Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(6): 620-628

Received: 05-09-2017
Accepted: 08-10-2017

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Studies on plankton diversity of River Sutlej, Punjab

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Abstract
The present study on river Sutlej deals with the seasonal variations in the diversity of phytoplankton and zooplankton population at two different sites of the river (one is River Sutlej before the confluence of the Buddha nallah (S-1) and second is River Sutlej after the confluence of the Buddha nallah (S-2)). Studies revealed that phytoplankton population was dominated by members of Bacillariophyceae, Chlorophycea, Cyanophycea and Euglenophycea and Zooplanktons population was dominated by Protozoan, Rotifer and Crustacea. Relative abundance of Bacillariophycea and Euglenophycea was higher at S-2 as compared to S-1 whereas that of Chlorophycea and Cyanophycea was higher at S-1 as compared to S-2. Relative abundance of Crustacea and Protozoa was higher at S-2 as compared to S-1 whereas that of Rotifera was higher at S-1 as compared to S-2 during the monsoon period.

Keywords: plankton, Sutlej, water pollution, diversity, Buddha Nallah

Introduction

Sutlej is one of the major rivers in the Northern region of India. It originates at the southwest of Tibetan lakes of Rakasthal and Mansarover which covers an area of about 1078 km. It enters the plain of Punjab at District Ropar and flows up to Fazilka via the industrial city of Ludhiana and meeting point of river Beas at Harike-Pattan, covering an area of about 280.02 Km in Punjab. The river Sutlej has been a major source of capture fisheries in India. In the recent past the biodiversity in river Sutlej witnessed a significant decline owing to anthropogenic activities, including fish population [6].

Fresh water is perhaps most vulnerable habitat and most likely to be changed by the anthropogenic activities. Chemical analyses of water provide a good indicator of the chemical quality of the aquatic system [11]. The composition of plankton may be used as a reliable tool for biomonitoring studies to assess the water quality of aquatic bodies. No individual factor like physical or chemical is singly responsible for the fluctuations of phytoplankton or zooplankton populations. Thus the number of physical, chemical and biological environmental factors affecting simultaneously must be taken into consideration in understanding the fluctuation in plankton population [9, 25, 27].

Qualitative and quantitative analyses of different groups of organisms lead to the establishment of bio-indicators, indices and systems which can be used to assess the pollution and trophic status of water bodies. Plankton is the starting point of energy transfer in the aquatic ecosystem and their well-being is of paramount importance to the overall health and integrity of the system [4]. The present study was aimed to find out the impact of industrial population on the plankton population of river Sutlej. Plankton samples were collected (in triplicate) from two different sites during the study period (June, 2015 – December, 2015) for three seasons i.e. Pre-monsoon, Monsoon and Post-monsoon.

Materials and Methods

Study area

The samples were collected from two different sites.

Site-1 (S-1): The first site was in Ludhiana district. The samples were collected from river Sutlej stretch before the confluence of Buddha Nallah near Rail/road Bridge at Ludhiana which is 86 km downstream from Ropar Head works over river Sutlej

Site-2 (S-2): The second site was 22 km downstream from site-1after the confluence of Buddha Nallah near village Walipur.

The qualitative [2] and quantitative analysis of phytoplankton and zooplankton was done by drop count method [26] and Sedgwick Rafter Cell method [1], respectively.

Collection and fixation of phytoplankton sample

Phytoplankton samples were collected in a 125 ml reagent bottle. To this 2 ml of Lugol's iodine solution was added to fix the phytoplankton. The sample in the bottle was left undisturbed for at least 24 hours to ensure complete sedimentation. The supernatant was then siphoned out and the sediments were further centrifuged to get a phytoplankton concentrate.

Enumeration

Phytoplankton sample was taken in the graduated centrifuged tube. Test tube was centrifuged and sample was made up to 5 ml.1 drop of sample was taken over the slide and observed under the microscope. Phytoplankton count in 10 randomly selected fields was recorded under microscope power 40X.

Collection and fixation of zooplankton sample

The sample was collected with the help of zooplankton net (mesh size 150 µm) by filtering 50 litres of river water through it. The sample thus collected was poured into a vial and fixed with few drops of formaldehyde solution (37-41% w/v). After fixing, the sample was left undisturbed.

Enumeration

The fixed samples were centrifuged to make a known volume of zooplankton concentrate. 1 ml of sample was taken in the Sedgwick rafter Cell (SRC). Number of zooplankton in 10 randomly selected fields was recorded under microscope power 10X.

Identification

Identification of phytoplanktons and zooplanktons were performed using binocular optical microscope at 40x and 10x, respectively and description of the organisms found in specialized literature [2].

Statistical analysis

One way ANOVA and Duncan Multiple range test was applied to find out the significant differences among plankton productivity.

Results and discussion

Phytoplankton

Chlorophyceae (Green algae)

Maximum mean value of Chlorophyceae population (No.x10^6 l^{-1}) was recorded during pre-monsoon period (June) and minimum was during monsoon period (August) at S-1 and S-2, respectively (Table 1, Fig. 1). The mean values of chlorophycea population differed significantly during different months within the sites and also between the sites ($P<0.05$). Chlorophycea constituted 48.37% and 27.70% at S-1 and S-2, respectively. At S-1, total 8 species were observed and among them dominant species were *Spirogyra sp., Zygnema sp., Cosmarium sp and Closterium sp* whereas at S-2, total 6 species were observed and among them dominant species were *Pandorina sp., Tetradron sp., Selenastrum sp.* and *Scenedesmus sp*. Relatively higher population of Chlorophyceae was recorded at S-1 as compared to S-2. Abundance of Chlorophycea was recorded in the month of June 2015 which was because of moderate values of turbidty, pH, DO, nitrates and high temperatures in conformity with the findings of Rai [20] who also recorded the dominance of chlorophytes at higher temperature in river Ganga and Yamuna at Allahabad.

