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ECOLOGY OF PLANKTON COMMUNITY OF RIVER SINDH IN KASHMIR HIMALAYA

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ABSTRACT

The present study reports on the ecology of plankton community along the longitudinal gradient of River Sindh, a tributary of River Jhelum in Kashmir valley. A total of 75 taxa of phytoplankton and 17 taxa of zooplankton were recorded in the plankton community. Various ecological factors responsible for controlling the density and diversity of these microscopic organisms are discussed. The zooplankton were observed to be negatively correlated with the current velocity ($r = -0.382$). In comparison to the fast flowing reaches, the slow flowing calm water reach of the river recorded a good density and diversity of both phytoplankton and zooplankton.

Key words: Potamoplankton, rhithron, potamon, ecology, River Sindh, Kashmir Himalaya.

INTRODUCTION

It has been a matter of debate for a long time whether or not the fluvial systems support a true plankton community. It was suggested that any river plankton was the result of displacement of cells from the benthos, backwaters and lakes or impoundments along the river's course, and reflected washout and export rather than a true 'potamoplankton' (Allan, 1995). Tett *et al.*, (1978) believed that periphytic algae can be swept away to form a 'pseudophytoplankton', especially in fast flowing rivers. Swanson and Bachmann (1976) opined that the river phytoplankton are simply the sloughed periphyton in transit. Studies in headwater streams have shown that the flowing water contains representatives of benthic algae (phytobenthos) as phytoplankton (Butcher, 1932; Cushing, 1964). According to Odum (1971) the plankton are assumed to be absent from streams, since such organisms are at the mercy of current, they are soon destroyed as they pass through rapids. The author believed the plankton to be of least importance in stream economy, but in slow moving parts of streams and rivers, they can rapidly grow and multiply. Some earlier reports on the plankton community of River Jhelum are available (e.g. Vass *et al.*, 1977; Raina *et al.*, 1982); however both these studies have been undertaken in the slow flowing reaches of the river, and a truly gradient-wise analysis is still lacking for Kashmir flowing waters. The present report aims to highlight some of the possible ecological factors that govern the growth and abundance of plankton communities in rivers and streams.

STUDY SITES

River Sindh is a major tributary of River Jhelum in Kashmir valley and flows in south-westerly direction through the Greater Himalayan range for about 118 km from the base of Saskūt peak upto Narayan Bagh where it merges with the River Jhelum. Sindh is a fast flowing torrential river in its upper and middle reaches, while as in the lower reaches it becomes calm and flows slowly. Four sites were selected for the analysis of plankton community, three (Sites I, II and III) in the mainstem channel of River Sindh and one (Site IV) in Kanknaz Nalla, a tributary of Sindh (Fig. 1.).

