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# Assessment of ecological aspects and impact of pollution on limnological conditions of river Yamuna in Dehradun district of Uttarakhand India

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**ABSTRACT**

*The present study was undertaken for a period of one year from August 2010 to July 2011 to assess the species diversity and impact of pollution on Limnological conditions of River Yamuna in Uttarakhand India. In the present study water samples were collected on monthly basis from three important sampling sites (Kalsi) S1, (Dakpathar) S2 and (Asan lake) S3 of River Yamuna in Dehradun District of Uttarakhand India. The samples were analysed for different physico-chemical attributes and various biological parameters including phytoplankton, zooplankton and Icthyofaunal diversity. In total, phytoplankton include 35 taxa belonging to three different families Chlorophyceae, Bacillariophyceae and Myxophyceae were recorded out of which highest diversity was found in case of Bacillariophyceae. Similarly 29 taxa of Zooplankton belonging to 4 different genera including Protozoa, Rotifera, Copepoda and Ostracoda were recorded with highest diversity in case of Rotifera. The results also revealed that Icthyofauna was recorded with 24 different taxa belonging to 7 families and 4 orders. The physico-chemical conditions were favourable for the growth and survival of aquatic organisms. The data collected was subjected to statistical analysis and significant correlation was found between the biological and physico-chemical parameters. The occurrence of plankton populations and fish diversity indicated a good water quality of River Yamuna in Uttarakhand with positive effect of physico-chemical factors on the growth of these ecological indicators of aquatic ecosystem.*

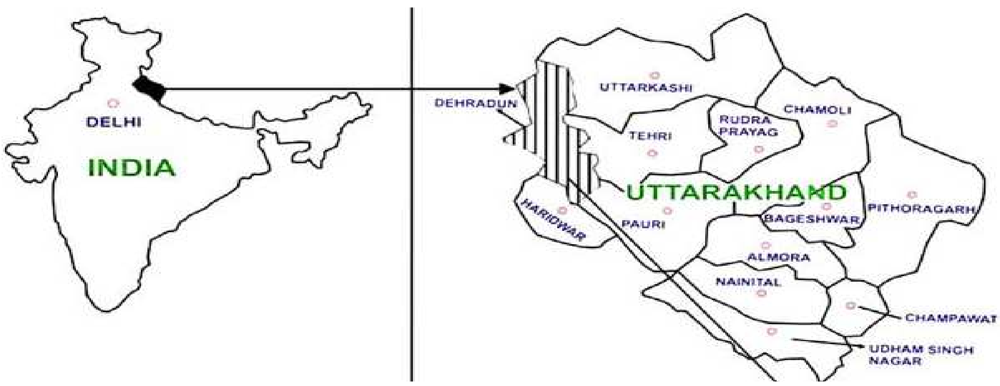
**Keywords:** Correlation, Ecological, Icthyofauna, Statistical, River Yamuna