Cyanophyceae (Blue green algae)

Maximum mean value of Cyanophyceae population (No.x$10^6 l^{-1}$) was recorded during pre-monsoon period (June) and minimum was during monsoon period (August) at S-1 and S-2, respectively (Table 2, Fig.2). The mean values of cyanophycea population differed significantly during different months within the sites and also between the sites ($P<0.05$). At S-1, total 4 species were observed and among them dominant species were *Anabena sp., Microcystis sp*., and *Oscillatoria brevis* whereas at S-2 total 4 species were observed and among them dominant species were *Microcystis sp*., and *Oscillatoria brevis*. Cyanophyceae constituted 26.80% and 17.84% at S-1 and S-2 respectively. Relatively higher population of cyanophycea were recorded at S-1 than S-2. It was ascribed to direct discharge of phillour sewage at S-1 which was contrary to the other results as Cyanaophyceae being the indicator of pollution should have been higher at Site-2. The reason behind more pronounced population of Cyanophyceae at Site-1 was the direct influx of domestic sewage from Philloaur which lead to nutrient rich conditions at Site-I. Abundance of Cyanophyceae was recorded in the month of June 2015 which was because of high values of temperature, free carbon dioxide, hardness, BOD and richness of nitrate and phosphates. Similar findings were reported at Kosi and Beas rivers [18, 8].

Bacillariophyceae (Diatoms)

Maximum mean value of Bacillariophyceae population (No.x$10^6 l^{-1}$) was recorded during post-monsoon period (December and November) and minimum was during monsoon period (August and September) at S-1 and S-2, respectively (Table 3, Fig. 3). The mean values of Bacillariophycea population differed significantly during different months within the sites and also between the sites ($P<0.05$). Bacillariophyceae constituted 18.90% and 46.46% at S-1 and S-2, respectively. At S-1, total 8 species were found and among them dominant were *Navicula sp., Nitzschia sp., Fragilaria sp.* and *Synedra ulna* whereas at S-2, total 5 species were found and among them dominant were *Navicula sp*. and *Synedra ulna*. Relatively higher population were recorded at S-2 as compared to S-1 which was because of high pollution load brought about by Buddha nallah but species diversity was found to be higher at S-1 than S-2. The population of diatoms was found to be quantitatively more at S-2 as compared to S-1. The presence of these species was an evidence of high pollution load as these species are pollutant tolerant forms. The diatoms are normally found to proliferate well in acidic pH and this may also be a reason of their higher population at S-2. During present study, diatoms were found in abundance between 15-17°C. Optimum temperature for the growth of diatoms was 9-14°C in river Alknanda and 12-21°C in river Nayar [15]. Bacillariophyceae as dominant life form in phytoplanktons and largest group of biomass producer on earth which has much more estimated diversity than 100,000 species [14].

Euglenophyceae

Maximum mean value of Euglenophyceae population (No.x$10^6 l^{-1}$) was recorded during post-monsoon period (December and November) and minimum was during monsoon period (August) at S-1 and S-2, respectively (Table

4, Fig. 4). The mean values of euglenophyceae population does not differed significantly during different months within the sites and also between the sites ($P<0.05$). Euglenophyceae population was slightly higher at S-1 as compared to S-2. Euglenophyceae constituted 5.93% and 8% at S-1 and S-2, respectively. At S-1, only 2 species were observed and all were found to be in less number whereas at S-2, total 3 species were observed and among them *Euglena viridis* was found to be an abundant which indicated a higher pollution load at S-2. Abundance of Euglenophyceae was recorded in the month of November 2015, which was because of moderate temperature and higher dissolved oxygen in conformity with the findings that correlated seasonal abundance of euglenophyceae to ecological conditions of Kosi River [18]. The abunadance of the euglenophycea members in the water body can be attributed to the entry of nutrients through the influx of domestic sewage which is an indicator of organic pollution [12, 13].

Total Phytoplankton Population

Among the total phytoplankton population, the maximum was contributed by Chlorophycea (48.37%) followed by Cyanophycea (26.80%), Bacillariophycea (18.90%) and Euglenophycea (5.93%) at S-1, whereas at S-2, maximum was contributed by Bascillariophycea (46.46%) followed by Chlorophycea (27.70%), Cyanophycea (17.84%) and Euglenophycea (8%) (Table 5, Fig.5). The maximum value of phytoplankton in winter was due to relatively less values of temperature and turbidity, moderate values of nutrients and moderate values of dissolved oxygen. Their abundance in summer was because of higher values of temperature, hardness and nutrients, moderate values of water current, turbidity and alkaline pH in conformity with the findings [22]. Minimum number of plankton in the month of July-August 2015 could be attributed to cloudy weather, high vales of turbidity, fast current of water and dilution in the concentration of some salts.

