

INVENTORYING AND MONITORING OF AQUATIC PLANT DIVERSITY OF FLUVIAL ECOSYSTEM OF RAJAJI NATIONAL PARK, UTTARAKHAND, INDIA

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Abstract : Aquatic plant diversity and the physico-chemical characteristics of the aquatic habitat of Song and Suswa river flowing in the Rajaji National Park, Uttarakhand, has been monitored seasonally. Four sampling sites S₁, S₂, S₃ and S₄ were identified. S₁ and S₂, at Song river S₃ and S₄ at Suswa river of Rajaji National Park. Seasonal sampling was done and the study revealed that diversity has been found to be high in winter months comparatively due to low turbidity, high water transparency, high dissolved oxygen and low water velocity

Keywords: Inventoring, Monitoring, Physico-chemical parameters, Aquatic, Habitats, Rajaji National Park

INTRODUCTION

Biodiversity or biological diversity encompasses all species of plants, animals and micro-organisms and the ecosystems and ecological processes of which they are parts. It is an umbrella term for the degree of nature's variety including both the number and frequency of ecosystems, species or genes in a given assemblage. Human survival depends on biodiversity, not only for food, fibre and health but also for recreation. yet human activities particularly for the last two decades, have led to extinction of many spacio-temporal variations in biodiversity and relationship of biodiversity with ecosystem stability and resilience have been the subject of concern of ecologists for some time now (Odum,1971). Aquatic biodiversity has been recognised as one of the most potential and essential characteristics of life for proper functioning of fluvial ecosystem and as a means for coping with natural and anthropogenic environmental changes. Aquatic biodiversity reflects the conditions existing in the environment and estimates the biological monitoring of water pollution level. For ascertaining the biological status of the river, the qualitative and quantitative investigations of trophic levels including Phytoplankton and Periphytic biota are important. The contribution on aquatic plant diversity of freshwater ecosystems have been made by Berner 1951; Schmitz 1954 1961; Douglas 1958; Mc Conell and Singler 1959; Whitford 1960; Grezenda *et al.* 1960; Holden and Green 1960; Woods 1965; Williams 1966; Golterman *et al.* 1969; Hynes 1971; Whitton 1975; Crayton and Summerfield 1979; Sze 1981; Stevenson 1984, 1996; Biggs and Close 1989; Allan and Flecker, 1993; Biggs 1995, 1996, 1998; Biggs and Thompson 1995; Biggs and Gerbeaux 1993; Benson-Evans *et al.* 1975; Haury 1996; Allan 1997; Quinn *et al.* 1997; Clausen and Biggs 2000; Biggs *et al.* 1998; Pollock *et al.* 1998; Horner *et al.* 1990; Biggs, 1996, Clausen and Biggs 1999; Iida and Ladona 2000, Smith *et al.* 2000; Walsh *et al.* 2001, Rojo *et al.* 2002; Hankinson and

Blanch 2003; Harrison *et al.* 2004 and Sharma 2002, 2005).

Study Sites

Rajaji National Park is situated in the foothills of Shiwalik Range of the newly carved out state Uttarakhand. It is the part of the Dehradun, Haridwar and Pauri district of Uttarakhand.

Three sanctuaries, Motichur Sanctuary (59.5sq.km), Rajaji Sanctuary (247.0sq.km), Chila Sanctuary (249.02sq.km) and other reserve forests (234.5sq.km) are amalgamated into large protected area which is named as Rajaji National Park. The total area of the Rajaji National Park is 820.42km². To the north of the Rajaji National Park lies the Dehradun and Tehri Forest Division. River Suswa forms the northern natural boundary upto Ganges.