## INTRODUCTION

Rivers play a major role in integrating and organizing the landscape and moulding the ecological setting of a basin. They are the prime factors controlling the global water cycle and in the hydrologic cycle, they are the most dynamic agents of transport [1]. Rivers carry elements in suspended or in dissolved form from their source and deposit them sequentially based on their physico-chemical nature at different locations. The suspended load in the river can act as a sink for nutrients and other elements in certain cases and as a source in certain other cases [2]. In spite of their wide-ranging role, presently rivers are under severe threat due to various anthropogenic pressures. Monitoring the surface run-off of a river on a regular basis provides valuable information on the eco-hydrological conditions of a river basin. Such data provide valuable insights into spatial and temporal variation in water quantity and quality, considered as a measure of the health of a river [3]. The River Yamuna sometimes called Jamuna or Jumna is the largest tributary of the River Ganges (Ganga) in northern India. It is perennial in nature as it receives all the three types of water inputs *i.e*., snowmelt runoff, rainfall runoff and groundwater. However, the three components vary in space and time. Therefore, the understanding of different components of water input to the River Yamuna may reveal its behavior at different locations that may be of great use to manage the groundwater as well as the river in a better way. The river gets maximum contribution of snowmelt during the month of May and June. But the main source to this river is precipitation that it receives. The extent of human activities that influence the environment particularly the freshwater has increased dramatically during the past few decades [4]. The scale of socio-economic activities, urbanizations, industrial operations and agricultural production has a widespread impact on water resources. As a result, very complex inter-relationships between socio-economic factors and natural hydrological and ecological conditions have developed [5]. The physical and chemical properties of fresh water body are characterized by the climatic, geochemical, geomorphological and pollution conditions [6]. The biota in the surface water is governed entirely by various environmental conditions. The water quality characteristics influence the ability of species living in a given river habitat. Aquatic biodiversity is one of the most essential characteristics of the aquatic ecosystem for maintaining its stability and a means of coping with any environmental change [7]. Phytoplankton plays the role of primary producer in the rivers food chain. They can convert inorganic material, such as nitrate and phosphate, into new organic compounds (e.g., lipids and proteins) through photosynthesis [8]. Zooplankton are microscopic free floating animals which play a vital role in aquatic ecosystem. They are choice food of fishes in general and juveniles in particular. They graze heavily on algae, bacteria and minute invertebrates [9]. Zooplankters are highly sensitive to environmental variation, as a result change in their abundance, species diversity or community composition can provide important indication of environmental change or disturbance [10]. Due to their short life cycle, these communities often respond quickly to environmental change. Rich diversity of organisms in an aquatic ecosystem reflects good water quality and any change in water quality due to addition of pollutant affects diversity and abundance of organisms. Riverine ecosystems have suffered from intense human intervention resulting in habitat loss and degradation and as a consequence, many fish species have become highly endangered, particular in rivers where heavy demand is placed on freshwaters [11]. Freshwater fish are one of the most threatened taxonomic groups because of their high sensitivity to the quantitative and qualitative alteration of aquatic habitats [12-15]. As a consequence, they are often used as bioindicator for the assessment of water quality, river network connectivity or flow regime [16]. Today the fish diversity and associated habitats management is a great challenge [17].

**Study area**

Dehradun is the capital city of the state of Uttarakhand in North India. It is located between 29058' and 310 2'30" north latitude and 77034'45" and 78018'30" east longitude. The River Yamuna originates from the Yamunotri Glacier at a height of 6,387 mtrs. on the south western slope of Banderpooch peak (38059' N and 78027' E) in the Mussoorie range of lower Himalayas at an elevation of about 6,320 mtrs. above mean sea level in Uttarkashi district of Uttarakhand. It travels a total length of 1,376 kilometers (855 mi) and has a drainage system of 366,223 km2, 40.2% of the entire Ganges Basin. The head waters of river Yamuna are formed by several melt streams, the chief of then gushing out of the morainic smooth at an altitude of 3250 m, 8 km North West of Yamunotri at the latitude 310 2'12" N and longitude 780 26' 10". Arising from the source, the river flows through series of curves and rapids for about 120 km to emerge into Indo-Gangetic plains at Dak Pathar in Uttaranchal.



## MATERIALS AND METHODS

The present study was conducted on River Yamuna covering a stretch of approximately 40 km from upstream to downstream. Three sites were selected along the river which includes Kalsi (S1), Dakpathar (S2) and Asan Lake (S3). The study was carried out for a time period of one year from August 2010-July 2011 on monthly basis. Water samples were collected every month early in the morning in sterilized sampling bottles and were analysed for twenty two important physical and chemical Parameters. Few physico-chemical parameters like Temperature (0C), Transparency (cm), Velocity (m/s), pH, Free CO2 (mg/l), and Dissolved Oxygen (mg/l) were performed on spot and other parameters like Turbidity (JTU), Electric conductivity (µmho/cm), Total Solids (mg/l), TDS (mg/l), TSS (mg/l), Total Alkalinity (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), BOD (mg/l), COD (mg/l), Phosphate (mg/l), Nitrate (mg/l), Sodium (mg/l) and Potassium (mg/l) were analysed in laboratory by following the methodology of APHA [18], Khanna and Bhutiani [19], Trivedi, and Goel [20], Wetzel and Likens [21]. Temperature, Transparency, Velocity was measured by using Celsius thermometer (0–110 0C), Secchi disc, and flow meter. Turbidity, Conductivity and pH were measured by using Jackson Turbidity unit, Conductivity meter and digital pH meter. Total Solids TDS, TSS were measured by volumetric analysis. Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Free CO2, DO BOD and COD were analysed by titration method. Phosphate and Nitrate were analysed by using UV-VIS Spectrophotometer and Sodium and Potassium by Fame photometer.