Zooplankton

Rotifera

Maximum mean value of Rotifera population ($No.l^{-1}$) was recorded during pre-monsoon period (June) and minimum was during monsoon period (July and August) at S-1 and S-2, respectively (Table 6, Fig. 6). The mean values of rotifer population differed significantly during different months within the sites and also between the sites ($P<0.05$). The abundance of rotifer was relatively more at S-1 when compared to S-2. Rotifera constituted 52.58% and 44.33% at S-1 and S-2, respectively. It was found to be dominant group of total zooplankton population. At S-1, total 6 species were observed and among them dominant were *Brachionus calyciflorus, Keratela tropica, Epiphanes senta* and *Trichocera sp*. whereas at S-2, total 5 species were observed and among them dominant were *Asplanchna sp., Brachionus calyciflorus* and *Brachionus angularis*. Rotifers were observed throughout the study period but they showed one maxima in the month of June 2015 and other in the month of November-December 2015 in conformity with the findings [7]. Abundance of *Brachionus sp.* at S-2 may be due to higher phytoplankton population on which rotifers grazed and flourished. The above results gave an indication that the higher organic load at S-2 lead to eutrophied conditions which supported more phytoplankton growth thus, encouraged the zooplankton growth. Diversity indices of Rotifers used for the assessment of pollution in Kukkarahalli and Karanji lakes in Mysore Karnataka State [16].

Crustacea

Maximum mean value of Crustacea population ($No.l^{-1}$) was recorded during pre-monsoon period (June) and minimum was during monsoon period (August and September) at S-1 and S-2, respectively (Table 7, Fig. 7). The mean values differed significantly during different months within the sites and also between the sites ($P<0.05$). The crustacean population was relatively higher at S-2 as compared to S-1. Crustaceans constituted 19.49% and 22.43% at S-1 and S-2, respectively. Crustacea population was represented by members of Cladocera, Copepoda and Ostracoda. At S-1, total 4 species were observed and among them dominant were *Cyclops brevicornis, Daphnia sp*. and *Moina sp*. whereas at S-2, total 5 species were observed and among them dominant were *Ceriodaphnia sp*., *Daphnia sp.* and *Mesocyclops sp*. Maximum number of cladocerns was recorded in the month of June 2015 which may be because of high concentration of nitrates, phosphates and chlorides in conformity with the findings [17] while that of copepods were recorded in the month of June and December, 2015 in conformity with the findings [23]. Minimum number of crustaceans was recorded in the month of July-August, 2015 which may be because of high water current in conformity with the findings [21]. Similarly, four species of Copepods were observed from Tungabhadra River [24].

Protozoa

Maximum mean value of Protozoa population ($No.xl^{-1}$) was recorded during pre-monsoon period (July) and minimum was during monsoon period (August and September) at S-1 and S-2, respectively (Table 8, Fig. 8). The mean values of protozoa population differed significantly during different months within the sites and also between the sites ($P<0.05$) except in the month of June. Protozoa constituted 27.93% and 33.24% at S-1 and S-2, respectively. At S-1, total 8 species were found and among them dominant were *Coleps sp., Epistylis sp., Peridinium sp*. and *Vorticella sp*. whereas at S-2, total 5 species were found and among them dominant were *Bodo sp., Stylonchia sp*. and *Vorticella sp*. The protozoa population was relatively higher at S-2 as compared to S-1 which could be attributed to high tolerance limits of protozoa to more organic pollution load. The abundance of protozoans during monsoon, which as explained by them was due to rising river water level flushing out protozoans [5] and this holds true for the present study also. Protozoa showed eight species and five species at S-1 and S-2, respectively, with next dominant to Rotifer; similarly, protozoan dominance was recorded in Gurha Brahmara, Jammu with different eleven species [3] whereas two dominant species of Protozoa were observed in Virla reservoirs, Madhya Pradesh [19].

Total Zooplankton Population

Among total zooplankton population, maximum was contributed by Rotifera (52.58% and 44.33%) followed by Protozoa (27.93% and 33.24%) and Crustacea (19.49% and 22.43%) at S-1 and S-2, respectively (Table 9, Fig. 9). Minimum numbers of zooplankton were recorded in the month of July-August 2015, which might be because of high water current and more turbid water. Turbidity prevented the proliferation of zooplankton population due to less light penetration whereas fast water current washed them off. The correspondence of maximum and minimum number of zooplankton with that of phytoplankton is reported. [10]

Table 1: Variations in Chlorophycae population (No.x$10^6 l^{-1}$) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$317^{a,1}$±8.66	$136^{a,6}$±0.008
July	15	$256^{bc,2,3}$±8.95	$125^{a,7}$±10.33
July	30	$271^{b,2}$±8.95	$120^{ab,7}$±8.95
August	45	$156^{g,7}$±5.00	$50^{f,13}$±5.00
August	60	$171^{fg,6,7}$±5.00	$55^{f,13}$±5.00
September	75	$186^{f,6}$±5.00	$55^{f,13}$±5.00
September	90	$176^{fg,6,7}$±13.22	$55^{f,13}$±5.00
October	105	$176^{fg,6,7}$±5.00	$70^{ef,12,13}$±5.00
October	120	$211^{e,5}$±8.66	$85^{de,11}$±5.00
November	135	$241^{cd,3,4}$±8.66	$85^{de,11}$±13.22
November	150	$221^{de,4,5}$±5.00	$95^{cd,10}$±5.00
December	165	$211^{e,5}$±8.66	$100^{bcd,8,9}$±10.00
December	180	$261^{bc,2,3}$±5.33	$115^{abc,8}$±5.00

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months (*P*< 0.05).
* Numerical superscripts indicate significant differences between sites during different months (*P*< 0.05).