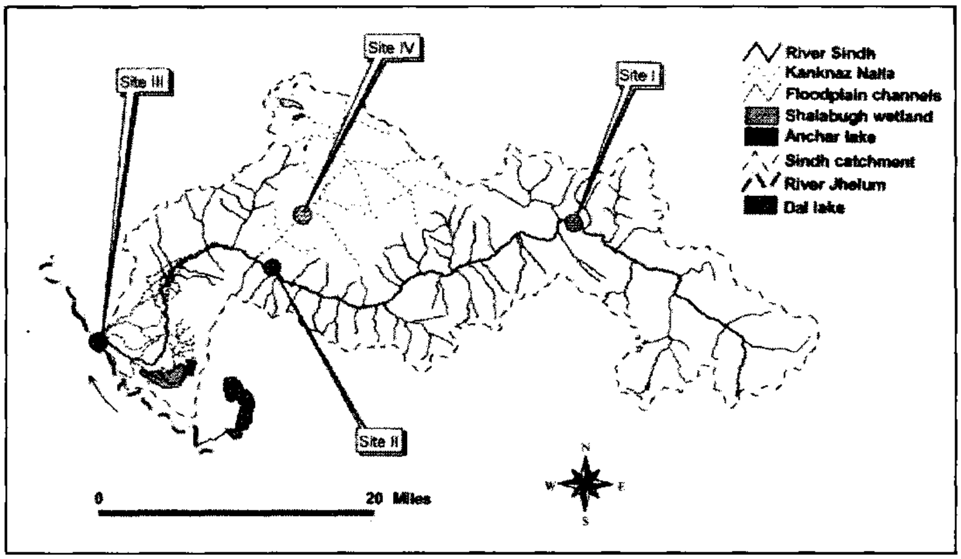

Fig. 1. Location map of River Sindh showing different study sites

Geographical attributes of the sites are given in Table 1. The sites varied in altitude, temperature, current velocity, depth, and many other characteristics. Three of the four sites (I, II, and IV) experienced rhithron conditions, while as Site III possessed potamon conditions. Site I was located at Sonamarg, a famous hill station. Site II was located near Kangan town, and Site III was located at Narayan Bagh near the confluence of the Sindh with the Jhelum. Site IV was located 50 m below the power house (Upper Sindh Hydel Project – II) barrage near Wangat village and experienced extremes of flow regulation with about four months (Jan., Feb., Nov., and Dec.), being almost without surface flow of water in the stream-bed, and hence no sampling was possible at this site during the winter season.

Table 1. Geographical attributes of the study sites

Sampling sites	Site number	Altitude (m.a.s.l)	Latitude	Longitude
Sonamarg	I	2684	34°18'17" N	75°17'36" E
Kangan	II	1824	34°15'32" N	74°54'17" E
Narayan Bagh	III	1580	34°11'02" N	74°40'44" E
Wangat	IV	2006	34°18'53" N	74°56'17" E

MATERIAL AND METHODS

Phytoplankton and zooplankton samples were collected on seasonal basis from December, 2005 to November, 2006, by filtering 100 L of the river water (through a plankton net of bolting silk having mesh size of 64 meshes cm^{-1}) obtained from four sampling sites. The sieved samples were transferred to bottles and preserved in 4% formalin (APHA, 1998). Lugol's solution was also added to the sieved residual plankton samples to ensure absolute preservation. Identification was done using the standard taxonomic keys of Edmondson (1959), Pennak (1978), Cox (1996), and Biggs and Kilroy (2000). Plankton were counted with the help of a Sedgewick Rafter (S-R) cell of 1 ml capacity. The zooplankton and unicellular algae were counted as individuals, the filamentous Chlorophyceae were recorded as cells, while as for filamentous Cyanophyceae 100 μm length of the filament was taken as the equivalents (Pandit, 1980). Water samples were collected in one liter polyethylene bottles between 10:00 and 16:00 hours and analyzed for various physico-chemical characteristics following CSIR (1974) and APHA (1998).

RESULTS AND DISCUSSION

(i) Phytoplankton

A total of 75 genera of phytoplankton were recorded from all the study sites. All of the genera were recorded for Site III, while as Sites I, II and IV recorded 51, 66, and 40 genera respectively. Of the 75 genera, 46 belonged to Bacillariophyceae, 16 to Chlorophyceae, 9 to Cyanophyceae, and 2 each to Euglenophyceae and Chrysophyceae. Among diatoms *Navicula*, *Cymbella*, *Hannaea*, *Didymosphenia*, *Fragilaria*, *Gomphonema*, and *Achnanthedium* were the most dominant genera at all the study sites. The dominant chlorophycean genera included *Spirogyra*, *Ulothrix*, *Closterium*, and *Cosmarium*, but *Hydrodictyon* and *Chlymadomonas* surpassed *Spirogyra* and *Ulothrix* at Site III. Euglenophyceae was represented by two genera namely *Euglena* and *Phacus* which had almost similar dominance at Site III. *Oscillatoria* and *Phormidium* were the most common blue-green algae, while as

Hydrurus was the major contributor among Chrysophyceae. The lowest density of phytoplankton was recorded for Site IV which recorded an annual mean density of 597.00±155.88 ind.L^{-1}, while as Site III recorded highest density, ranging between 599 ind.L^{-1} in winter and 1669 ind.L^{-1} in spring (Table 2; Fig. 2). Sites I and II had more than 77% contributions from diatoms, while as the other two sites (III and IV) had less than 69% individuals of diatoms. However, the density of Chlorophyceae recorded a marked increase from 9.94% at Site I to 18.11% at Site III (Table 3; Fig. 3.). After diatoms and green algae, the third important group was blue-green algae which made 6.80–10.11% of the total phytoplankton density. The group registered the highest annual mean density (82.50±32.92 ind.L^{-1}) at Site III. Among the various algal classes Chrysophyceae (relative density fluctuating between 2.26% at Site III and 6.20% at Site IV) and Euglenophyceae (relative density ranging from nil at Sites I and IV to 4.32% at Site III) were the least abundant and, therefore, contributed very little to the overall standing crop of phytoplankton. The seasonal behaviour of phytoplankton density revealed a bimodal growth curve with spring and autumn peaks.

