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Microbial biomass at land water interface and its role in regulating ecosystem properties of a fresh water dry tropical woodland lake

J. Pandey*

Department of Environmental Sciences, M.L.Sukhadia University, Udaipur - 313 001, India

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Abstract: *This study was aimed at determining microbial biomass at land water interface and the role it plays in regulating ecosystem properties of a fresh water dry tropical woodland lake. Four microbial variables namely biomass-C (C_{mic}), fumigated CO_2–C, substrate induced respiration (SIR) and basal respiration (BR) were measured in humus samples collected from land water interface over a period of one year. Microbial biomass (C_{mic}) was maximum during February (718 µg CO_2–C g^{-1}).Similar was the case of fumigated CO_2–C (560 µg CO_2–C g^{-1}10 d^{-1}), SIR (2900 µg CO_2-C g^{-1}) and BR (480 µg CO_2–C g^{-1}). Humus- N appeared maximum (1.60 %) during November and phenolics (204 µg g^{-1}) during December. Gross primary productivity (GPP) was found maximum (3.30 g C $m^{-2} d^{-1}$) during March. Almost similar trend appeared for chlorophyll and phytoplankton density. Variation in microbial biomass at land water interface can be explained by seasonality and the quality of substrate material. Asynchrony in the peaks of microbial variables with phytoplankton pulsation and GPP suggested that the microbial biomass through nutrient mineralization regulates ecosystem functioning of a fresh water woodland lake. This has relevance for evaluating the nature of anthropogenic perturbations and for maintenance of fresh water lakes void of human disturbances.*

Key words: *Land water interface, Ecosystem, Phytoplankton, Humus, Microbial biomass*
*PDF of full length paper is available with author **(*jiten_pandey@rediffmail.com)***

Introduction

Microbial biomass is the principal component of decomposer system regulating nutrient release and mineralization and ultimately ecosystem functioning. The temporal variability in microbial biomass is important in determining the pattern of release of nutrients and their availability to other components of the ecosystem (Wardle, 1998; Smitha *et al.,* 2007). Soil microorganisms and the process they control (decomposition and mineralization) are essential for long-term sustainability of ecosystems (Wardle *et al.,* 1999; Tiwari and Chauhan, 2006; Sridhar *et al.,* 2006). Microbial biomass dynamics are regulated by climate across broad ecosystem types but at finer scale it is determined to a large extent by litter quality (Wardle and Lavelle, 1997), hydrology (Wetzel, 2001), natural and anthropogenic disturbances (Pandey and Verma, 2004). Amongst the most accepted properties of litter quality are C: N ratio, lignin content, structural properties of the substrate material and concentration of secondary metabolites such as phenolics (Wardle *et al.,* 1999 ; Pandey and Pandey, 2001).

Allochthonous organic matter often forms the major fraction of organic-C pool in woodland lakes. For example, leaf litter production in many stands of tropical forests frequently exceed 0.5 kg m^{-2} yr^{-1}(Kominkova *et al*., 2000). According to Lang (1974), in deciduous forests, 30-94% (65% on average) of net above ground production is annually transformed into litter. In dry tropics, the bulk of this plant biomass tends not to be consumed during the growing season (Kominkova *et al.,* 2000) but eventually added to downstream ecosystems and enters the detritus pool and is broken down by fungi, bacteria and detritus feeding invertebrates (Polunin, 1984). In moist tropical deciduous woodland, leaves are normally dropped within a month following senescence just before the onset of summer. Due to high temperature, dry and staggered leaves in the woodland catchment are less likely to be colonized by microorganisms. At the onset of monsoon, major part of this litter is added to downstream aquatic ecosystems which undergo considerable microbial colonization and decay after entry into the aquatic environment. While considerable research efforts have been devoted to investigating microbial biomass and factors of its temporal variability in terrestrial ecosystems, data on the magnitude of microbial biomass at land water interface, its dynamics and contributions to lake ecosystem functioning are lacking. Therefore, the present research is an effort to investigate temporal variability in microbial biomass at land water interface and its bearing with ecosystem functioning of a freshwater woodland lake of Rajasthan, India.

