THE INFLUENCE OF CATCHMENT MODIFICATIONS ON TWO FRESHWATER LAKES OF UDAIPUR

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ABSTRACT

The present research is an effort to invesitigate the effects of catchment modifications on chemical and biological characteristics of two freshwater tropical lakes of Udaipur, Rajasthan. The lakes, Fateh sagar and Bari, considered in this study, differ wih respect to the catchment characteristics and level of human interference. The chosen determinants were pH, chloride, sulphate, dissolved organic-C, nitrate-N, phosphate-P, phytoplankton density, chlorophyll biomass and primary productivity. Changes in water chemistry were related with the nature of catchment flushing and trophic status of both the lakes.

The study indicated that the catchment characteristics and the extent of human modifications have influenced the water chemistry and ecosystem functioning of both the lakes considered in this study. Lake Bari although situated away from direct human interference, supported good phytoplankton density and productivity due to input of nutrients as atmospheric deposition from aerial catchment in addition to the drainage through the terrestrial catchments. The study demonstrated that the modifications in terrestrial catchment when combined with atmospheric deposition accelerate eutrophication of freshwater lakes.

INTRODUCTION

Recent global attention has shown serious concern towards the need for water resource conservation and evaluation of the role of anthropogenic perturbations in modifying surface water resources. Of the many factors, nutrient flushing is an important determinant of lake ecosystem structure and functioning. Most of the nutrients found in lakes enter through rain drainage from the terrestrial catchment, direct discharge from anthropogenic sources and through atmospheric deposition from the aerial catchment. Nutrient levels in lake waters often reflect the land-use within the catchment. For instance, allochthonous organic matter is the major source of nutrients for woodland lakes (Pandey and Pandey, 2001). The amount and quality of such inputs depend on the types of vegetation in the catchment area (Gessner *et al.*, 1999). For instance, substrate with high resource quality (e.g. high N) increase nutrient release in lake water (Nilsson *et. al.*, 1999). Similarly, agricultural activity in the catchment adds sizeable amount of nutrient into the lakes and consequently increases their productivity (Pandey *et al.*, 1999). Thus, lakes with different catchment characteristics and the nature and magnitude of anthropogenic modifications differ with respect to their nutrient level and ecosystem properties. It is therefore, important to quantify the external nutrient loading through different catchment types and to analyse the magnitude of spatial variations under different anthropogenic perturbations. Substantial efforts have been spent on quantifying nutrient outputs from different land-use categories in temperate regions (Lepisto *et al.*, 1995). However, data on these lines for tropical freshwater lakes of India are lacking. The present study deals with run-off losses of carbon, sulphates and various species of nitrogen and phosphorus from different land-use categories in the catchment of two lakes in southern Rajasthan. An effort is made to relate catchment nutrient import with water chemistry and biology of these lakes.

MATERIALS AND METHODS

The present study was conducted from March 2004 to February 2005 at two freshwater lakes of Udaipur. Lake Fatehsagar (24° 35′ N lat and 73° 37′ E long ; 578 m above msl) receive nutrients partly from urban wash and partly from forests. Lake Bari, situated about 9 km NW of Udaipur city (24° 36′ N lat and 73° 37′ E long and 588 m above msl) is subjected to less human interference as direct discharge but under the influence of changes in land-use in its catchment. Climate of the region is tropical with extended period of dryness. The mean annual precipitation during the study period was 567 mm falling mainly in monsoon. Mean monthly summer temperature some time exceeds 40°C. The region is situated in in the Aravali hill tract characterized by its Cambrian geology mainly composed of quartzite sandstone and limestones. Six catchment 'categories' were chosen based on the nature of parent material, dominant plant species and the type of disturbances to which they were subjected. Three of these were situated around Fatehsagar and remaining three around the lake Bari (Table 1). Two of these are undisturbed (woodland; bare and tussocked) and the remaining four are subjected to physical disturbances by various human activities (soil ploughed and agriculture; excavated for exploitation of sediment and the bedrock; urban and pasture land).