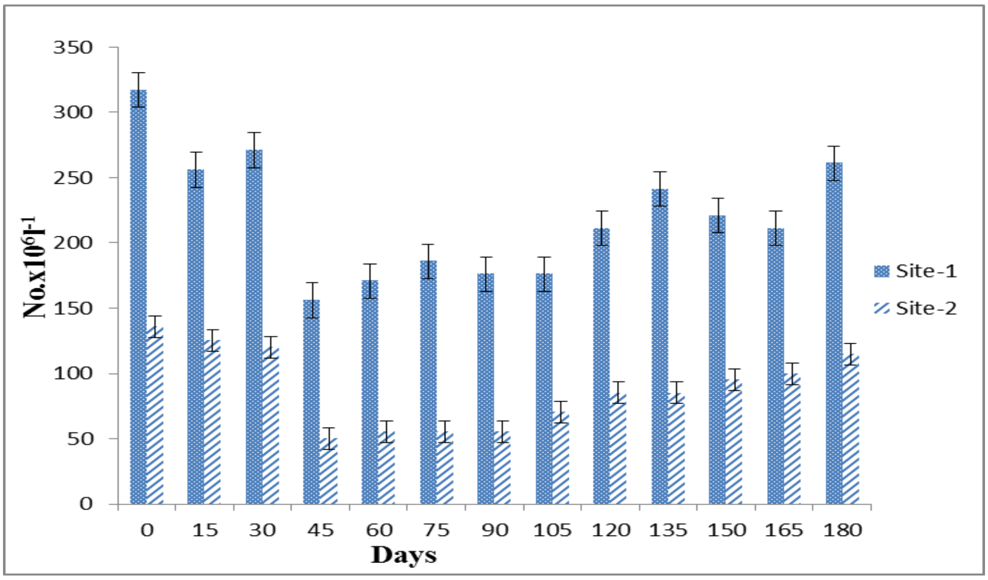


Fig 1: Variations in the Chlorophycae population (No.x$10^6 l^{-1}$) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Table 2: Variations in Cyanophyceae population (No.x10^6 l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$166^{a,1}$±8.66	$105^{a,5,6}$±8.66
July	15	$151^{ab,1,2}$±8.66	$60^{cd,8}$±8.66
July	30	$146^{abc,2,3}$±5.00	$60^{cd,8}$±8.66
August	45	$90^{ef,6,7}$±8.66	$55^{cd,8,9}$±5.00
August	60	$85^{f,7}$±10.00	$20^{e,11}$±5.00
September	75	$90^{ef,6,7}$±8.66	$35^{de,10}$±13.22
September	90	$110^{def,5,6}$±5.00	$35^{de,10}$±5.00
October	105	$115^{de,4,5}$±5.00	$45^{de,9}$±8.66
October	120	$125^{cd,4}$±13.54	$40^{de,9}$±5.00
November	135	$120^{cd,4,5}$±8.95	$45^{de,9}$±8.66
November	150	$120^{cd,4,5}$±8.95	$75^{bc,7,8}$±8.66
December	165	$136^{bcd,2,3}$±0.00	$95^{ab,6}$±13.22
December	180	$135^{bcd,2,3}$±8.95	$95^{ab,6}$±5.00

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months (*P*< 0.05).
* Numerical superscripts indicate significant differences between sites during different months (*P*< 0.05).