Materials and Methods

Study area: The present research investigation was conducted during 2003-2004 at Baghdara lake (catchment 500 ha; water spread 1.8 km^2; max depth 8.5 m; fed entirely by rainfall), situated 20 km SE of Udaipur city (24°40′ N lat and 73° 86′ long and 577m above msl) of Rajasthan, India. Being situated away from the Udaipur urban settlement, this lake has the least human interference. Climate of the region is tropical with distinct seasonality. The rainfall that range between 500 and 750 mm, although staggered, concentrate mainly during monsoon. The day time summer temperature sometimes exceeds 42°C and winter night temperature sometimes drops below freezing. The catchment vegetation comprises of tropical dry deciduous forest with scattered patches of shrubs at uplands.

The dominant woody perennials in the catchment include *Lannea coromandelica, Bauhinia purpurea, Sterculia urens, Phoenix dactylifera, Ficus racimifera, Terminalia belerica, Holoptelia*

Table - 1: Physico-chemical properties of water samples collected from Baghdara lake (values are mean ± SD ; n = 9)

Month	pH	Conductivity	DO	DOC	NO_3-N	PO_4-P
April	8.2 ± 0.30	1080.3 ± 84.6	7.6 ± 0.60	3.61 ± 0.06	112.00 ± 9.20	40.23 ± 3.91
May	8.2 ± 0.20	1136.3 ± 70.8	6.2 ± 0.33	3.78 ± 0.12	110.50 ± 12.05	27.10 ± 2.20
June	8.3 ± 0.09	1170.5 ± 91.3	6.0 ± 0.52	3.90 ± 0.16	92.10 ± 7.00	25.33 ± 3.82
July	8.6 ± 0.09	1182.4 ± 82.5	7.4 ± 0.43	3.34 ± 0.08	125.00 ± 12.56	49.85 ± 4.12
August	8.1 ± 0.3	942.8 ± 118.4	7.6 ± 0.15	3.30 ± 0.14	165.56 ± 20.15	42.10 ± 4.20
September	8.0 ± 0.3	926.3 ± 102.6	7.6 ± 0.24	3.08 ± 0.22	168.00 ± 12.56	40.32 ± 5.12
October	8.0 ± 0.2	983.7 ± 82.4	7.9 ± 0.36	2.68 ± 0.15	224.74 ± 20.05	46.15 ± 3.95
November	8.1 ± 0.06	1018.4 ± 78.5	8.5 ± 0.64	2.52 ± 0.32	262.00 ± 18.68	42.18 ± 3.25
December	8.1 ± 0.08	1046.2 ± 81.4	8.9 ± 1.10	2.29 ± 0.18	321.50 ± 20.92	36.35 ± 5.05
January	8.2 ± 0.15	1059.8 ± 92.8	9.2 ± 1.00	2.10 ± 0.20	320.62 ± 16.70	32.05 ± 3.66
February	8.2 ± 0.22	1105.2 ± 102.2	8.7 ± 1.11	2.54 ± 0.09	259.00 ± 22.07	30.38 ± 3.22
March	8.15 ± 0.30	1100.5 ± 79.5	7.9 ± 0.68	2.96 ± 0.14	175.20 ± 15.40	28.06 ± 2.35

All values, except pH, conductivity ($\mu S\ cm^{-1}$), nitrate-N ($\mu g\ l^{-1}$) and PO_4-P ($\mu g\ l^{-1}$) are in mg l^{-1}