River Ganges divides the Park into two units, the Chila Sanctuary complex in the east and Rajaji Motichur Sanctuary Complex in the west. To the south of Rajaji lies the revenue lands and villages of Haridwar District. Part of south eastern portion is covered by Bijnore forest division. The Garhwal forest division lies to the east of the park. Rawsan river forms a small portion of natural south eastern boundary of the park. To the west of the Rajaji lies the Shiwalik Forest Division. Song and Suswa are two perennial rivers draining Rajaji National Park in north eastern slopes of Shiwalik. The north eastern slopes of Shiwaliks are very steep and rugged in the upper portion but in the lower portion it has a quiet easy gradient. There are large number of short, shallow dry and bouldery streams locally known as "raus" coming down from upper slopes and carrying their discharge into Song and Suswa rivers. The forest on both the sides of the Suswa river is more or less on flat or gently sloping area often cut by nalas. The forests of eastern Doon are drained by Suswa and Song rivers. River Song and Suswa form its confluence in the Banbaha forest block. From there, it flows in a south eastern direction till it discharges into the Ganges near Satyanarian. Some seasonal

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tributaries also meet Song and Suswa river at Bindal, Rispana, Ren and Jakhan. The river Suswa flows very nearly opposite to Asan river to the east of Saharanpur-Mussoorie highway and flows in a south easterly direction to discharge into the Song. After a preliminary survey of Song and Suswa river, four sampling sites (S_1 , S_2 , S_3 and S_4) were selected. S_1 and S_2 were identified at Song river and S_3 and S_4 were identified at the Suswa river. Site S_1 was selected at Shampur, S_2 at Chidderwala, S_3 at Satyanarian and S_4 at Kansrao.

Considerable work has been done on the terrestrial biodiversity of Rajaji National Park (Diwakar; 1995, Panwar and Mishra; 1994), but less information is available so far on the aquatic plant diversity and the function of fluvial ecosystem of Rajaji National Park. Therefore the present work on the inventoring and monitoring of aquatic plant diversity of the river Song and Suswa of Rajaji National Park was carried out.

MATERIAL AND METHOD

Sampling was conducted seasonally winter (November-February), Summer (March-June) and Monsoon (July-October). Air and Water temperature was recorded with the help of a Centigrade 0-110 °C thermometer. The mean velocity was measured using electromagnetic current meter (model-PVM-2A). pH was estimated by control dynamics pH meter (model-APX15\°C) while turbidity was measured by turbidity meter (model-5D1M). Nitrates and phosphates were estimated by the spectrophotometer (Spectronic 20D Series) and sodium and potassium were estimated by the digital flame photometer (model-1381). Dissolved oxygen and Free CO₂ were measured following methods outlined in APHA (1998). The control dynamics conductivity meter (model-API 185) was used for measuring conductivity. All these parameters were determined following the standard methods outlined in Welch (1952), APHA (1998) and Wetzel and Likens (1992). Some of the physico-chemical parameters were analysed at the spot and rest were determined at the laboratory. For the analysis of biological parameters, the samples of periphyton were preserved in 4% formalin for quantitative study, while phytoplankton was preserved in Lugol's solution and 3% formalin, respectively. The quantitative analysis was made by using Ward and Whipple (1992) and several taxonomic keys and manuals of Freshwater Biological Association, UK.

The percentage cover of different sized substrata within each surber quadrat was estimated visually using the substrate size classes (after Bovee and Milhous 1978) of sand (0.06-2mm), fine gravel (2-32mm), coarse gravel (32-64mm), cobbles (64-256mm) and boulders (>256mm) with Surber Sampler (0.5mm mesh net) to a depth about 10cm in a quadrat. Samples were preserved in 4% formalin.

