ZOO-Journal 5: 41-47, 2019 **Research Article** ***ISSN: 2631-2204***

TEMPORAL CHANGES OF WATER QUALITY PARAMETERS IN RUPA LAKE AND THEIR IMPACT ON PRODUCTIVITY

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ABSTRACT

Knowledge on nutrient dynamics of the lake provide basis for modality and extent of exploitation of fishery resources. Therefore, a long-term data of physico-chemical parameters was analyzed for the assessment of changing aquatic environment and its impact on aquatic biodiversity. The physical and chemical properties of water have been changed over 14 years (1994 to 2007). Increase in mean annual concentrations of dissolved oxygen in recent years (2002 to 2007) were recorded in the lake, which indicate improvement in water quality due to lake restoration. Annual mean pH levels were not consistent to produce specific trends. The pH of the water increased from 1994 to 2002, and then decreased continuously in later period. Water transparency increased with the decreased chlorophyll 'a' concentration during 1999 to 2002 due to degraded condition. The higher concentrations (0.010-0.017 mgl^{-1}) of soluble reactive phosphorous (SRP- PO_4) were recorded during 1994 to 2000, later SRP concentration (0.003-0.012 mgl^{-1}) tend to reduce. Effect of fluctuation in the physico-chemical properties on the lake productivity in terms of fish yield was assessed.

Key words: Nutrients, pH, DO, transparency, $chlorophyll_a$.

INTRODUCTION

Ever increasing population, urbanization and modernization are posing problems of sewage disposal and contamination of surface waters. Natural water gets contaminated due to weathering of rocks, leaching of soils and mine processing, etc. Various types of problems in lake which cause nutrient enrichment have been reviewed (Bhateria and Jain, 2016). Most energy enters a small lake through terrestrial photosynthesis in the watershed. About one-half of the incident PAR (photosynthetically active radiation) is reflected or refracted at the lake surface, and much of the rest may be absorbed by lake water and organic matter dissolved in it. Where suitable conditions develop at the water sediment interface, substances contained in the sediments including nutrients are released into the water column. The quantity of nutrients in lake water is mainly determined by bedrock type, vegetation cover size, and human activities in the catchment area (Kalif, 2002; Wetzel, 2006).

Water level fluctuations play a significant role in the lake nutrient dynamics, and consequently may have a strong influence on the biological communities and productivity (Stefanidis and Papastergiadou, 2013). The current tragedy for most small lakes in Nepal is their rapid sedimentation associated with high rainfall, traditional agriculture in catchments, deforestation, landslide, flood, eutrophication, draining for agricultural use and encroachment (Bhandari, 1998; IUCN, 2004). Mostly, all Asian lakes are known for over human activities in catchment areas (Groombridge and Jenkins, 1998). A considerable number of studies have

DOI: https://doi.org/10.3126/zooj.v5i0.34781

been done on limnological features of Rupa Lake (Ferro, 1981/1982; Nakanishi, *et al*. 1998; Rai, 1998; Rai, 2000; Gurung, 2007). This study attempts to analyze the long-term physico-chemical data for the assessment of the changing trends in environmental variables of Rupa Lake for further management in relation to lake productivity and sustainability.

MATERIALS AND METHODS

Study Area

Lake Rupa watershed is located between 28° 08′ N to 28°10′ N latitude and 84° 06′ E to 84° 07 E longitudes, at 600 m above sea level in central Nepal with an estimated water surface area of about 100 hectare (Gurung, 2007) (Figure 1). The total catchment area of the lake is about 30 km². The lake is elongated from north to south like a river basin surrounded by hills in east and west, while in immediate north are rice fields followed by hills. The outlet opens at southern end in between the rice fields. The lake was known to originate by depression or the blockage on its outlets. The water sampling sites for limnological variables were located in the middle part of the lake.

Figure 1. Location map of study area.

Sampling

The time series data were taken from FRS, Pokhara. Water samples for physical and chemical parameters of water were collected monthly from middle part of Lake Rupa starting from January to December from year 1994-2007. Samples were taken from three depth gradients viz., 0.0m, 1.0 m, and 2.0 m using Vandorn water sampler of 3 liter capacity. Water temperature and pH were measured in situ using a thermometer and SIBATA pH kit, respectively. A sub-sample of 1 liter water was taken for chlorophylla and water nutrient analysis. Nutrient analysis of water began after the collection of the samples in the laboratory at FRC, Pokhara. The standard methods involved in the nutrient analysis of water were ammonium - nitrogen (NH_4-N) by Bower and Hansen (1980), nitrite and nitrate - nitrogen (NO_2 and NO_3-N) by Downes (1978), and phosphate – phosphorous (PO_4-P) by Murphy and Rilay (1962). Chlorophyll 'a' was determined using the acetone extraction method (Lorenzen, 1967). Fourteen years of physico-chemical variables data were summarized for assessment of trend in Rupa Lake using Microsoft Excel Program 2013 and SPSS version 15.