The plankton collection was made by hauling of water by plankton net (0.1mm mesh size) and preserved in 4% formaline solution. The plankton count was made by Sedgewick rafter cell under the microscope (Model No.CH-20i.) by using the formula [18];

$$\text{No. of Species/l} = \frac{C \times 1000\text{mm3}}{L \times D \times W \times S}$$

Here,
C= No of organisms counted
L= Length of each stripe (mm)
D= Depth of each stripe (mm)
W= Width of each stripe (mm)
S= No. of stripes

The qualitative analysis of the plankton samples were made with the help of Alfred et al. [22], Needham and Needham[23], Randhawa [24], Tonapi [25] and Ward and Wipple [26-27], Welch [28], Smith [29],Murugan et al. [30], Vollenwinds [31], Peat [32]. Besides personal fish collection, fishes were also procured from local fishermen fishing at different sites using indigenous fishing method. Fish specimen were collected and preserved in 10% formaldehyde solution. The identification of fishes were done on the basis of various morphological characters by following the standard keys, literature and work of Jhingran et al. [33], Talwar and Jhingran [34], Jayaram [35].

**Statistical Measurement**

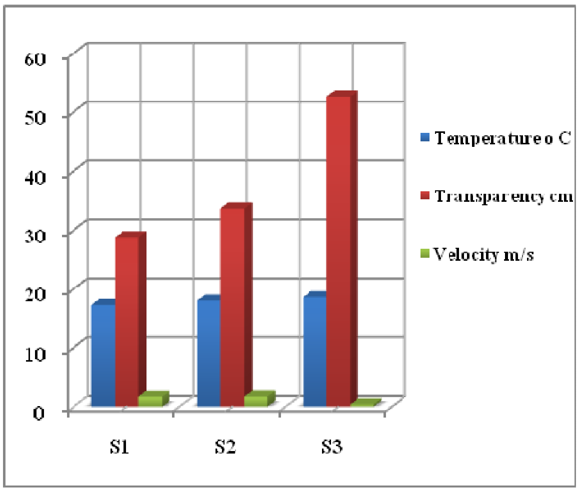
Statistical analysis like Standard deviation, Analysis of Variance (ANOVA) and Karl Pearson's correlation coefficient (r value) were was carried out to find the relation between the hydrological attributes and their impact on biological variables.

## RESULTS AND DISCUSSION

**Physico-Chemical parameters of water**

The physico-Chemical parameters (Avg.± SD) values obtained from the three sites of River Yamuna is given in table 1. From the results the temperature recorded at S1 was minimum (17.25±2.45 0C) and at S3 it was found maximum (18.58±2.31 0C) showing a great variation from upstream to downstream. The highest value of velocity was recorded at S2 (1.71±0.50 m/s) while the lowest value of velocity was found at S3 (0.392±0.10 m/s). The pH recorded at S2 was maximum (8.4±0.28) and it was found minimum at S3 (8.0±0.14) and S1 (8.27±0.25) showing little variation from each other. Total Alkalinity was found to be highest at S3 (171.83±24.29 mg/l) and it was found minimum at S2 (150.75±22.34 mg/l). The concentration of Dissolved oxygen was found to be maximum at S2 (11.24±0.71 mg/l) and it was found minimum at S3 (10.18±0.83mg/l). Other parameters like Transparency showed a decreasing trend from S1 to S3 while as Conductivity and Turbidity showed an increasing trend from S1 to S3.

Turbidity was found to be highest at S1 (336.66±382.54 JTU) and it was found lowest at S3 (253.33±330.72 JTU).Parameters like TS, TDS and TSS showed an irregular trend at all three sites during the whole year. Total Hardness was found to be highest at S1 (84.58±10.73 mg/l) and lowest at S3 (73.66±15.72 mg/l). Free $CO_2$ was found to be highest at S3 (1.52±0.234 mg/l) and COD was found lowest at S2 (4.51±0.993mg/l). BOD was recorded highest at S1 (2.59±0.40) and lowest at S2 (2.51±0.284). The parameters like Phosphate, Nitrate, Sodium and Potassium showed an irregular trend and a great variation in their concentration from S1 to S3 during the study period.