RESULT AND DISCUSSION

Periphytons (attached algae) are also the dominant primary producers in the fluvial system of Rajaji National Park. A total of 51 genera of periphyton were recorded from the fluvial ecosystem of Rajaji National park. Periphyton were represented by Bacillariophyceae (38 genera), Chlorophyceae (9 genera) and Myxophyceae (4 genera) Table 2. Periphyton community showed maximum abundance during winter season and minimum during monsoon season. Maximum periphytonic biomass was observed in Danish lowland streams during spring season (Sand Jenson *et al.* 1988). Gusain (1991) recorded maximum periphyton biomass during winter in Bhilangana river, Garhwal Himalayas. While Shamsudin and Sleight (1994) recorded maximum periphyton biomass during spring season in Chalk stream and soft water stream. Moore (1997) and Morin (2004) recorded an increase in periphytic biomass in sub-arctic streams during summers when low temperature was recorded. For temperate streams, Cox (1990) recorded a minimum biomass in winter, with a spring maxima, followed by unpredictable fluctuations in biomass during summer.

The water temperature was recorded maximum (23.95+_{-1.77}°C) in monsoon season and minimum (20.56+_{-1.43}°C) in winter season during the study period. The air temperature was found to be maximum (28.21+_{-0.86} °C) again in monsoon season and minimum (24.58+_{-1.84} °C) in winter season. The dissolved oxygen was found higher in winter months and minimum in monsoon while free CO₂ was found to be maximum in monsoon and minimum in winter while turbidity, conductivity and total dissolved solvents show decreasing trend in summer and winter months. Sodium and potassium show irregular trend in their concentration (Table 1). The water temperature fluctuated with the air temperature at all the four sampling sites. Both air and water temperature were correlated positively ($r = 0.804$) during the present investigation. Dissolved oxygen showed negative correlation ($r = -0.674$) with water temperature and turbidity ($r = -0.893$) during the study period. (Table 3). Welch (1952) stated that capacity of water for oxygen enhanced with the decrease in temperature. The concentration of dissolved oxygen in water gives a measure of photosynthetic production minus loss by diffusion, consumption, decomposition and respiration.

Water temperature was found to have negative relationship with periphyton density ($r = -0.747$ $p > 0.02$) under the present study. Water current showed a negative relationship with periphyton density in both the rivers (Table 4). Many aquatic plant populations living in the harsh environment of unpredictable flow suffer high mortality from physiological stress during high flow (Cushman 1985). Increased velocities flush and remove attached algae by abrasion from surfaces and may also break off long strand of filamentous

algae (Biggs and Thomsen 1995). Elevated velocities alone can be very destructive for stream periphyton (Boulten *et al.* 1992; Sharma *et al.* 2002, 2005), Peterson and Stevenson 1990). Even rolling of stones occurs during flash floods and creates an unstable habitat for periphyton. The periphyton density was found to be minimum during monsoon season, when the water velocity was found to be maximum. Therefore, it was inferred that low biomass during monsoon season was reasonably due to frequent disturbances (frequent floods and unstable bed sediments) in riverine ecosystem of Rajaji National park.

Periphytonic density was negatively correlated with turbidity. Turbidity was recorded maximum in monsoon season, when the periphyton abundance and diversity was recorded to be minimum. Welch (1952) also pointed out an adverse impact of turbidity on algal populations. Sharma *et al.* (2002) observed that the periphyton loss rate increases as the concentration of suspended solids attained higher concentration. During high flows, increased sediment movement from the catchment area and rainfall reduced the periphyton mass in the fluvial system of Rajaji National park.

No significant relationship was found to occur between dissolved oxygen concentration and periphytonic density. The total dissolved solids (TDS) showed a significant negative relationship with periphyton density. Biggs and Gerbeaux (1993) also noticed a negative correlation between temporal changes in periphyton biomass and dissolved inorganic nutrient in fresh water ecosystem of New Zealand. Inorganic nutrient supplies are also one of

the important driving variables for primary production and potentially act in association with disturbance to set the overall habitat template for periphyton in stream ecosystem (Biggs 1995, 1998)

The amount and nature of biological activities are directly correlated with the concentration of free CO₂ available in water (Morin *et al.* 2004). During the present investigation very low concentration of free CO₂ was observed in water of Song and Suswa rivers. It was recorded higher in monsoon while a low concentration was observed in winters. The rise in monsoon may be attributed due to retarded photosynthetic activity or due to low oxygen consumption by the organic matter in turbid state of water or due to failure of carbon dioxide being poorly utilized during the state of low phytoplankton density (Bhat *et al.* 1985 and Sharma 2000).