Table 2. Phytoplankton density at various sites of River Sindh from Dec. 2005 to Nov. 2006

Site	Winter	Spring	Summer	Autumn	*Mean*	*S.D.*
I	523	1096	919	1004	885.50	252.24
II	630	1486	1149	1210	1118.75	357.30
III	599	1669	1062	1258	1147.00	444.35
IV	n.r	507	507	777	597.00	155.88

n.r. = not recorded

Table 3. Relative density of various phytoplankton groups at different sites in River Sindh

Class	I	II	III	IV
Bacillariophyceae	79.87	77.52	68.11	67.95
Chlorophyceae	9.94	12.24	18.11	15.74
Euglenophyceae	0.00	0.02	4.32	0.00
Cyanophyceae	7.06	6.80	7.20	10.11
Chrysophyceae	3.13	3.42	2.26	6.20

The greater taxonomic diversity of diatoms as evinced by a record of 46 genera and a much higher relative density of 68–80% in River Sindh gives credence to the fact that diatoms constitute the major proportion of phytoplankton density in rivers and streams (Shadin, 1956). The study gains support from the findings of Talling and Rzóska (1967), who also registered diatoms to be dominant phytoplankters in the Blue Nile. However, the downstream increase in the relative density of Chlorophyceae is in accordance with the assumption of Vannote *et al.* (1980), who assumed an increase in the density and diversity of green algae on moving downstream. Though Chrysophyceae did not show any significant site variation in the present study, yet the group registered higher density at upper reaches compared to lower density at lower reaches, a fact also substantiated by Vavilova and Lewis (1999), who recorded the group to dominate at sub-alpine mountain reaches of streams. In general, there was a seasonal trend in the phytoplankton community at all the sites. The lowest phytoplankton density was, however, recorded during winter and the highest density during spring. Malard *et al.* (2006) reported that the reduced light and low temperatures severely limit the accrual of benthic algae and hence phytoplankton in streams. The same very reason justifies the higher density of phytoplankton recorded in spring season for all the sites. The higher density in spring may also be related to the release of the algal cells from the periphytic mat as a result of scuffing by faster current (Shadin, 1956). The decrease in phytoplankton density during summer season at all the study sites may be attributed to the higher turbidity of water reducing the light penetration and in turn production (growth) of periphyton and phytoplankton. Lakshminarayana (1965) also found the turbid floodwater to greatly reduce the phytoplankton of the River Ganga. Following diatoms and green algae, blue-green algae also recorded higher diversity and density at Site III. Compared to other three sites, Site III recorded highest density of phytoplankton for all the four seasons. The seasonality of phytoplankton depicting a bimodal growth curve with the density showing its numerical surge in spring and autumn is attributed to the moderate water temperature conditions and the release and availability of plant nutrients during these periods (Pandit, 1980).