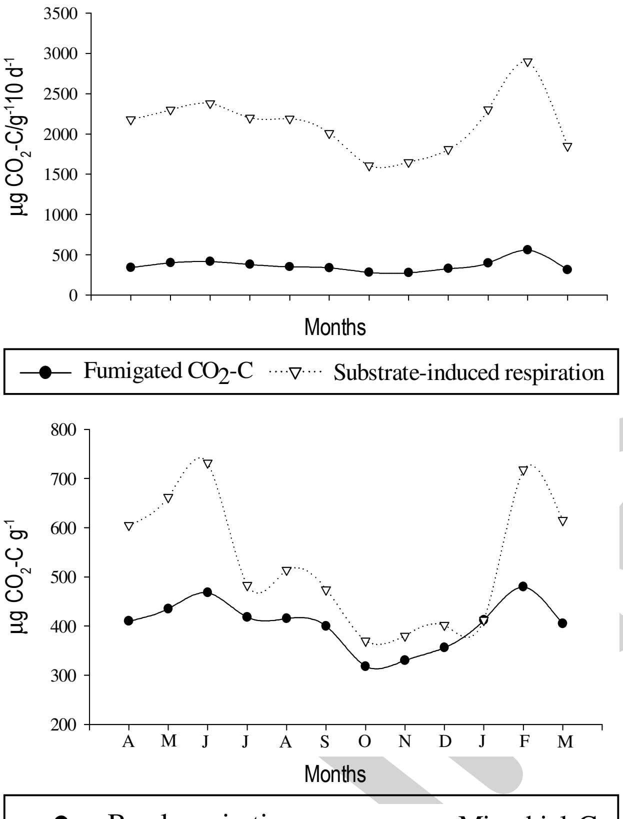

Fig. 1: Microbial biomass (C_{mic}) in humus collected from land water interface of Baghdara lake

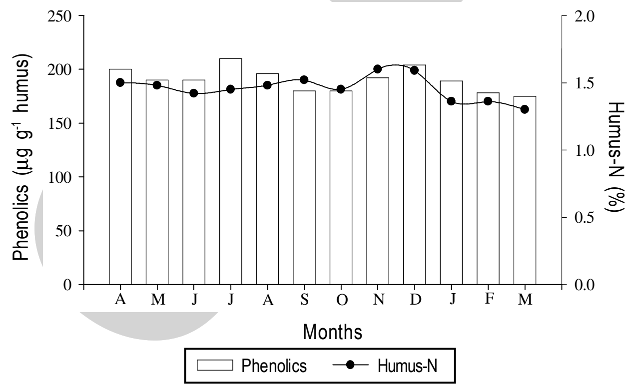

Fig. 2: Concentrations of total-N and phenolics in humus collected from land water interface of Baghdara lake

integrifolia, Acacia leucophlea and many others. The marginal weeds and land water interface vegetation include *Bacopa monnieri, Dichanthium annulatum, Barleria cristata, Polygonum glabrum, P. amphibium* and *Cyperus rotundus.*

Sampling and analysis: The present study includes three tiers of sampling for (a) microbial biomass at land water interface, (b) chemistry and biology of lake water and (c) sediment quality. Humus samples from land water interface and sub-surface water samples from the lake were collected in triplicates in pre-sterilized plastic containers and brought to the laboratory for analysis. Sediment samples (5-10 cm long cores) were collected using 2.5 cm diameter PVC tubes. Phytoplankton samples were collected using phytoplankton net of bolting silk. Phytoplankton samples were also collected using small sample bottles followed by concentration through centrifugation as described in Pandey and Sharma (2002).

Microbial biomass in humus was determined in terms of basal respiration and substrate induced respiration (SIR) following the method as described in Wardle (1993) and in terms of fumigated -C and microbial-C following Jenkinson and Powlson (1976). Phenolics and humus -N were measured using Folin's reagent method (Sadasivam and Manikam, 1996) and micro Kjeldahl analysis respectively. Organic -C in sediment was measured following Page *et al.*(1982). Sediment -N and P were determined following micro Kjeldahl method and Jackson (1973) respectively.

Water pH and conductivity were measured in the field using a Soil and Water Analysis Kit (Electronics India). Dissolved oxygen (DO) in sub-surface water samples were measured following modified Winkler method (APHA, 1998). Nitrate-N was determined by brucine- sulphanilic acid method. The details of the procedure is