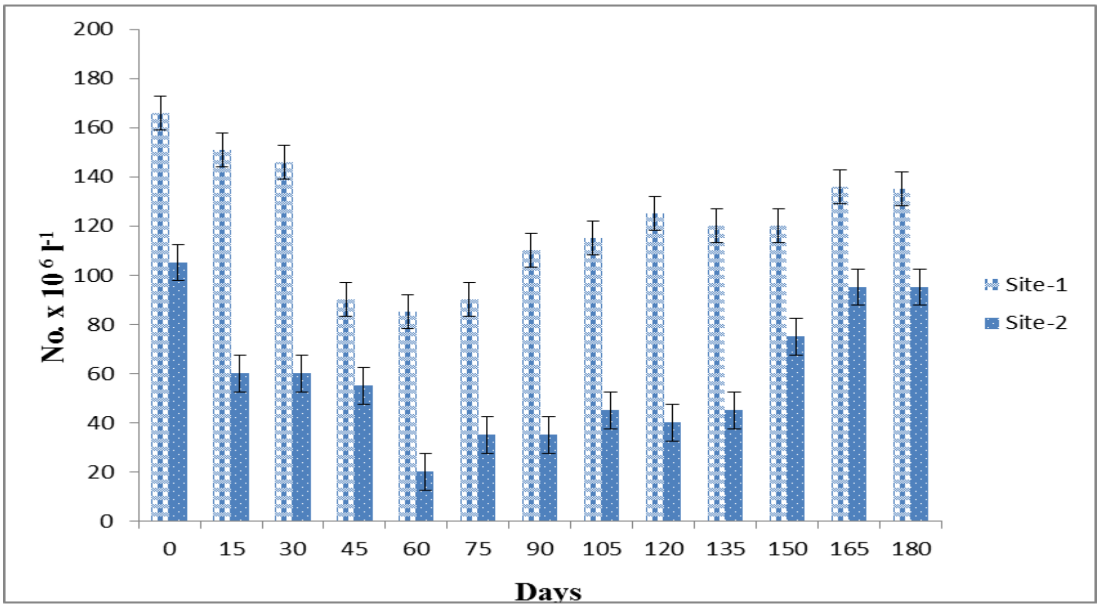


Fig 2: Variations in Cyanophycae population (No.x10 ^{6} l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Table 3: Variations in Bacillariophycae population (No.x10 ^{6} l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$60^{fe,10}\pm8.66$	$196^{ab,1,2}\pm8.66$
July	15	$80^{de,9}\pm5.00$	$191^{ab,1,2}\pm5.00$
July	30	$100^{cd,8}\pm5.00$	$115^{de,6,7}\pm5.00$
August	45	$50^{f,10,11}\pm5.00$	$115^{de,6,7}\pm5.00$
August	60	$40^{f,11}\pm10.00$	$135\pm^{cde,5,6}17.60$
September	75	$40^{f,11}\pm5.00$	$135^{cde,5,6}\pm8.95$
September	90	$75^{de,9,10}\pm8.66$	$105^{e,7,8}\pm0.00$
October	105	$80^{de,9}\pm5.00$	$115^{de,6,7}\pm13.48$
October	120	$115^{bc,6,7}\pm5.00$	$141^{cde,4,5}\pm5.00$
November	135	$90^{d,8,9}\pm8.66$	$150^{cd,4}\pm15.33$
November	150	$130^{ab,5,6}\pm10.33$	$216^{a,1}\pm13.22$
December	165	$120^{abc,6}\pm8.95$	$171^{bc,3,4}\pm18.02$
December	180	$140^{a,4,5}\pm13.48$	$186^{ab,2,3}\pm13.22$

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months ($P< 0.05$).
* Numerical superscripts indicate significant differences between sites during different months ($P< 0.05$).

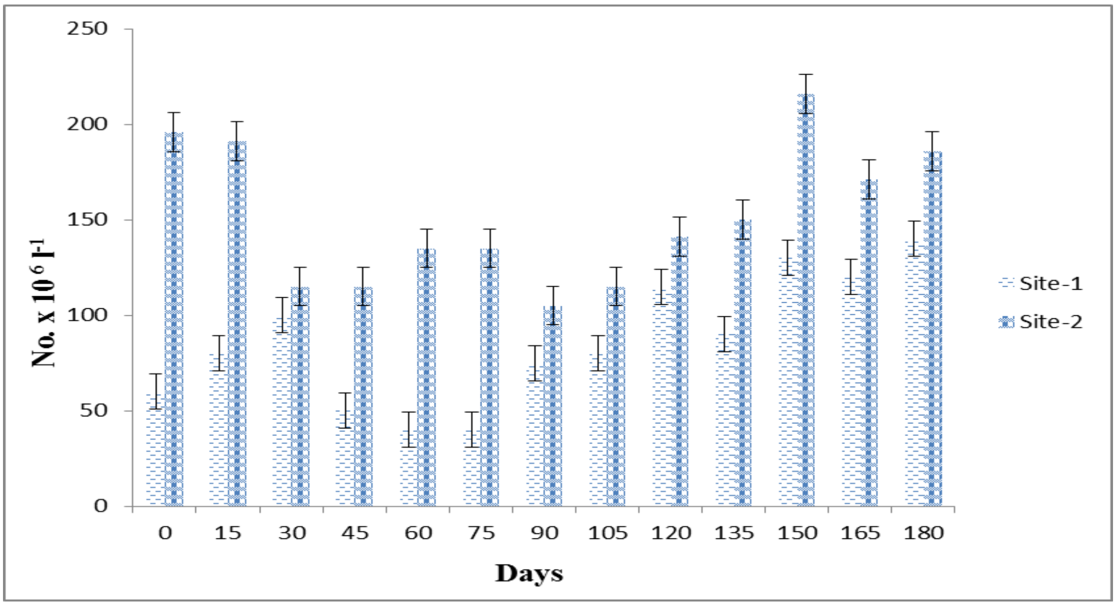


Fig 3: Variations in the Bacillariophycae population (No.x10 ^{6} l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Table 4: Variations in Euglenophycea population (No.x10 ^{6} l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$20^{c,5,6}\pm5.00$	$15^{e,6}\pm0.001$
July	15	$35^{abc,3,4}\pm13.22$	$30^{bcde,3,4,5}\pm8.66$
July	30	$25^{bc,4,5}\pm5.00$	$35^{bcd,3,5}\pm5.00$
August	45	$15^{c,6}\pm0.001$	$25^{cde,4,5}\pm5.00$
August	60	$15^{c,6}\pm0.001$	$15^{e,6}\pm0.001$
September	75	$20^{c,5,6}\pm5.00$	$20^{de,5,6}\pm5.00$
September	90	$20^{c,5,6}\pm5.00$	$15^{e,6}\pm0.001$
October	105	$15^{c,6}\pm0.002$	$15^{e,6}\pm0.001$
October	120	$15^{c,6}\pm0.001$	$20^{de,5,6}\pm5.00$
November	135	$25^{bc,4,5}\pm5.00$	$15^{e,6}\pm0.001$
November	150	$50^{a,2}\pm5.00$	$60^{a,1}\pm8.66$
December	165	$55^{a,1,2}\pm13.22$	$45^{ab,2,3}\pm8.66$
December	180	$45^{ab,2,3}\pm8.66$	$40^{bc,3}\pm5.00$

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months ($P< 0.05$).
* Numerical superscripts indicate significant differences between sites during different months ($P< 0.05$).