Table 1. Characteristics of the catchments

Catchment 'category'	Lake	Parent material	Dominant plant species
Woodland (W)	Bari	Calcareous	*Acacia senegal, Zizyphus jujuba, Bauhinia racemosa Acacia leucopholea*
Agricultural (A)	Bari	Clayey alluvium	Wheat, Maize, Sorghum
Bare and tussocked (BT)	Bari	Silicified quartzite	*Euphorbia royleana, Calotropis procera*
Urban (U)	Fatehsagar	Silicified quartzite	*Cassia tora, Parthenium sp, Lantana camara*
Pasture land (P)	Fatehsagar	Clayey alluvium	*Dichanthium annulatum, Cynodon dactylon, Cyperus rotundus, Calotropis procera*
Excavation (E)	Fatehsagar	Calcareous quartzite	*Acacia senegal, Zizyphus jujuba, Calotropis procera*

The run-off waters in triplicate were collected during monsoon along the topographical gradient from six different catchment categories. The variables such as dissolved organic-C, nitrate, nitrite, ammonium, soluble organic-N, orthophosphates and total soluble-P in run-off waters were measured following standard methods (APHA, 1998). Water samples in triplicate were collected from both the lakes at monthly intervals for the same hydrological cycle. Water quality variables studied were pH, dissolved organic-C (Michel, 1984) nitrate-N, and phosphate-P (APHA, 1998).

Phytoplankton enumeration was done following Pandey and Pandey (2002). Chlorophyll was measured following Brody and Brody (1961). For primary productivity, light and dark bottle method was followed (Wetzel and Likens, 1979). The results obtained for chemical and biological characteristics of lake waters were analyzed using two-way analysis of variance.

RESULTS AND DISCUSSION

The run-off concentrations of dissolved organic-C (DOC), sulphates and different fractions of nitrogen and phosphorus varied with catchment (Table 2). For dissolved organic-C, the run-off

Table 2. Run-off output of DOC, sulphates and different fractions of N and P from different catchment of two lakes. (values are mean ± 1SD)

Variables	W	A	BT	U	P	E
Dissolved organic-C (mg L^{-1})	8.10 ± 0.95	7.15 ± 0.92	4.20 ± 0.58	5.20 ± 0.61	6.95 ± 0.74	3.25 ± 0.38
Sulphates (mg L^{-1})	4.82 ± 0.54	14.02 ±1.50	8.20 ± 0.86	14.67 ± 1.60	7.65 ± 0.77	7.20 ±0.76
Nitrate-N (µg L^{-1})	58.4 ± 6.12	126.2 ±12.95	20.5 ± 1.80	67.15 ± 7.20	88.67 ± 9.16	14.15 ±1.60
Nitrite-N (µg L^{-1})	30.50 ± 3.67	68.80 ± 7.22	16.84 ± 1.76	36.80 ± 4.10	55.80 ± 5.90	9.10 ± 1.24
Ammonium-N (µg L^{-1})	34.00 ± 3.80	112.50 ± 12.05	12.20 ±1.41	15.12 ± 1.67	104.00 ±10.9	6.80 ± 0.67
Soluble organic-N (µg L^{-1})	106.10 ±12.18	190.65 ±20.04	38.10 ± 4.33	109.28 ±11.21	180.20 ± 19.60	285.6 ± 3.21
Orthophosphates (µg L^{-1})	16.84 ± 2.05	25.10 ± 2.67	6.20 ± 0.72	18.80 ± 1.69	21.26 ±2.50	7.80 ± 0.86
Total soluble-P (µg L^{-1})	20.25 ± 2.40	40.86 ± 4.67	10.6 ±1.30	28.6 ± 3.10	29.80 ± 3.30	16.80 ± 1.76

output ranged from 3.25 to 8.10 mg L^{-1}. The values being maximum at woodland catchment and minimum at excavation sites (Table 2). An almost similar trend was observed for different fractions of P. The run-off loss of orthophosphates varied between 6.20 µg L^{-1}, (bare and tussocked catchment) and 25.10 µg L^{-1} (agricultural catchment). Sulphate in run-off was maximum for urban catchment. For nitrogen, the run-off loss was observed maximum at agricultural catchment followed by pasture land and lowest for bare and tussocked catchment.