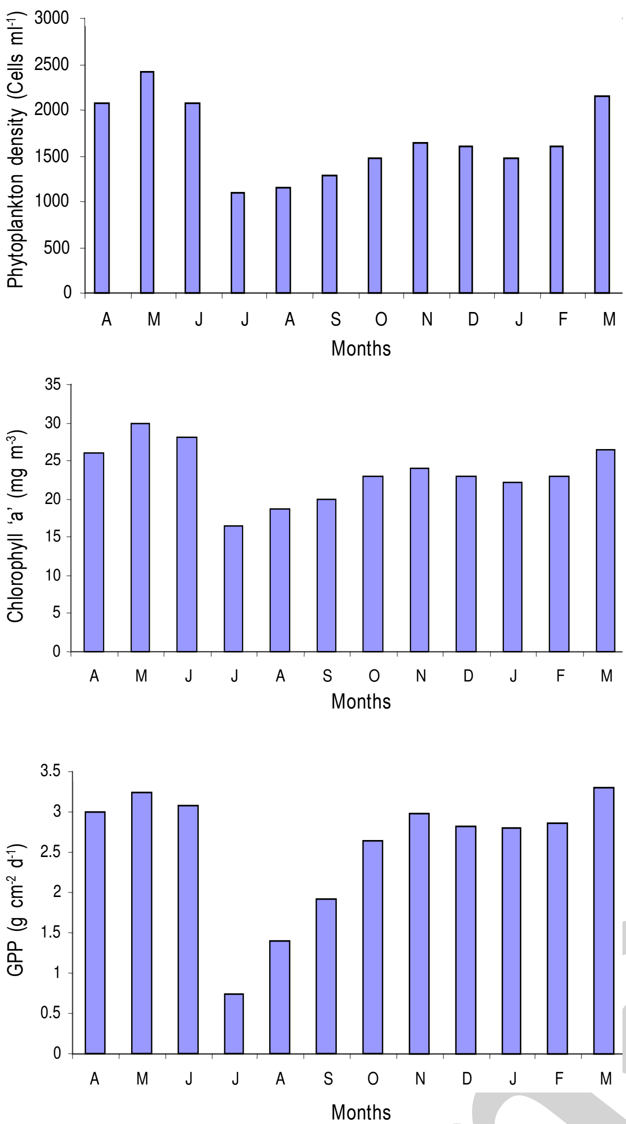

Fig. 3 : Monthly variations in phytoplankton density, chlorophyll concentration and gross primary productivity (GPP) of lake Baghdara