RESULTS AND DISCUSSION

Annual trends of water quality parameters

The mean, standard deviation and range of all variables from year 1994-2007 are presented in Table 1. The physico-chemical properties of water varied annually in Rupa Lake as indicated by annual mean value (Figure 2A-G and Table 1).

Annual mean value (1994-2007) of Dissolved Inorganic Nitrogen (DIN) varied year to year. The highest concentration was found in the year 2003 (0.053 mg.l^{-1}) and lowest in the year 2007(0.019 mg.l^{-1}). The annual mean value of Soluble Reactive Phosphorus (SRP) concentration was declining with annual fluctuation. The annual mean value (1994-2007) of chlorophyll 'a' concentration showed decreasing trend from the year 1998 to 2001 and thereafter increasing trend from the year 2002 to 2007. Decline of chorophyll 'a' concentration was due to degraded condition of lake with heavy macrovegetation coverage and the increase in chlorophyll 'a' after 2002 was due to restoration of lake with cleaning of unwanted vegetation (Gurung, 2007). The annual mean value of water temperature (1994-2007) were not consistent and ranged from 11°C to 33°C. The annual mean (1994-2007) of dissolved oxygen concentration showed increasing trend from the year 1997 to 2004 and thereafter concentration decreased in the next two years with lowest concentration (5.5 mg L^{-1}) in the year 1997 and the highest concentration (7.3 mg L^{-1}) in 2007. The annual fluctuation value of water quality parameters of Rupa Lake may be due to annual rainfall fluctuation in the Pokhara Valley. Wehwnmeyer *et al.* (2004) found that water quality parameters change with heavy precipitation in the catchment area.

Table 1. The range, mean and standard deviation (SD) of water quality parameters in Rupa Lake (1994-2007).

Variable	**Depth →**	0.0 m	1.0 m	2.0 m	Whole column
	Range	11.0-33 .0	11.0 - 28.5	11.0 - 28.5	11.0 -33.0
Temperature (°C)	Mean ±SD	22.0±4.4	21.9 ±4.6	21.6 ±4.6	21.8±4.3
pH	Range	4.5 – 8.4	5.8 – 8.4	6.1 – 8.5	4.5 – 8.6
	Mean ±SD	7.9	7.9	7.8	7.8
Dissolved oxygen	Range	1.6 -11.6	1.3 -12	0.6 -12	1.3 -12
(mg l^{-1})	Mean ±SD	6.8 ± 2.0	6.6 ±2.0	6.0 ± 2.2	6.4 ±2.0
	Range	0.1- 3.2	-	-	-
Transparency (m)	Mean ±SD	1.5 ± 0.6			
Chlorophyll $_a$ (mg m^{-3})	Range	1.0 – 74.5	1.0 -78.2	1.0 -49.4	1.0 -78.2
	Mean ±SD	11.27±13.1	10.1±11.5	9.2± 9.0	10.2 ±11.2
SRP (mg l^{-1})	Range	0.0 – 0.155	0.0 - 0.140	0.0 – 0.105	0.0 – 0.155
	Mean ±SD	0.010±0.117	0.010 ± 0.014	0.009±0.012	0.010 ± 0.014
DIN (mg l^{-1})	Range	0.0- 1.935	0.0 – 0.892	0.0 – 0.892	0.0- 1.935
	Mean ±SD	0.119±0.204	0.108 ± 0.134	0.110±0.136	0.112 ±0.156

Depthwise trends of water quality parameters

The column annual mean (1994-2007) value of water quality parameter trends showed variation with depth. The DIN concentration was highest in upper layer followed by lower layer and lowest concentration in column of water. Soluble reactive phosphorus, chlorophyll 'a', water temperature, pH and dissolved oxygen decreased as depth increased, as also summarized by Kalif (2002) and Wetzel (2006).

Table 2. Seasonal mean values of water quality parameters of Rupa Lake (1994 -2007).

