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THE INFLUENCE OF CATCHMENT ON ECOSYSTEM PROPERTIES OF A TROPICAL FRESH WATER LAKE

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PANDEY J. and PANDEY U. *The influence of catchment on ecosystem properties of a tropical fresh water lake.* BIOTRONICS, 30, 85–92, 2001. We investigated the effects of catchment characteristics on ecosystem properties of Baghdara lake, a tropical fresh water reservoir of Udaipur, India. Being situated away from human settlement, the lake is subjected to comparatively minor human interference. The results indicated that the types of vegetation in lake catchment play a major role in determining soil biological properties such as microbial biomass at land–water interface, which in turn, affects nitrogen mineralization and consequently, phytoplankton populations and primary productivity of the lake. This has important bearing for ecosystem properties of fresh water lakes void of anthropogenic activities.

Key words: Lake catchment; ecosystem; phytoplankton; humus; microbial biomass.

INTRODUCTION

Lake catchment is frequently a major determinant of lake water chemistry (1), in turn, often has important effects on species composition and community structure (4); and consequently, on functioning of lake ecosystems (6, 19). For instance, allochthonous organic matter is the major source of energy (C–pool) and nutrient inputs for woodland lakes (11). Litter in such lakes may reach as vertical fall or as run-off material through rain drainage from around the catchment (1). The amount and quality of inputs in such lakes depend on the types of vegetation in the catchment area (5, 27). Similarly, a lake with intense agricultural activity in its catchment is likely to have high nutrient concentrations and productivity (17). Therefore, it is expected that lakes with different catchment characteristics would differ with respect to ecosystem properties. However, there have been few attempts at using catchment characteristics for evaluating ecosystem properties of fresh water lakes (7, 27). The present investigation aimed at determining the effects of catchment on ecosystem properties of a fresh water lake of southern Rajasthan.

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MATERIALS AND METHODS

Study Area

Our data are the result of two consecutive years of study conducted at Baghdara lake, a fresh water tropical reservoir (24°40' N lat. and 73°86' E long.), situated about 20 km SE of Udaipur city in the midst of a deciduous forest. Being situated away from Udaipur urban settlement, the lake is subjected to comparatively minor human interference. The lake (catchment 500 ha: water spread 1.8 km; max depth 8.5 m) is fed entirely by rainfall during monsoon and has no tributaries leading to it. The lake receive nutrients from natural sources such as weathering of rocks, microbially fixed-N, animal excreta including bird droppings and from run-off (both organic and inorganic materials) through rain drainage from the catchment.

Climate of the region is tropical. The year is divisible into three distinct seasons, a hot and dry summer (March to June), a warm and wet rainy (July to October) and a cool and dry winter (November to February). During study period, annual rainfall averaged 630 mm, about 90% of which occurred during rainy season. Relative humidity ranged between 20% (summer) to 90% (monsoon season). During summer, day time temperature ranged from 34° to 46.2°C. During winter, temperature varied between 10° to 23°C and night temperature some time dropped below 4°C.

Sampling and Analysis

Sampling was done at monthly intervals at two sampling stations selected on the basis of surrounding vegetation. Station I receive litter (both, vertical fall as well as run-off material through rain drainage) predominantly from tree species such as *Lannea coromandelica*, *Sterculia urens*, *Ficus racemifera*, *Phoenix dactylifera*, *Terminalia belerica*, *Bauhinia purpurea*, *Holoptelia integrifolia* and *Acacia leucophlea*. Station II is characterized by excessive growth of marginal weeds including *Polygonum glabrum*, *P. amphibium*, *Bacopa monnieri*, *Dichanthium annulatum*, *Cassia tora*, *Barleria cristata* and many other.

Water samples in triplicate were collected in presterilized bottles between 08:00 and 10:00 AM from three microsites of each station. Water temperature, transparency, pH and conductivity were all measured in the field (16). Remaining water quality parameters were measured following standard methods (2). Phytoplankton enumeration was done following Pandey et al. (18). Chlorophyll was estimated following Brody and Brody (3). Primary productivity was estimated by light and dark bottle method (29). Sediment samples in triplicate (5-10 cm long cores) were taken using 2.5 cm diameter PVC tubes. Organic-C in lake sediment was estimated following Page. et al. (15). Total N was determined through Kjeldahl analysis and total P as described by Jackson (8). Humus samples were collected from three microsites at land-water interface of each sampling station. Total phenolics in humus samples were measured using Folin-Ciocalteu reagent (20). Humus-N was determined as described above. Substrate induced respiration (SIR) was determined as described by

Wardle et al. (24) and fumigation approach was used for total microbial-C (C_{mic}) (9).