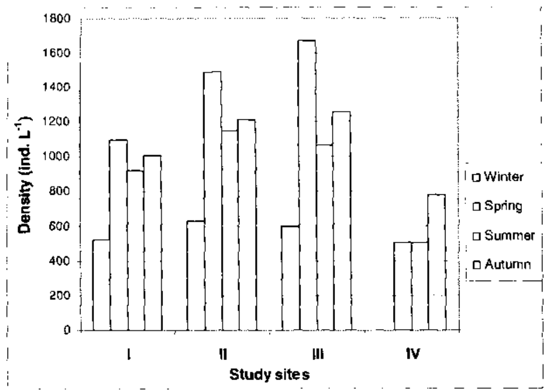

Fig. 2. Phytoplankton density at various selected sites in River Sindh

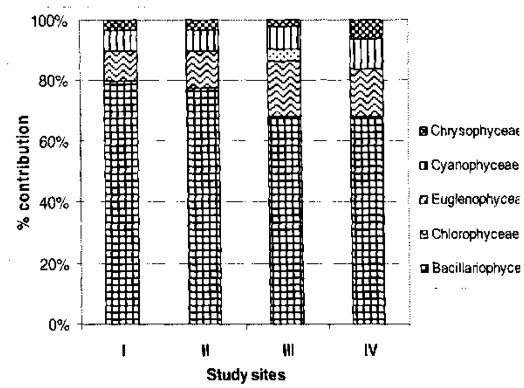

Fig. 3. Relative density of different phytoplankton groups at various study sites

(ii) Zooplankton

The zooplankton recorded a pattern of distribution and seasonality similar to that of phytoplankton. A total of 17 species, belonging to Protozoa, Rotifera, and Crustacea (Cladocera and Copepoda), were recorded during the entire study period. Like phytoplankton community Site III registered all the 17 species of zooplankton, while the other three sites recorded only four species. Among the 17 species encountered, the maximum number of species (7) was registered for Crustacea (5 cladocerans and 2 copepods), followed by Protozoa (6 species) and Rotifera (4 species). Site I recorded two species, *Arcella discoidea* and *Difflugia oblonga*, being present only during spring and summer. Similarly, Site II recorded three species namely *Difflugia oblonga*, *Euglypha* sp. and *Daphnia magna* and Site IV recorded four species viz. *Arcella discoidea*, *Difflugia oblonga*, *Euglypha* sp., and *Daphnia magna*. Site III was the only site where greater zooplankton density and diversity were obtained. Among protozoans, *Amoeba* sp. was the most dominant taxon, followed by *Arcella discoidea*. *Brachionus quadridentata* and *Keratella cochlearis* were the dominant forms among rotifers, while as *Bosmina coregoni* and *Daphnia magna* dominated in Cladocera, being followed by *Cyclops* sp. among Copepoda. The zoocenosis of Sites I, II, and IV was of least importance because of poor representation of zooplankton, recording annual mean densities of 0.018±0.021 ind.L^{-1}, 0.055±0.067 ind.L^{-1} and 0.087±0.059 ind.L^{-1} respectively and low species diversity of 2, 3, and 4 species respectively. Contrarily, Site III recorded the maximum zooplankton density, ranging between 0.41 ind.L^{-1} in summer to 4.17 ind.L^{-1} in spring (Table 4; Fig. 4). A bimodal growth pattern of the microscopic animals was observed with the two peaks occurring in spring and autumn. However, considerable variations were observed in the populations of various zooplankton groups. Thus, at Site III Protozoa was the most dominant group making 39.10% of the zooplankton population, followed by Crustacea (35.20%) and Rotifera (25.70%), while as the other three sites had higher proportions of Protozoa and lesser contributions of Crustacea, rotifers being absent (Table 5; Fig. 5).

Table 4. Zooplankton density at various sites of River Sindh from Dec. 2005 to Nov. 2006

Site	Winter	Spring	Summer	Autumn	Mean	S.D.
I	0.00	0.04	0.03	0.00	0.018	0.021
II	0.00	0.15	0.02	0.05	0.055	0.067
III	0.46	4.17	0.41	2.12	1.790	1.775
IV	n.r.	0.13	0.02	0.11	0.087	0.059

n.r. = not recorded

Table 5. Relative density of various zooplankton groups at different sites

Group	I	II	III	IV
Protozoa	100.00	81.82	39.10	88.51
Rotifera	0.00	0.00	25.70	0.00
Crustacea	0.00	18.18	35.20	11.49