Variable	Season		
	Winter	**Dry**	**Wet**
SRP (mgL^{-1})	0.006	0.007	0.014
Chlorophyll a (mgm^{-3})	10.2	8.3	11.3
DIN(mgL^{-1})	0.146	0.105	0.090
Temperature (^{0}C)	16.9	22.5	25.5
DO (mgL^{-1})	7.7	4.4	6.7
p^H	7.8	7.9	7.8
Transparency(m)	1.7	1.2	1.5

Seasonal trends of water quality parameters

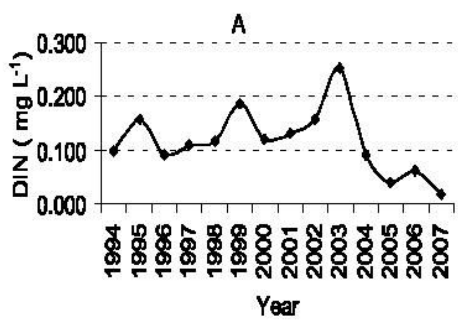
The mean value of environmental variables by season from 1994 to 2007 showed changing trends in the Rupa Lake (Table 2). The DIN concentration was highest in the winter followed by dry with lowest concentration in the wet season. In contrast to DIN, SRP concentration was higher in the wet followed by dry season with lowest in the winter season. This pattern of SRP was due to inflow of water containing heavy sediments and organic matter from the catchment area in the wet season. Miranda and Matvienko (2000) gave details of phosphorus (P) sources in a small reservoir Saupaulo, Brazil, as 82% from rivers, 12% from ground water and 6% from direct rainfall. The chlorophyll 'a' concentration was highest in the wet followed by winter and lowest in the dry season. The increased nutrients input was favorable in wet for algal growth. This nutrients input increased from catchments cultivated area (Oli, 1996). The dissolved oxygen concentration was highest in the winter followed by wet season and lowest in the dry season, which was coincided to transparency trends. pH value did not fluctuate with season.

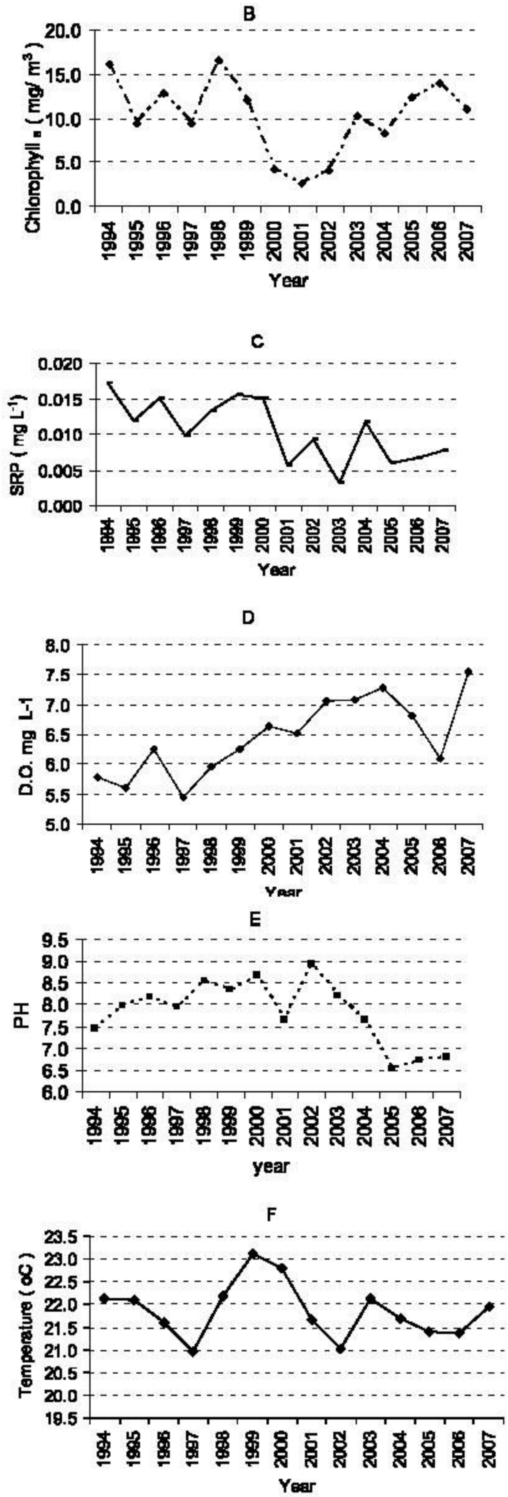
The DIN concentration peaked in the months January and May (0.166 mgl^{-1}) and lowest (0.041 $mg.l^{-1}$) in October. The DIN concentration trend steadily declined from the months of June to October (Figure 3A). Soluble reactive phosphorus was lowest in March (0.005 $mg.l^{-1}$) and thereafter concentration steadily increased from April-August and highest in August (0.024 $mg.l^{-1}$) and then steadily declined till December (Figure 3C). Both nitrate (NO_3-N) and ammonia (NH_4-N) concentrations were highly variable during lake seasonal cycles (Bhateria and Jain, 2016).

