pawar RT (2016) Zooplankton diversity and seasonal variation of Majalgaon reservoir, Maharashtra State, India. *Int J Environm Sci* 6 (5) : In press.

Santhosh SV, Sobha S, Girijalakshmi,Thara JC (2007) Phytoplankton abundance of Paravarkappil back water of Kerala. *Sea weed. Res Util* 29 (112) : 155—163.

Satkauskiene I, Glasaite R (2013) Periphyton composition and diversity in the Kaunas lagoon and Nemunas River. *Biologija* 59 (2) : 141—150.

Schroeder F, Peters L,Transpurger W (2012) Temporal variations in epilithic nematode assemblages in lakes of different productivities. *Fundam Appl Limnol* 18 (2) : 143—157.

Sharifinia M, Ramezanpour Z, Namin JI (2016) Distribution of benthic centric diatom Pleurosiralaevis (Compère 1982) in different substrate type and physical and chemical variables. *Acta Limnologica Brasiliensia* 28: e-1.

Sharma KK, Sarbjeet K, Neha A, Shvetambri (2013) Habitat preference of rotifers inhabiting some waters of Jammu Province, J&K, India. *Int Res J Biol Sci* 2 (6) : 35—38.

Singh DN (2000) Seasonal variation of zooplankton in a tropical lake. *Geobios* 27 (2-3) : 97—100.

Skalskayaa A, Gagarina VG (2019) Nematodes of meiobenthos and periphytonin Rybinsk reservoir tributaries. *Inland Water Biol* 12 (2): 69—80.

Srivastava K, Das SCS, Thakur VR, Alam A, Joshi KD (2019) Biodiversity and spatio-temporal variation of periphyton of the river Ganga (Gangotri to Vidhyachal). *Int J Fish Aquatic Stud* 7 (1) : 109—115.

Vanjare AI, Pai K (2013) Ecology of freshwater Rotifera in a seasonal pond of the University of Pune (Maharashtra, India). *Appl Ecol Environm Res* 11(4) : 525—539.

Vidyavati (2007) Biodiversity in desmids. *Ind Hydrobiol* 10 (1): 27—33.

Wu Y (2017) Periphyton: Functions and application in environmental remediation. *Eisevier,* pp 1—24.