Compared to the lakes of the J&K State (Pandit, 1999; Wanganeo and Wanganeo, 2006), the diversity of zooplankton in River Sindh was very low, being represented by only 17 species. Among the four study sites, the comparatively higher density and diversity of zooplankton at Site III can be related to the intrusion of backwaters from Anchar lake and Shalabugh wetland, harbouring a good growth of plankton (Bhat and Pandit, 2003), into the River Sindh near the site. In fact, a number of small distributaries arise from River Sindh and enter Anchar lake and Shalabugh wetland and then re-unite with the Sindh. Similar situation has been reported by Saunders and Lewis (1988) in another study. The seasonal periodicity of zooplankton depicted two peaks of zooplankton, one in spring and the other in autumn. The rise in water temperature in spring enhances planktonic growth in the water bodies in general and lakes and wetlands in particular (Yousuf, 1989). The connectivity of Anchar lake and Shalabugh wetland, therefore, regulates the growth of plankton in the lower reaches or River Sindh. The numerical surge of plankton population in the lentic environment in the close proximity of River Sindh (Siraj *et al.*, 2007) coincides with the spring and fall peaks of zooplankton density. Similar observations were made by Casanova and Henry (2004), who related the higher density of zooplankton in rainy season with the higher connectivity between the adjacent lakes and the main river. During summers, the high turbidity of water restricts the phytoplankton growth, consequently resulting in the decrease of growth of zooplankton as well. Autumn again provides optimum and favourable conditions for the growth of phytoplankton as well as zooplankton, thus making another peak of growth. According to Yousuf (1989), there occurs a positive correlation between the phytoplankton and zooplankton and a negative relationship between zooplankton and turbidity and water current in lotic habitats. The higher density and diversity of protozoans in addition to the presence of species like *Brachionus quadridentata* and *Keratella cochlearis* suggests the eutrophic origin of the zooplankton from the adjacent Anchar lake and Shalabugh wetland (Pandit and Yousuf, 2003), which drain into the Sindh. Similar observations were made by Hynes (1970), Saunders and Lewis (1988, 1989) and Casanova and Henry (2004).

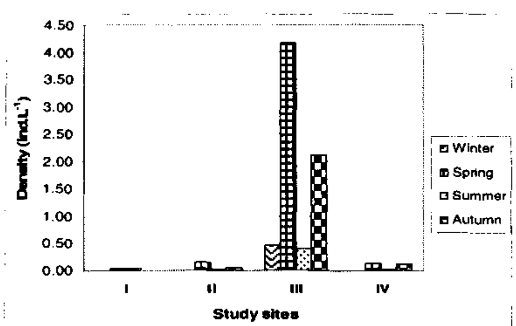

Fig. 4. Density of zooplankton at various study sites in River Sindh

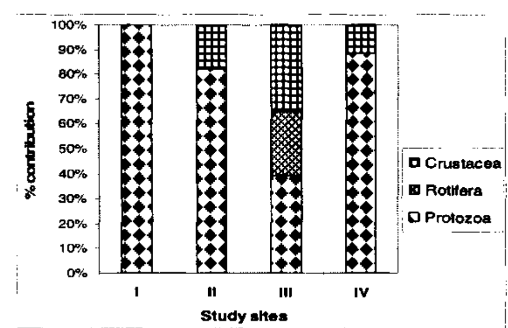

Fig. 5. Relative density of different zooplankton groups at various study sites

(iii) Physico-chemical features of water

The physico-chemical characteristics of water show a close relationship with the occurrence and abundance of plankton. The water temperature recorded during the study period revealed that on moving downstream the water temperature increased from an annual mean of 5.05 ± 2.11 °C at site I to 10.67 ± 3.80 °C at Site III (Table 6). Thus, the low water temperatures at the upper reaches and during winters decelerate the growth of zooplankton and, therefore, cause a marked decrease in their density. Conversely, the rising temperatures downstream enhance the growth and reproduction of the animalcules. Edmondson (1965) and Claudson (1975) are of the opinion that the warm water conditions boost the zooplankton growth while the low temperatures hinder their growth. The study gains further support from the earlier findings of Kaul *et al.* (1978), who opined that higher transparency and temperature seem to be quite conducive for the dominance of algae and consequently zooplankton. Compared to temperature, a reverse trend of plankton density was observed for current velocity which ranged between an annual mean of 0.50±0.11 ms^{-1} at Site III to 1.10±0.30 ms^{-1} at Site I, signifying that the velocity of water current decreased while moving downstream. According to Hynes (1970), the fast water current sweeps up more individuals and during periods of rising water the phytoplankton numbers go up. The assumption supports the findings of the present investigation as the phytoplankton density was noted to rise in fast flow periods. Total absence or sporadic presence of zooplankton in the upper and middle reaches of the river can be attributed to the fact that the turbulent and foaming flow is not hospitable for the sustenance of the microscopic animals. According to Rzóska (1978), stream flow (velocity and turbulence) can have negative effects on zooplankton by physically damaging them, diluting their food resources and hindering reproduction. Hynes (1970) and Odum (1971) noted similar observations and proposed that any such presence of zooplankton in fast flowing rivers and streams is the outcome of the entry of pond/ lake/ spring waters to the streams. The present data also corroborates the above fact.