RESULTS

The seasonal mean water temperature ranged from 16.5°C. (winter) to 26.5°C (summer). pH of lake water remained >7. Transparency was low at station I. Average water conductivity ranged from 435 $\mu\text{S cm}^{-1}$ at station I to 482 $\mu\text{S cm}^{-1}$ at station II. Dissolved oxygen varied with season and was low at station II (Table 1). At station I, nitrate -N and phosphate-P ranged between 92.6 and 126.4 $\mu\text{g L}^{-1}$ ($\bar{x}=107.1 \mu\text{g L}^{-1}$) and between 15.6 and 20.6 $\mu\text{g L}^{-1}$ ($\bar{x}=17.0 \mu\text{g L}^{-1}$) respectively. At station II concentrations of N and P were high. Organic-C in lake sediment averaged 2.39% at station I and 3.20% at station II. Sediment N and P were high at station II (Table 2). Seasonal variations in organic-C and, in N and P concentrations in lake sediment were not significant.

Biological characteristics of lake water such as phytoplankton populations (cells ml^{-1}), chlorophyll *a*, and primary productivity varied with season and were high during summer (Table 3). Station II indicated a general superiority with respect to these parameters. Primary productivity ranged between 1.21

Table 1. Physico-chemical characteristics of water at two stations of Baghdara lake. *, ** indicate that differences between station I and II differ significantly at $p=0.05$ and 0.01 respectively (Analysis performed using paired t-tests).

Variables	I			II		
	W	S	R	W	S	R
Temperature (°C)	16.5	25.8	23.4	17.0	26.5	24.2
Transparency (m)	1.32	1.21	0.49	1.52**	1.38*	0.58*
pH	7.52	7.56	7.58	7.53	7.55	7.58
Conductivity ($\mu\text{S cm}^{-1}$)	435	439	456	450	468**	482*
Dissolved Oxygen (mg L^{-1})	9.5	6.1	6.6	6.6**	4.9*	5.2*
Nitrate-N ($\mu\text{g L}^{-1}$)	92.6	102.5	126.4	142.2**	148.0**	156.1*
Phosphate-P ($\mu\text{g L}^{-1}$)	15.6	16.1	19.4	16.3	18.2*	20.6

W: Winter; S: Summer; R: Rainy

Table 2. Chemical characteristics (mean \pm S.D.) of sediment cores collected from two stations (8 m reach) of Baghdara lake.

Parameters	Stations	
	I	II
Organic-C (%)	2.39 \pm 0.40	3.20 \pm 0.51
Total- N (%)	0.16 \pm 0.05	0.25 \pm 0.05
Total- P (%)	0.012 \pm 0.006	0.019 \pm 0.01

Table 3. Phytoplankton populations, chlorophyll *a* and primary productivity at two stations of Baghdara lake. Explanations for asterisks as in Table 1.

Stations Variables	I			II		
	W	S	R	W	S	R
Phytoplankton (cells ml ⁻¹)	1660	1920	1250	2650*	3165*	1740**
Chlorophyll <i>a</i> ($\mu\text{g L}^{-1}$)	24.5	26.2	19.8	41.5*	43.1**	35.6**
Primary productivity (g C m ⁻² d ⁻¹)	1.42	1.57	1.21	2.17**	2.26**	1.72*

W: Winter; S: Summer; R: Rainy

and 1.57 g C m⁻² d⁻¹ at station I and between 1.72 and 2.26 g C m⁻² d⁻¹ at station II. Other parameters showed similar trends. Humus chemical and microbial characteristics also showed significant between site variations (Fig. 1). Humus N and phenolics were high at station I whereas microbial biomass (C_{mic}) and substrate-induced respiration (SIR) were maximum at station II. Seasonal variations in humus N and phenolics were less marked.

DISCUSSION

Our results indicate that the nutrient status of Baghdara lake have reached the level close to be mesotrophic (28). This fresh water reservoir has no anthropogenic source of nutrient input. The important sources of N- and P import may be traced to be the natural processes such as weathering, microbially fixed N, animal excreta and the run-off materials through rain drainage from lake catchment (17). Our observations on phytoplankton populations (cells ml⁻¹), chlorophyll and primary productivity were found to be consistent with other studies on tropical fresh water lakes (21).

Decomposition process is regulated mainly by climate across broad ecosystem types, but at finer scales, it is determined to a large extent by litter quality (25). Amongst the most widely accepted properties are C:N ratio, lignin content, structural properties and concentrations of secondary metabolites such as phenolics. Significance of phenolics in regulating soil microflora and in determining processes associated with nutrient cycling and decomposition is widely accepted (8, 25). High concentration of phenolics, low microbial biomass (C_{mic}) and reduced microbial activity in humus at station I suggest that the resources rich in phenolics could reduce microbial biomass available to decompose substrate and mineralize nutrients (14). Presence of lignin and thick cuticle on leaves and twigs of woody species also delay microbial colonization (23). Humus N was high at station I suggesting that N at station I becomes immobilized due to formation of protein-phenolics complexes (14, 25). Inhibi-