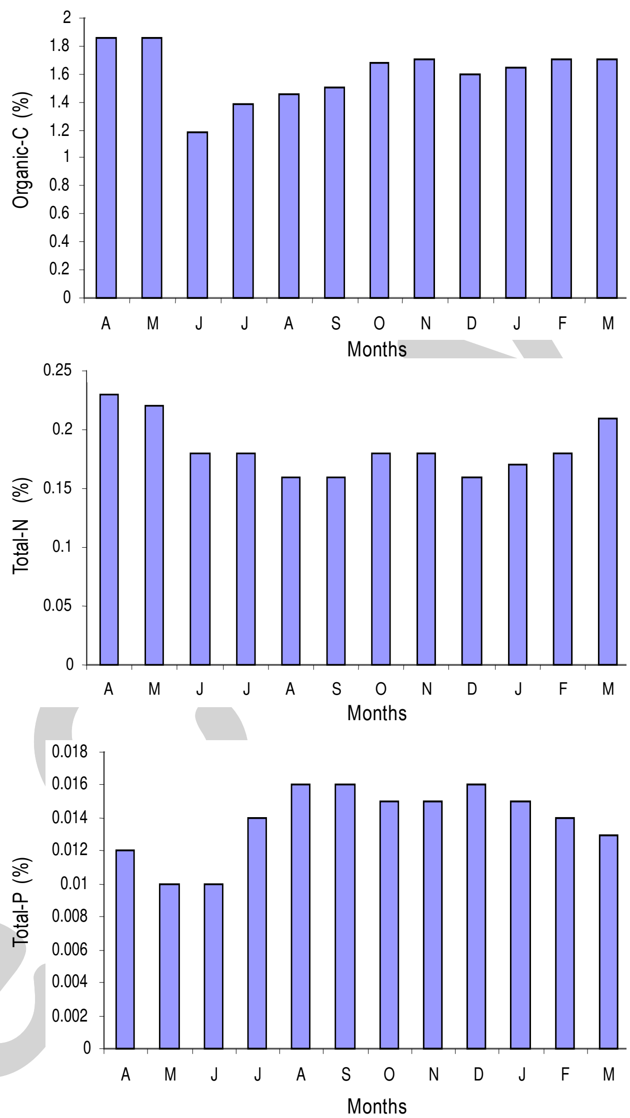

Fig. 4: Chemical characteristics of sediment cores collected from Baghdara lake

described in Manivaskam (1996). For determining phosphate-P, Olsen method was followed (Mackereth, 1963). For dissolved organic- C (DOC), $KMnO_4$ digestion method was followed (Michel, 1984). Phytoplankton density and chlorophyll pigment were determined as described in Pandey and Sharma (2002). Primary productivity was measured following light and dark bottle method (APHA, 1998).

Results and Discussion

Figure 1 shows the microbial biomass (C_{mic}) in humus samples collected from the land water interface of Baghdara lake. Microbial biomass – C in terms of basal respiration (BR) was maximum during February (480 µg CO_2-C g^{-1}) and minimum during October (318 µg CO_2-C g^{-1}). For substrate induced respiration (SIR), the trend was almost similar. Microbial-C extracted through chloroform fumigation was found maximum during February (560 µg CO_2-C g^{-1} 10 d^{-1}) and minimum during November (275 µg CO_2-C g^{-1} 10 d^{-1}). Humus-N and phenolics showed trends almost opposite to those observed for C_{mic} (Fig. 2). Humus-N accumulation was observed maximum during November (1.60%) and concentration of phenolics was maximum during December (204 µg g^{-1}). Lowest value of both (humus-N and phenolics) was observed during March.

Table 1shows physico-chemical properties of lake water. The pH of lake water although varied, remained almost above 8.0. Water conductivity remained maximum during June and minimum during September. The concentration of dissolved oxygen was high during winter and low during summer months. With rise in temperature dissolved oxygen declined from January to June from 9.2 mg l^{-1} to 6.0 mg l^{-1}(Table 1). Dissolved organic carbon (DOC) ranged between 2.10 mg l^{-1} (January) to 3.90 mg l^{-1} (June). Between month variations in DOC were well marked. Maximum concentration of nitrate-N in this study was 321.50 µg l^{-1} (during December) and that of phosphate-P was 49.85 µg l^{-1} (July). Concentration of NO_3–N and PO_4-P were lowest during June.

Phytoplankton density (number of cells ml^{-1}) averaged 2178 cells ml^{-1} during summer, 1250 cells ml^{-1} during monsoon and 1530 cells ml^{-1} during winter seasons (Fig. 3). Chlorophyll 'a' concentrations ranged from 16.53 mg m^{-3} (July) to 29.90 mg m^{-3} (May). Gross primary productivity also varied characteristically, the values being maximum during March (3.30 g C m^{-2} d^{-1}) and minimum during July (0.74 g C m^{-2} d^{-1}) (Fig. 3). The sediment –C concentration was highest during April to May (1.86%) and lowest during June (1.18%). For sediment-N, the trend was almost similar, the values being highest during April (0.23%) and lowest during June to July (0.18%). Sediment-P showed almost a similar trend.

The lake considered in the present study has no direct source of anthropogenic nutrient inputs. The important source of N and P import may be traced to be the natural processes such as weathering, microbially fixed-N, animal excreta and run-off materials through rain drainage from woodland catchment (Pandey and Pandey, 2001). The data indicate that the nutrient status of Baghdara lake have reached to the level close to be mesotrophic (Wetzel, 2001). Observations on chemical and biological characteristics of the lake are consistent with those of other studies on tropical lakes of India (Vyas *et al.*, 1990; Kaushik and Saxena, 1995; Venugopalan *et al*., 1998; Pandey and Pandey, 2002; Pandey and Yaduvanshi, 2005).