Table 3. Atmospheric deposition of N, P and S at two lake sites of Udaipur

Variable	Fatehsagar	Bari
Dry deposition (Kg ha^{-1} a^{-1})		
Total –N	9.96 ± 0.98	4.16 ± 0.46
Total- P	0.78± 0.08	0.37 ± 0.04
SO_4-S	13.06± 1.40	6.19 ± 0.71
Wet deposition (Kg ha^{-1} a^{-1})		
Total –N	14.90± 1.62	8.28 ± 0.92
Total- P	1.96± 2.18	1.21 ± 0.13
SO_4-S	18.74 ± 2.02	16.15 ± 1.78

This trend was similar for all the nitrogen fractions. Among the nitrogen species, the export of nitrite-N appeared to be the lowest for all the catchments. Input of N, P and S through aerial catchment remained high for Fatehsagar (Table 3). With respect to the lake water quality, pH remained high for Bari lake while chloride, SO_4-S, NO_3-N, and PO_4-P remained high for lake Fatehsagar (Table 4). Between lake variations for DOC were not significant (Table 4 and 5).

The spatial variations in nutrient import through run-off as observed in the present study, may be explained by catchment heterogeneity and by the human modifications such as the changes in land-use (Rhazi *et.al.*, 2001). Effects of anthropogenic forcing have been indicated by the rising trends in nutrient concentrations (Pandey and Verma, 2004). The run-off import of N from the catchment characterized by agricultural activities (catchment A) was higher relative to those from the woodland (catchment W) and other less disturbed areas. Because geological sources of nitrogen are small, the nitrogen yields in run-off from less disturbed catchments were low. The run-off yields of phosphate-P and total-P were higher for urban catchment in comparison to the others. Total-P concentrations more than 20 µg L^{-1} could be considered high for catchments that are undisturbed, vegetated and poor in nutrients (Lepisto *et.al.*, 1995). The high phosphorus yield may indicate high weathering rates or atmospheric transport and deposition through aerial catchment.

Table 4. Physico-chemical characteristics of lake waters. Values are mean ± SD

	Lake					
	Fateh Sagar			**Bari**		
	S	R	W	S	R	W
pH	7.10 ±0.67	7.50 ± 0.71	7.20 ± 0.46	7.80 ± 0.60	8.10 ±0.51	7.38 ± 0.47
TDS (mg L^{-1})	618.10 ±67.00	854.30 ± 90.22	586.60 ± 64.05	500.50 ± 52.80	682.10 ± 73.10	475.00 ± 50.86
Chloride (mg L^{-1})	236 .46 ± 25.05	181.40 ± 20.01	201.79 ± 22.04	161.35 ± 16.18	127.30 ± 13.67	142.00 ±15.10
SO_4-S (mg L^{-1})	36.76 ± 4.11	20.18 ± 1.92	30.05 ± 2.96	34.20 ±4.40	16.90 ±2.00	26.70 ±3.02
NO_3-N (µg L^{-1})	179.85 ± 22.01	249.05 ± 31.50	205.10 ± 24.81	76.22 ± 6.90	107.67 ± 11.80	90.37 ± 10.40
PO_4-P (µg L^{-1})	82.30 ± 9.28	116.52 ± 13.48	101.00 ± 12.01	39.04 ± 5.20	56.39 ± 6.76	49.27 ± 5.18
DOC (mg L^{-1})	2.27 ± 0.30	2.49 ± 0.31	2.40 ± 0.26	2.10 ± 0.23	2.36 ± 0.22	2.21 ± 0.25

The atmospheric deposition of nutrients to terrestrial ecosystem in many part of the world has increased dramatically due to anthropogenic activities (Kauppi *et al.*, 1990). Löfgren (1991) estimated the range of dry deposition to be upto 6 kg N ha^{-1} a^{-1} in background areas of Scandinavia. This could be significantly enhanced in areas receiving anthropogenically transported nutrients as was evident in case of Fateh sagar.