Free CO₂ was negatively correlated with dissolved oxygen ($r = -0.731$) and pH ($r = -0.350$) during the study period. Reduction in pH is attributed due to influx of carbon dioxide in the form of carbonic acid through rain water (Khan 1994). Similar relationship was also ascertained by Badola and Singh (1981), Nautiyal (1986) and Sharma (1991), in the rivers of Garhwal Himalaya. Conductivity showed a positive correlation with alkalinity and total dissolved solvents during the study period. (Table 3).

Mountain stream may show very little plankton even in their lower course and true plankton is absent in the upper parts of the stream system (Welch, 1952). Periphyton was dominated in winters and early summers while scanty specimens were available during flash floods of monsoon seasons in the fluvial system of Rajaji National Park. (Table 5)

Table 1. Seasonal Variations in physico-chemical parameters in the fluvial system of Rajaji National Park.

Parameters	Winter (Nov.-Feb.)	Summer (Mar.-Jun.)	Monsoon (Jul.-Oct.)
Air temperature (°C)	24.58±1.84	27.31±0.95	28.21±0.86
Water temperature (°C)	20.56±1.43	23.69±1.41	23.95±1.77
Water current (m sec ⁻¹)	0.48±0.11	0.58±0.10	1.07±0.47
Turbidity (NTU)	0.00±0.00	84.00±6.48	81.50±16.29
HMD (cm)	42.11±1.93	44.11±2.84	45.96±2.52
Transparency (cm)	42.11±1.93	44.11±2.84	45.96±2.52
Conductivity (µm cm ⁻¹)	0.34±0.02	0.40±0.06	0.38±0.04
TDS (mg l ⁻¹)	244.3±79.07	491.87±80.92	607.50±155.11
Dissolved oxygen (mg l ⁻¹)	14.48±0.70	12.65±1.46	10.28±1.67
Free CO ₂ (mg l ⁻¹)	0.33±0.24	0.58±0.24	0.99±0.67
pH	8.19±0.24	8.21±0.23	8.15±0.18
Phosphates (mg l ⁻¹)	0.07±0.00	0.07±0.00	0.07±0.00
Nitrates (mg l ⁻¹)	0.02±0.02	0.02±0.02	0.03±0.02
Chlorides (mg l ⁻¹)	4.46±0.40	5.58±0.75	4.70±0.39
Alkalinity (mg l ⁻¹)	20.93±8.20	39.06±10.20	46.56±9.95
Sodium (mg l ⁻¹)	14.18±2.97	14.93±2.86	18.37±2.52
Potassium (mg l ⁻¹)	0.45±0.12	0.58±0.09	0.75±0.11

Table 2. Mean seasonal variations in the density (org.m⁻²) of periphyton dwelling in fluvial system of Rajaji National Park