The process of decomposition is regulated mainly by climate across broad ecosystem types, but at finer scales, it is determined to a large extent by litter quality (Wardle and Lavelle, 1997). Among the most commonly accepted properties, the role of C:N ratio, lignin content, structural properties and concentrations of secondary metabolites such as phenolics in regulating soil microorganisms and the processes associated with nutrient cycling and decomposition is widely accepted (Northup *et al*., 1995; Nilsson *et al*., 1999). High concentrations of phenolics coinciding with the period of low microbial biomass (C_{mic}) and reduced microbial activity (SIR) in humus at land water interface suggest that the resources rich in phenolics could reduce microbial biomass available to decompose substrate and mineralize nutrients (Northup *et al.*, 1995). Presence of lignin and thick cuticle on fresh dry leaves and twig of woody species also delay microbial colonization (Taylor *et al*., 1980). Synchronized peaks of phenolics and humus-N further suggest that when humus phenolics was high, for instance during July to December, N at land water interface become immobilized due to the formation of protein-phenolics complexes (Northup *et al*., 1995). On temporal scale, both SIR (a relative measure of active microbial biomass) and C_{mic} declined when phenolics was higher.

Earlier studies have indicated that phytoplankton pulses, chlorophyll and primary productivity in tropical lakes are largely controlled by nutrient regimes (Pandey and Pandey, 2002). The data in this study were consistent with such observations. For instance, the synchronized peaks of phenolics with phytoplankton, chlorophyll 'a' and primary productivity suggest that during the phase of low resource quality (high phenolics), the declining microbial biomass at land water interface could increase nutrient release in lake water and consequently the productivity. During the period of rapid microbial growth (time of increasing microbial biomass), sizeable amount of nutrient is fixed in the proliferating cells which in turn, lower the concentration of nutrients available for other components of the ecosystem (Singh *et al*., 1989). Evidently, drawing upon the local nutrient sources (period of declining microbial biomass) phytoplankton could maintain high productivity in the ecosystem. Further, since the amount of sinking organic matter reaching to the sediment is generally proportional to the intensity of lake productivity (Aaby and Berglund, 1986), temporal dynamics of organic-C and nutrient concentrations in sediment correlated well with phytoplankton pulsation and productivity. The study suggests that the nature of substrate material may be the major factor in determining microbial biomass at land water interface, which in turn, affects nutrient mineralization and consequently, phytoplankton pulsation and primary productivity in woodland lakes void of direct human interference. Such observations may add new dimensions in freshwater ecology and help develop lake conservation and restoration strategies. This has relevance as the conservation of inland water bodies is our national priority.

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References

Aaby, B. and B. Berglund: Characterization of peat and lake deposits. *In*: Handbook of holocene palaeoecology and palaeohydrology (*Ed*.: B.E. Berglund) John Wiley and Sons, New York. pp. 231-246 (1986).

APHA.: Standard methods for the examination of water and wastewater. 20st Edn., Washington D.C. (1998).

Jackson, M.L.: Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi (1973).

Jenkinson, D.S. and D.S. Powlson: The effects of biocidal treatment on metabolism in soil, V.A. method for measuring soil biomass. *Soil Biol. Biochem.,* **8**, 209-213 (1976).

Kaushik, S. and D.N. Saxena: Trophic status and rotifer fauna of certain water bodies in central India. *J. Environ. Biol.,* **16**, 283-291 (1995).

Kominkova, D., K.A. Kuehn, N. Buising, D. Steiner and M.O. Gessner: Microbial biomass, growth and respiration associated with submerged litter of *Phragmites australis* decomposing in a littoral reed stand of a large lake. *Aqua. Microb. Ecol.,* **22**, 271-282 (2000).

Lang, G.E.: Litter dynamics in mixed oak forest on the New Jersey. *Piedmount. Bull. Torrey Bot. Club,* **101**, 277-286 (1974).

Mackereth, F.J.H.: Some methods of water analysis for limnologists. Fresh Water Biology Association for Scientific Publications, Ambleside (1963).

Manivaskam, N.: Physico-chemical examination of water, sewage and industrial effluents. Pragati Prakashan, Meerut (1996).

Michel, P.: Ecological Methods for Field and Laboratory Investigation. Tata McGraw Hill Publication Company, New Delhi (1984).

Nilsson, M.C., D.A. Wardle and A. Dahlberg: Effects of plant litter species composition and diversity on boreal forest plant soil system. *Oikos,* **86,** 16-26 (1999).