Table 6. Physico-chemical features of water (ranges and averages) recorded at various study sites

Site	Parameters							
	Water temperature (°C)		Velocity (ms^{-1})		NO_3-N (μgL^{-1})		OPP (μgL^{-1})	
	Range	Average	Range	Average	Range	Average	Range	Average
I	1.00 to 8.00	5.05±2.11	0.75 - 1.55	1.10±0.30	150 - 185	164.09±10.44	28 - 60	44.45±11.61
II	3.00 to 14.50	10.29±3.98	0.50 - 1.62	1.00±0.40	133 - 195	164.17±17.00	28 - 70	39.50±12.54
III	5.00 to 16.00	10.67±3.80	0.33 - 0.68	0.50±0.11	150 - 266	188.25±35.95	40 - 225	78.17±56.88
IV	5.50 to 14.00	8.75±2.71	0.18 - 1.50	0.75±0.56	128 - 150	137.00±8.26	22 - 50	38.50±9.37

A perusal of Table 6 shows that the concentrations of the two plant nutrients – nitrate nitrogen (NO_3-N) and orthophosphate phosphorus (OPP) – were higher at Site III than other sites. The comparatively higher concentration of both nitrate nitrogen and orthophosphate phosphorus may have resulted in the higher density and diversity of phytoplankton at Site III. The assumption gains support from the findings of many workers (Pandit, 1999; Biggs and Kilroy, 2000; Allan, 2004) who opined the two nutrients to be the main factors controlling the growth of phytoplankton. Furthermore, all the plankton groups were more dense and diverse at Site III than other sites, probably because the site provides comparatively more hospitable environment for plankton growth as it receives a larger input of agricultural run-off and sewage bringing the key nutrients, especially phosphorus and nitrogen (Pandit, 1999), into the water column in addition to higher water temperature and slower current (Hynes, 1970). Søballe and Kimmel (1987) have also noticed a positive relationship between phosphorus concentrations and phytoplankton biomass in rivers.

Table 7. Pearson's correlation coefficient (r) between various physico-chemical parameters and plankton density

	W.T.	Vel.	NO_3-N	OPP
Phytoplankton	0.575	0.106	0.514	0.131
Zooplankton	0.294	-0.382	0.314	0.118

W.T. = Water temperature, Vel. = Velocity, NO_3-N = Nitratenitrogen, OPP = Orthophosphate phosphoru

The Pearson's coefficient of correlation between different variables revealed that water temperature and nitrate-nitrogen had significant positive correlations (r = 0.575 and 0.514 respectively) with phytoplankton density at p = 0.05 (Table 7). Orthophosphate phosphorus was also positively correlated with the phytoplankton density, but the correlation coefficient was insignificant. However, Lewis (1988) reported that plankton in rivers do not get enough time to grow and utilize the nutrients present in river water. The author also opined that the plankton, especially the phytoplankton in rivers, actually have some other original source rather than the true plankton in river itself. Velocity of water current was observed to be negatively correlated with the zooplankton density (r = -0.382) and it can be said that the current velocity has a negative impact on zooplankton community. However, for phytoplankton the higher velocity may add organisms from the periphytic algae by scuffing effect. Zooplankton were also noted to have insignificant positive correlations with water temperature and nitrate-nitrogen.

In conclusion, it can be said that the physico-chemical variables like water temperature, velocity of water current, nitrate-nitrogen, and orthophosphate phosphorus are all important ecological factors governing the growth of plankton community directly or indirectly. However, in lotic system the most important factor among all is the current velocity, as the plankton community always remains at its mercy, no matter how good other conditions be.

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