Periphyton	Winter	Summer	Monsoon	Autumn
Bacillariophyceae				
<i>A.lanceolata</i>	+++	+++	—	++
<i>A.lanceolata</i> f. <i>capitata</i>	+++	++	+	++
<i>A. ovalis</i>	+++	++	+	++
<i>A. bisoletiana</i>	++	++	++	++
<i>A. brevipes</i>	+++	++	-	++
<i>A. clevie</i>	++	+++	-	++
<i>A.exilis</i>	+++	++	-	++
<i>Amphora ovalis</i>	+++	++	+	++
<i>Bacillara paradoxa</i>	++	+++	--	++
<i>Cyclotella glomerata</i>	++	++	-	++
<i>Cyclotella stelligera</i>	++	+++	-	++
<i>Cymbella affinis</i>	+++	++	-	+
<i>C. lacustris</i>	+++	-	+	++
<i>C. turgida</i>	+++	-	+	++
<i>Diatoma anceps</i>	+++	+++	-	++
<i>D. vulgare</i>	++	++	-	+
<i>Fragilaria capucina</i>	++	++	-	++
<i>F.intermedia</i>	++	++	-	++
<i>F. lapponica</i>	+++	+++	-	++
<i>F. Pinnata</i>	++	-	-	++
<i>Gomphonema gracile</i>	+++	+++	-	++
<i>G. longiceps</i>	++	+++	-++	+
<i>G. subtile</i>	+++	+	+	++
<i>Hantzschia amphioxys</i>	+++	++	++	++
<i>Meridion circulare</i>	+++	++	+	++
<i>Navicula bacillum</i>	++	+	+	++
<i>N. radiosa</i>	+++	++	+	+
<i>N. rostellata</i>	+++	++	+	++
<i>N. dissipata</i>	++	+++	+	++
<i>N. ampibia</i>	+++	+++	+	++
<i>N. capitella</i>	+++	+	+	++
<i>Nitzschia sigmoidea</i>	+++	++	-	++
<i>N. denticulate</i>	++	++	-	++
<i>N. linearis</i>	++	++	-	++
<i>Synedra acus</i>	++	++	-	+
<i>S. rumpens</i>	+++	++	-	++
<i>S. ulna</i>	+++	+	-	++
<i>Tabellaria fenestrata</i>	+++	++	-	++
Chlorophyceae				
<i>Chlomydomonas</i> spp.	+++	++	+	++
<i>Chlorella</i> spp.	+++	+	+	+
<i>Cadophora glomerata</i>	++	-	-	-
<i>Closterium</i> spp	+++	++	-	++
<i>Gonatozygon</i>	++	++	-	+
<i>Glomerata</i>	++	+++	-	++
<i>Spirogyra</i>	++	++	-	++
<i>Ulothrix zonata</i>	++	++	+	++
<i>Zygnema</i>	+++	++	+	++
Cyanophyceae				
<i>Anabaena</i> spp.	+++	++	-	++
<i>Microcrosis</i> spp.	++	++	-	+
<i>Oscillatoria</i> spp.	+++	++	-	++
<i>Phormidium</i> spp.	++	+	-	+

+++ abundant; ++ present; + rare; - absent

Table 3. Correlation between hydrological attributes of the fluvial system of Rajaji National Park .

	AT	WT	WC	Tu	HMD	Ta	Co	TDS	DO	F Co2	pH	PO3	NO3	Chl	Alk	Na	K
AT	1																
WT	0.804	1															
WC	0.520	0.476	1														
Tu	0.676	0.605	0.681	1													
HMD	0.535	0.675	0.556	0.618	1												
Ta	0.535	0.675	0.556	0.618	1.000	1											
Co	0.167	-0.044	0.268	0.368	0.273	0.273	1										
TDS	0.869	0.749	0.672	0.751	0.589	0.589	0.208	1									
DO	-0.830	-0.674	-0.659	-0.893	-0.609	-0.609	-0.246	-0.870	1								
F Co2	0.592	0.602	0.668	0.756	0.656	0.656	0.084	0.740	-0.731	1							
pH	0.161	0.082	-0.101	0.002	-0.101	-0.101	-0.021	-0.061	-0.062	-0.104	1						
PO3	0.199	0.542	-0.029	0.165	0.235	0.235	-0.333	0.101	-0.137	0.135	0.374	1					
NO3	0.094	0.146	0.171	0.185	0.561	0.561	0.352	0.162	-0.167	0.270	-0.350	-0.170	1				
Chl	0.115	0.368	-0.179	-0.194	0.025	0.025	-0.504	-0.020	0.113	-0.175	0.044	0.396	-0.218	1			
Alk	0.072	-0.215	0.200	0.109	-0.243	-0.243	0.291	0.117	-0.084	0.043	0.400	-0.333	-0.503	-0.192	1		
Na	0.530	0.350	0.573	0.565	0.359	0.359	0.146	0.576	-0.661	0.511	0.128	-0.074	0.158	-0.269	0.146	1	
K	0.791	0.721	0.632	0.712	0.606	0.606	0.152	0.774	-0.819	0.593	0.128	0.196	0.093	0.148	0.118	0.539	1