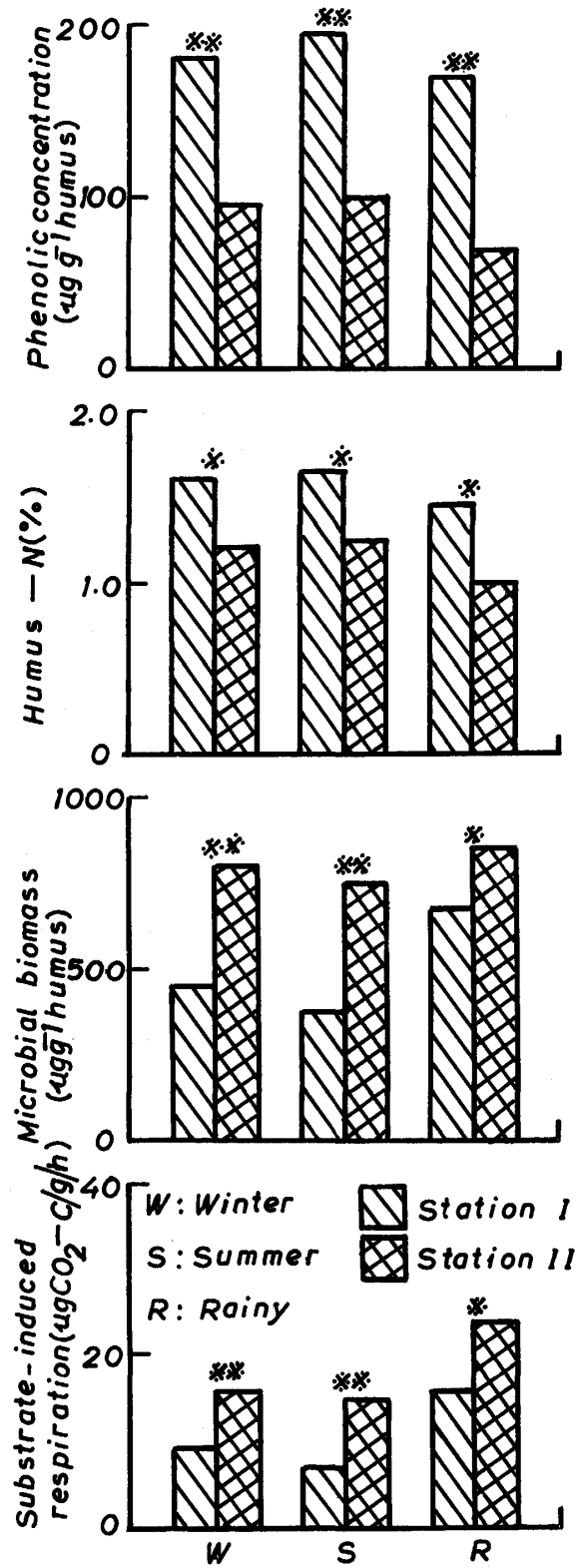


Figure 1. Humus chemical and microbial characteristics at two stations of Baghdara lake of Udaipur. Explanations for asterisks as in Table 1.

tion of microbial activity at land-water interface probably contributes to the substantial accumulation of humus at station I (data not shown). Both SIR (a relative measure of active microbial biomass) and C_{mic} were high at station II characterized by effective growth of marginal weeds. This effect of herbaceous weed residues relative to those of trees is probably because herb residues are more easily decomposable and have higher nutrient contents than do the tree foliage (26). Further, temporal variation in C_{mic} was greater at station I; higher during monsoon when vertical fall of litter was frequently mixed with run-off materials from lake catchment. Thus, tree foliage seems to promote a less stable microbial biomass and weed residues act as a stable source of nutrient release across the year.

Earlier observations have indicated that phytoplankton pulses and primary productivity in tropical lakes are largely controlled by nutrient regimes (10). Our observations were consistent with this - we found high concentrations of phytoplankton (cells ml^{-1}), chlorophyll *a* and high primary productivity at station II. It appears that higher resource quality (e.g., high N and low amounts of cuticle and phenolics) provided by herbaceous weed residues (12, 13) at station II, increase microbial activity at land-water interface and consequently, increase nutrient release in the lake water. Evidently, drawing upon the local nutrient sources, phytoplanktons at station II maintained high productivity in the ecosystem. Further, since the amount of sinking organic matter reaching the sediment is generally in proportion to the intensity of lake productivity (2), organic-C and nutrient concentrations were high in sediment at station II.

Our study has demonstrated that catchment effects can be of critical importance in determining ecosystem properties of fresh water lakes void of human interference. The types of vegetation in lake catchment are the major factors in determining soil biological properties such as microbial biomass at land-water interface, which in turn, affect nitrogen mineralization and consequently, phytoplankton populations and primary productivity in woodland lakes. The study further suggests that, unlike dry tropical forests and savanna where microbial biomass declines during wet season (22), microbial biomass at land-water interface in woodland lakes increases during this period when vertical fall of litter is frequently mixed with run-off materials from the lake catchment. However, more studies are needed to clarify this issue.

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