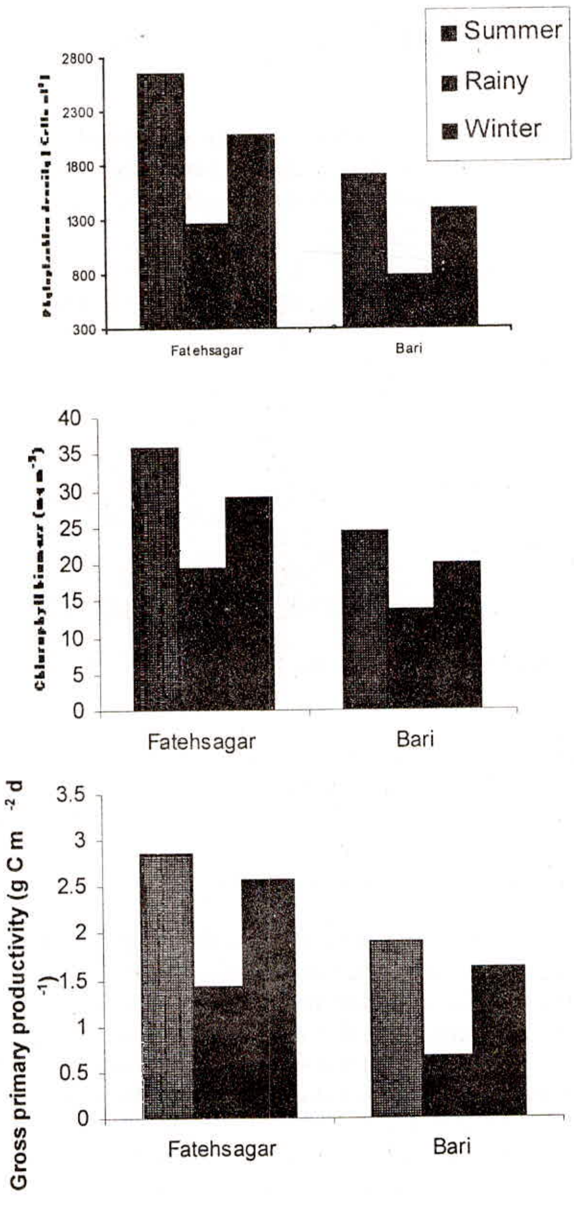

Figure 1. Biological characteristics of two lakes at Udaipur

Anthropogenic activities in catchment may upset nutrient cycle by decreasing plant uptake or enhancing mineralization (Lepisto *et al.*, 1995). Studies conducted in forested catchment have indicated that nutrient retention is most pronounced during biomass accumulation (Vitousek and Reiners, 1975) and mature forest ecosystems have high yield of critical nutrients (Lewis, 1986). However, since the region considered in the present study is charaterized by extended period of dryness where forest growth is arrested for most months of the year, significant biomass accumulations and nutrient retention seemed unlikely. Furthermore, according to Gundersen (1992), at high C:N ratio in soil, readily available-C increase the immobilization of N by

Table 6. Variance ratios (F) obtained from two-way analysis of variance (ANOVA) for different water quality variables

(Data were log transformed when necessary to equalize variance)

Parameters	L	S	L x S
pH	18.25**	26.74**	1.08 ^{NS}
TDS	31.04**	47.28**	16.71**
Chloride	22.24**	36.18**	19.20**
SO_4-S	16.20**	24.86**	0.98 ^{NS}
NO_3-N	49.30**	68.10**	41.20**
PO_4-P	30.10**	39.44**	21.71**
DOC	2.10 ^{NS}	13.67**	5.91**
Phytoplankton density	118.00**	263.75**	98.07**
Chlorophyll biomass	49.08**	71.82**	36.90**
GPP	86.40**	138.76**	63.20**

(L : lakes; S : seasons; L x S : interactions)

F ratios significant at 5 %; **significant at 1 %; NS: not significant

microflora and consequently the capacity of soil to retain N. When compared with those having agricultural activity, the run-off output from woodland catchment was found to be enriched in carbon. For the former however, the yield was enriched in nitrogen. These trends were also reflected in lake water as the DOC was equally high in Bari characterized by large woodland catchment while N and P concentration were high in Fatehsagar characterized by agricultural activity, pasture land and urban catchment.

Our study suggests that the nature of catchment and the extent of human modification play important role regulating ecosystem properties of freshwater lakes. The type of vegetation in the terrestrial catchment, land-use pattern and the atmospheric deposition through aerial catchment were the major determinant of nutrient status and consequently, phytoplankton population and primary productivity in these lakes. Furthermore, although direct human discharge affects lake water quality in a major way, the latter appeared to be the result of cumulative effects of all possible forcing factors including catchment characteristics, land-use change, atmospheric deposition and other modifications. Among the catchment modifications, agricultural practices appeared to contribute maximally in determining lake water quality. This has relevance in formulating catchment management plans and strategies for rejuvenation of freshwater lakes.

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