Abbreviations : A.T= Air temperature, W.T = Water temperature, W.C = Water Current, HMD = Hydro medium depth, Ta = Transparency, Tu = Turbidity, Co = Conductivity, TDS = Total Dissolved Solids, pH = Hydrogen Ion Concentration, D.O = Dissolved Oxygen, F.CO₂ = Free Carbon dioxide, NO₂ = Nitrates, PO₃ = Phosphates, Na = Sodium, K = Potassium

Table 4. Correlation between hydrological attributes and density of aquatic diversity dwelling in the fluvial system of Rajaji National Park.

	Dn	AT	WT	WC	Tu	HMD	Ta	Co	TDS	DO	F Co2	pH	PO3	NO3	Chl	Alk	Na	K
Dn	1																	
AT	-0.894	1																
WT	-0.747	0.804	1															
WC	-0.585	0.520	0.476	1														
Tu	-0.721	0.676	0.605	0.681	1													
HMD	-0.683	0.535	0.675	0.556	0.618	1												
Ta	-0.683	0.535	0.675	0.556	0.618	1.000	1											
Co	-0.340	0.167	-0.044	0.268	0.368	0.273	0.273	1										
TDS	-0.880	0.869	0.749	0.672	0.751	0.589	0.589	0.208	1									
DO	0.868	-0.830	-0.674	-0.659	-0.893	-0.609	-0.609	-0.246	-0.870	1								
F Co2	-0.624	0.592	0.602	0.668	0.756	0.656	0.656	0.084	0.740	-0.731	1							
pH	-0.098	0.161	0.082	-0.101	0.002	-0.101	-0.101	-0.021	-0.061	-0.062	-0.104	1						
PO3	-0.119	0.199	0.542	-0.029	0.165	0.235	0.235	-0.333	0.101	-0.137	0.135	0.374	1					
NO3	-0.243	0.094	0.146	0.171	0.185	0.561	0.561	0.352	0.162	-0.167	0.270	-0.350	-0.170	1				
Chl	-0.016	0.115	0.368	-0.179	-0.194	0.025	0.025	-0.504	-0.020	0.113	-0.175	0.044	0.396	-0.218	1			
Alk	-0.086	0.072	-0.215	0.200	0.109	-0.243	-0.243	0.291	0.117	-0.084	0.043	0.400	-0.333	-0.503	-0.192	1		
Na	-0.545	0.530	0.350	0.573	0.565	0.359	0.359	0.146	0.576	-0.661	0.511	0.128	-0.074	0.158	-0.269	0.146	1	
K	-0.767	0.791	0.721	0.632	0.712	0.606	0.606	0.152	0.774	-0.819	0.593	0.128	0.196	0.093	0.148	0.118	0.539	1

Abbreviations : Den = density, A.T= Air temperature, W.T = Water temperature, W.C = Water Current, HMD = Hydro medium depth, Ta = Transparency, Tu = Turbidity, Co = Conductivity, TDS = Total Dissolved Solids, pH = Hydrogen Ion Concentration, D.O = Dissolved Oxygen, F.CO₂ = Free Carbon dioxide, NO₂ = Nitrates, PO₃ = Phosphates, Na = Sodium, K = Potassium

Table 5. Seasonal Variations in diversity indices of aquatic plants dwelling in the fluvial system of Rajaji National Park

Season/Year	Winter	Summer	Monsoon	Autumn
2001-2002	3.495±0.15	3.375±0.13	3.088±0.08	3.247±0.04
2002-2003	3.613±0.17	3.485±0.17	3.203±0.40	3.288±0.05

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