Northup, R., Z. Yu, R.A. Dahlgren and K.A. Vogt: Polyphenol control of nitrogen release from pine litter. *Nature,* **377**, 227-229 (1995).

Page, A.L., R.H. Miller and D.R. Keeney: Methods of soil analysis. Part 2. Chemical and microbial properties. ASA, Madison (1982).

Pandey, J. and U. Pandey: The influence of catchment on ecosystem properties of a tropical freshwater lake. *Biotronics,* **30**, 85-92 (2001).

Pandey, J. and M.S. Sharma: Environmental Science - Practical and Field manual, Yash Publications, Bikaner (2002).

Pandey, J. and U. Pandey: Cyanobacterial flora and the physico-chemical environment of six tropical fresh water lakes of Udaipur, India. *J. Environ. Sci.,* **14**, 54-62 (2002).

Pandey, J. and A. Verma: The influence of catchment on chemical and biological characteristics of two freshwater tropical lakes of southern Rajasthan. *J. Environ. Biol.,* **25**, 81-87 (2004).

Pandey, J. and M.S. Yaduvanshi: Rejuvenation of urban lakes in dry tropics: Problems and perspectives. *In*: Urban lakes in India : Conservation, management and rejuvenation (*Eds.*: K.K.S. Bhatia and S.D. Khobragade). M/S Anubhav Printers, Roorkee. pp. 321-328 (2005).

Polunin, N.V.C.: The decomposition of emergent macrophytes in freshwater. *Adv. Ecol. Res.,* **14**, 115-166 (1984).

Sadasivam, S. and A. Manickam: Biochemical Methods. 2nd Edn. New Age International (P) Ltd, New Delhi (1996).

Singh, J.S., A.S. Raghubanshi, R.S. Singh and S.C. Srivastava: Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. *Nature,* **338**, 499 - 500 (1989).

Smitha, P.G., K. Byrappa and S.N. Ramaswamy: Physico-chemical characteristics of water samples of Bantwal Taluk, south-western Karnataka, India. *J. Environ. Biol.,* **28**, 591-595 (2007).

Sridhar, R., T. Thangaradjou, S. Senthil Kumar and L. Kannan: Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. *J. Environ. Biol.,* **27**, 561-566 (2006).

Taylor, B.R., D. Parkinson and W.F.J. Parsons: Nitrogen and lignin contents as predictors of litter decay rates: A microcosm test. *Ecology,* **70**, 97-104 (1980).

Tiwari, Ashish and S.V.S. Chauhan: Seasonal phytoplanktonic diversity of Kitham lake, Agra. *J. Environ. Biol.*, **27**, 35-38 (2006).

Venugopalan, V.P., K. Nandakumar, R. Rajamohan, R. Sekar and K.V.K. Nair: Natural eutrophication and fish kill in a shallow freshwater lake. *Curr. Sci.*, **74**, 915-917 (1998).

Vyas, L.N., K.P. Sharma, S.K. Sankhla and B. Gopal: Primary production and energetics. *In*: Ecology and management of aquatic vegetation in the Indian subcontinent (*Ed.*: B. Gopal). Kluwer Academic Publishers, The Netherlands. pp.149- 175 (1990).

Wardle, D.A.: Response of the microbial biomass and metabolic quotient to leaf litter succession in some New Zealand forest and scrubland ecosystem. *Functional Ecol.,* **7**, 346-355 (1993).

Wardle, D.A.: Controls of temporal variability of the soil microbial biomass. A global scale synthesis. *Soil, Biol. Biochem.,* **30**, 1627-1637 (1999).

Wardle, D.A., G.W. Yeates, K.S. Nicholson, K.I. Bonner and R.N. Watson: Response of soil microbial biomass dynamics, activity and plant litter decomposition to agricultural intensification over a seven year period. *Soil Biol. Biochem.,* **31**, 1707-1720 (1999).

Wardle, D.A. and P. Lavelle: Linkage between soil biota, plant litter quality and decomposition. *In*: Driven by nature : Plant litter quality and decomposition (*Eds.*: G. Cadisch and K.E. Giller). CAB International, Wallingford (1997).

Wetzel, R.G.: Limnology - Lake and River Ecosystem. Academic Press, New York (2001).