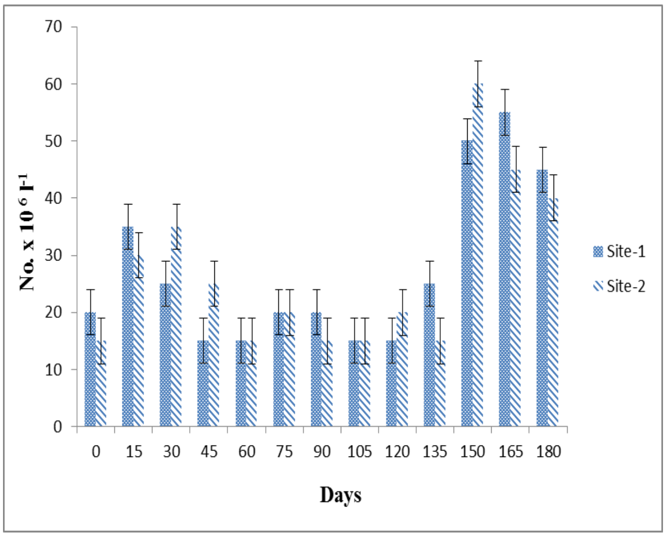


Fig 4: Variations in the Euglenophycae population (No.x10 ^{6} l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

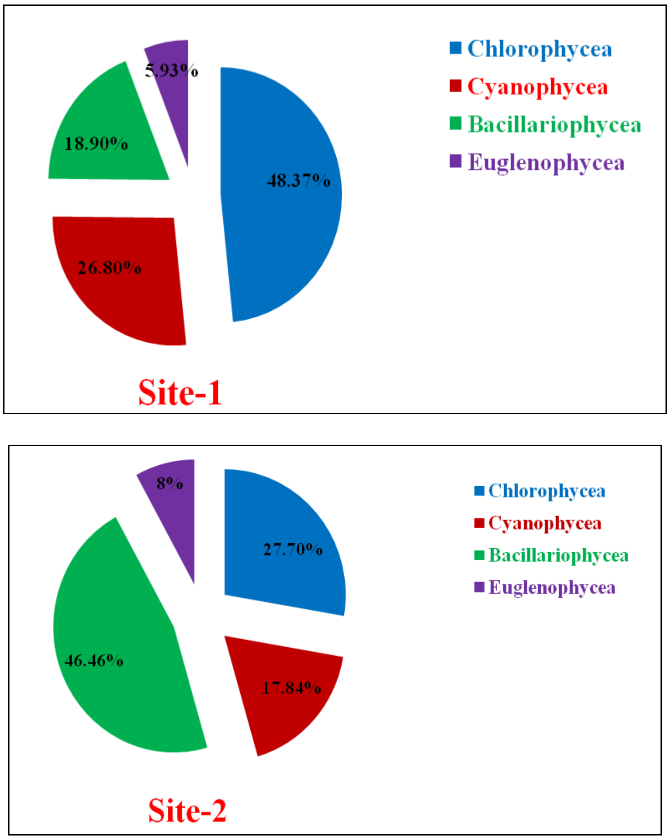


Fig 5: Relative abundance of phytoplankton population at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Table 5: Relative abundance (%) of phytoplankton population at Site-1 and Site-2 during the study period (June 2015 –December 2015).

Phytoplankton	Site-1	Site-2
Chlorophycea	48.37%	27.70%
Cyanophycea	26.80%	17.84%
Bacillariophycea	18.90%	46.46%
Euglenophycea	5.93%	8%

Table 6: Variations in Rotifer population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$374^{a,1}\pm12.91$	$204^{a,6}\pm8.66$
July	15	$364^{a,1}\pm8.37$	$189^{ab,7,8}\pm8.37$
July	30	$335^{b,2}\pm8.37$	$106^{c,11}\pm9.66$
August	45	$165^{f,9}\pm5.00$	$111^{c,11}\pm17.70$
August	60	$165^{f,9}\pm5.00$	$194^{ab,7}\pm5.00$
September	75	$169^{f,9}\pm9.66$	$126^{c,10}\pm5.00$
September	90	$169^{f,9}\pm9.66$	$189^{ab,7,8}\pm8.37$
October	105	$174^{f,9}\pm8.37$	$174^{ab,9}\pm8.37$
October	120	$287^{d,4}\pm5.00$	$131^{c,10}\pm16.74$
November	135	$257^{e,5}\pm4.66$	$174^{ab,9}\pm8.37$
November	150	$238^{e,5}\pm12.66$	$189^{ab,7,8}\pm8.37$
December	165	$291^{cd,3,4}\pm8.37$	$165^{b,9}\pm5.00$
December	180	$316^{bc,2,3}\pm5.00$	$165^{b,9}\pm5.00$

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months ($P< 0.05$).
* Numerical superscripts indicate significant differences between sites during different months ($P< 0.05$).