The concentration of chlorophyll 'a' was peaked in September (16.2 mgm^{-3}) and go down in April (6.2 mgm^3) coincided to PEG (Plankton Ecology Group) model (Sommer *et al.*, 1986) and it is associated with SRP (Figure 3C). Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events including accelerated plant growth, algal blooms, low dissolved oxygen and the death of certain fish, invertebrates and other aquatic animals (Bhateria and Jain, 2016).

Transparency was highest (1.9 m) in January and lowest in May (1.0 m). pH value was highest in May (8.0) and steadily declined and reached to lowest in November (7.6). Dissolved oxygen concentrations peaked in the month of January (8.0 mgl^{-1}) and thereafter decreased to lowest concentration in April (4.0 mgl^{-1}). Water temperature increased from February with the increasing atmospheric temperature and reached to maximum in June, stable from July to September and then gradually declined to minimum level in January.

Chlorophyll 'a' concentration is best parameter for assessing trophic status of lake. Based on Wetzel (2006) classification, mean value (from year 1994 to 2007) of chlorophyll 'a' concentration (10.2 mg/m^3) is under eutrophic condition, also concluded same by Nakanishi *et al.* (1988), Rai (1998) and Gurung (2007).





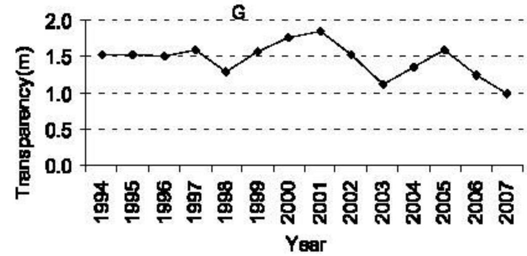


Figure 2. Annual mean value (1994-2007) of environmental variables in Lake Rupa. A. Dissolved inorganic nitrogen, B. $Chlorophyll_a$, C. Soluble Reative Phoshphorus, D. Dissolved oxygen, E. pH, F. Water temperature and G. Transparency.

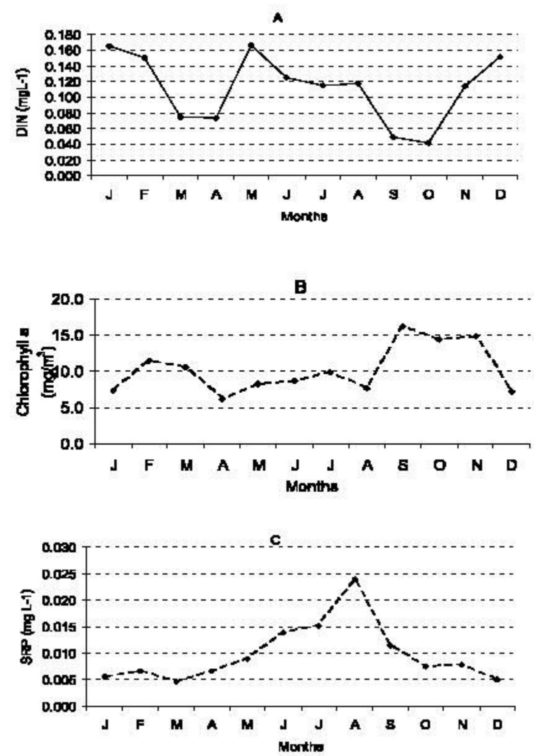


Figure 3. Monthly mean variation of nutrients and chlorophyll 'a' in Rupa Lake from year 1994-2007. A. Dissolved inorganic nitrogen, B. $Chlorophyll_a$ and C. Soluble reactive phosphorus.

CONCLUSION

The mean depth, surface area and total depth have been continually decreasing in Lake Rupa. These changes bring a lot of variations in water quality parameters which will certainly bring significant impact on lake productivity. The increase in eutrophication may cause sudden mass mortality of fish. It is now necessary to make a dam for raising the water level. Rupa Lake is at present managed by Rupa Lake Cooperative initiated in the year 2002. However, it is still necessary to initiate a master plan for lake conservation and management for future sustainability.

ACKNOWLEDGEMENTS

We thank all staff of Fishery Research Station, Pokhara for regular water quality monitoring. The fund for present study was provided by Nepal Agricultural Research Council (NARC)

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(Received July 7, 2019; revised accepted September 9, 2019)