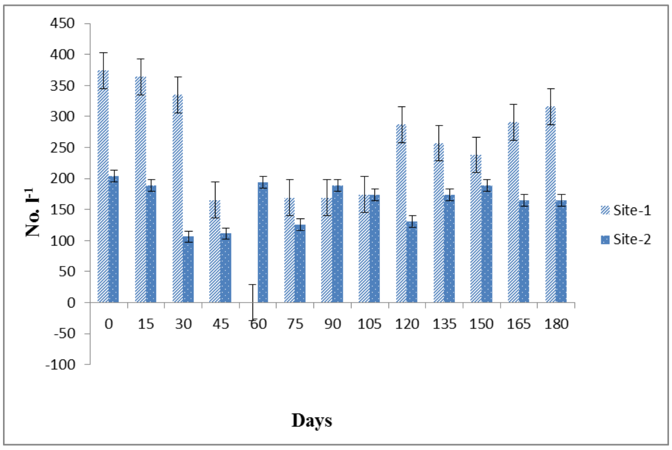


Fig 6: Variations in the Rotifer population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

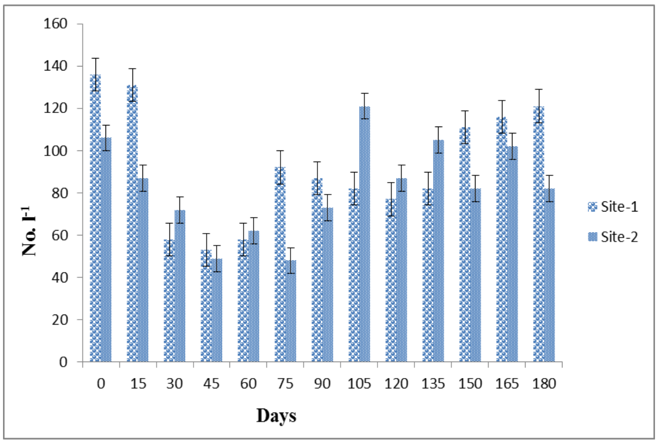


Fig 7: Variations in the Crustacean population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Table 7: Variations in Crustacean population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$136^{a,1}\pm5.00$	$106^{ab,3,4}\pm4.66$
July	15	$131^{a,1}\pm8.66$	$87^{bc,4,5}\pm8.37$
July	30	$58^{ef,7}\pm8.66$	$72^{bcd,5,6}\pm8.37$
August	45	$53^{f,7}\pm5.00$	$49^{d,8}\pm5.00$
August	60	$58^{ef,7}\pm8.66$	$62^{cd,6,7}\pm12.91$
September	75	$92^{bcd,4}\pm12.66$	$48^{d,8}\pm5.00$
September	90	$87^{cd,4,5}\pm8.37$	$73^{bcd,5,6}\pm0.001$
October	105	$82^{de,4,5}\pm12.91$	$121^{a,2}\pm5.00$
October	120	$77^{def,5,6}\pm4.66$	$87^{bc,4,5}\pm16.74$
November	135	$82^{de,4,5}\pm4.66$	$105^{ab,3,4}\pm4.66$
November	150	$111^{abc,3}\pm4.66$	$82^{bc,4,5}\pm9.66$
December	165	$116^{ab,3}\pm8.37$	$102^{ab,3,4}\pm16.74$
December	180	$121^{a,2}\pm9.66$	$82^{bc,4,5}\pm17.38$

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months (P< 0.05).
* Numerical superscripts indicate significant differences between sites during different months (P< 0.05).

Table 8: Variations in Protozoa population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015).

Month	Days	Site-1	Site-2
June	0	$165^{a,2,3}\pm9.66$	$165^{a,2,3}\pm5.00$
July	15	$169^{a,2}\pm9.66$	$184^{a,1}\pm17.70$
July	30	$116^{cd,7,8}\pm0.004$	$155^{ab,3,4}\pm4.66$
August	45	$121^{c,7}\pm12.97$	$160^{ab,3}\pm14.33$
August	60	$87^{d,9}\pm16.74$	$72^{d,10}\pm8.37$
September	75	$106^{cd,7,8}\pm12.91$	$57^{d,11}\pm14.66$
September	90	$126^{bc,6,7}\pm5.00$	$53^{d,11}\pm12.91$
October	105	$136^{abc,5,6}\pm10.00$	$67^{d,10,11}\pm12.97$
October	120	$116^{cd,7,8}\pm8.37$	$145^{abc,4,5}\pm8.37$
November	135	$136^{abc,5,6}\pm5.00$	$121^{bc,7}\pm5.00$
November	150	$168^{a,2}\pm9.66$	$155^{ab,3,4}\pm17.38$
December	165	$155^{ab,3,4}\pm12.91$	$160^{bc,3}\pm25.40$
December	180	$155^{ab,3,4}\pm9.66$	$111^{c,7,8}\pm4.66$

*Alphabetical superscripts indicate significant differences within a site (in a column) during different months (P< 0.05).
* Numerical superscripts indicate significant differences between sites during different months (P< 0.05).

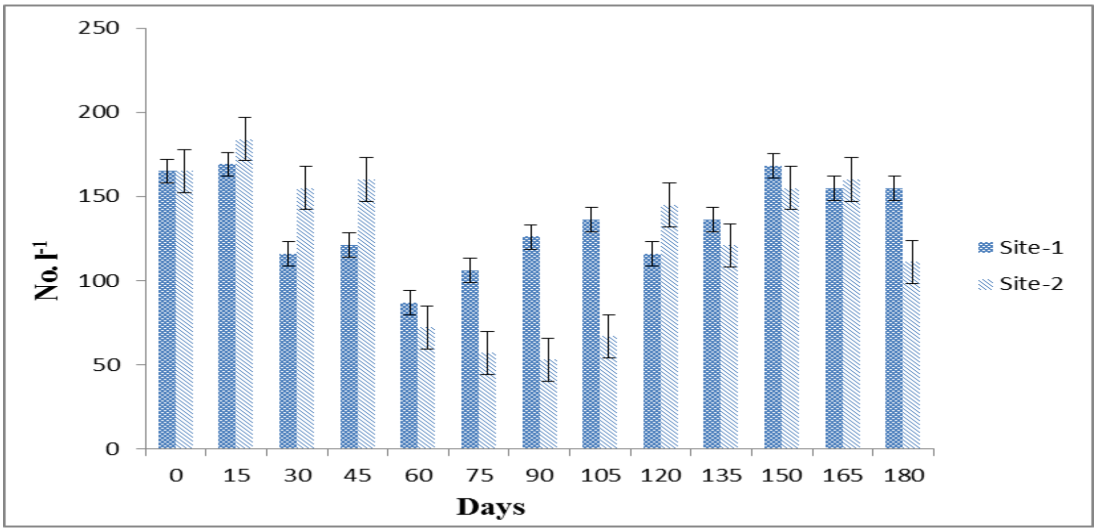
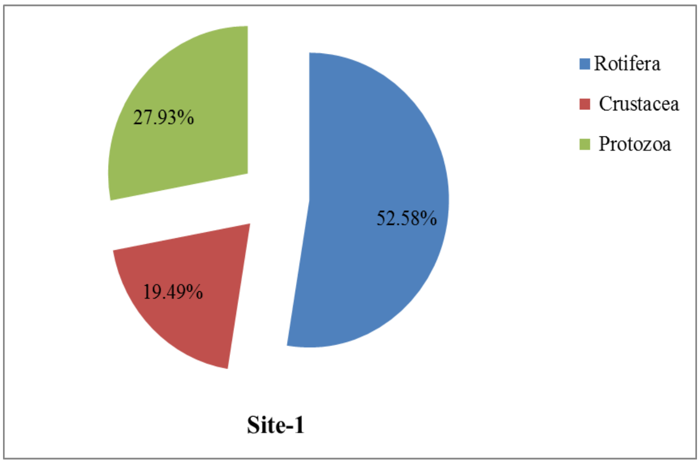


Fig 8: Variations in the Protozoa population (No. l^{-1}) at Site-1 and Site-2 during the study period (June 2015 – December 2015)

Table 9: Relative abundance (%) of zooplankton population at Site-1 and S-2 during the study period (June 2015 – December 2015).

Zooplankton	Site-1	Site-2
Rotifera	52.58%	44.33%
Crustacea	19.49%	22.43%
Protozoa	27.93%	33.24%



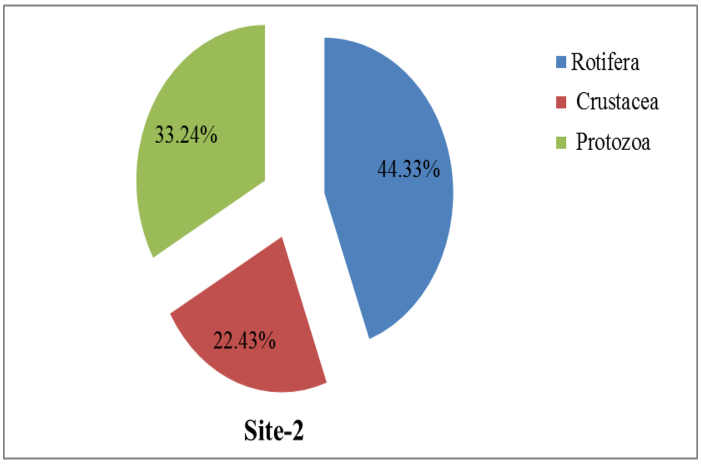


Fig 9: Relative abundance (%) of zooplankton population at Site-1 and Site2 during the study period (June 2015 – December 2015).

Conclusion

From the present study, it was concluded that River Sutlej which is one of the productive riverine systems of North India, Punjab, has rich diversity of phytoplankton and zooplanktons recorded. However, the present study showed less diverse forms of plankton at the more polluted site after the confluence of Buddah Nallah. Low diversity in polluted water might be due to the fact that many pollution sensitive species were eliminated from the community and only a few pollution tolerant organisms flourished in the absence of competition and in the presence of abundant food supply. Thus the present study warrants about the extent of pollution in the river which is directly affecting the flora and fauna. Thus studies are warranted for continuous bio-monitoring of the Sutlej riverine ecosystem to avoid irrevocable damage to flora and fauna.

Acknowledgement

The authors are highly thankful to Dean College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana for providing financial support and laboratory facilities for carrying out this work. The support of Head Department of Fisheries Resource Management for carrying out this work is duly acknowledged.

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