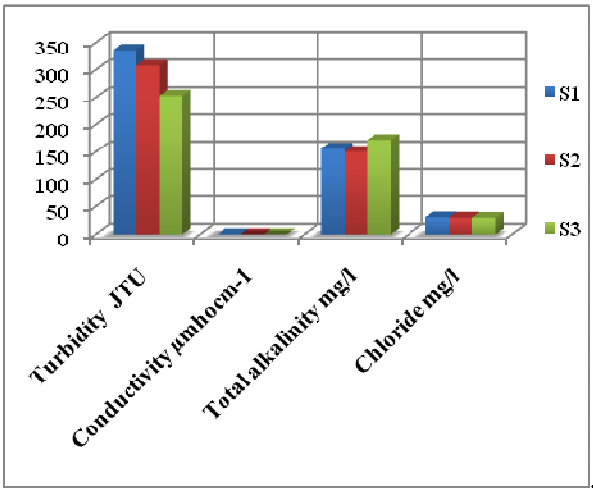
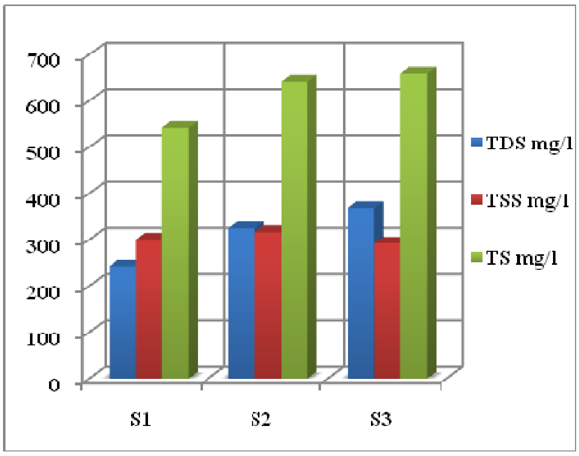




**Fig 1 showing Velocity, Transparency and Temperature at S1, S2 and S3 of River Yamuna**

**Fig 2 showing Turbidity, Conductivity, Total alkalinity and chloride at S1, S2 and S3 of River Yamuna**



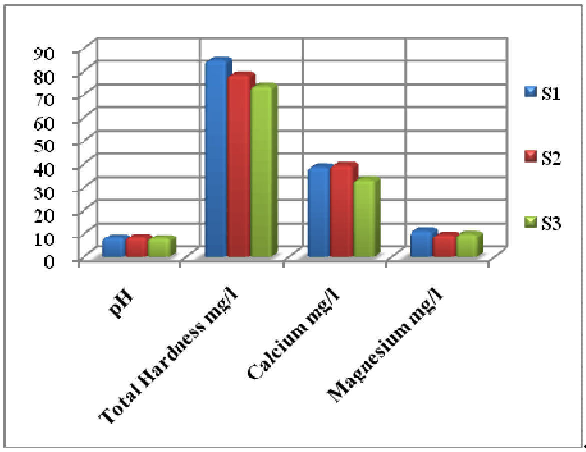



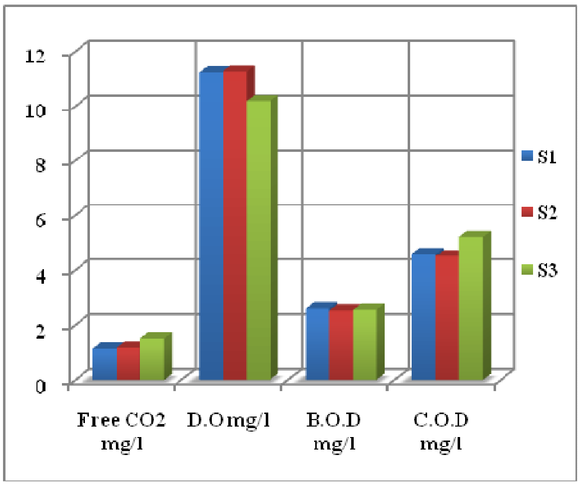

**Fig 3 showing TDS, TSS and TS at S1, S2 and S3 of River Yamuna**

**Fig 4 showing pH, Total hardness, calcium and magnesium at S1, S2 and S3 of River Yamuna**

### Phytoplankton, Zooplankton and Icthyofaunal diversity and density

The phytoplankton inhabitating the River Yamuna at S1, S2 and S3 comprises of 35 taxa out of which Chlorophyceae constitutes (15 genera), Bacillariophyceae (14 genera) and Myxophyceae (6 genera). Mean variation of all the three sites is shown in table 2. The diversity recorded at S1 was maximum for Bacillariophyceae (812.75±351.51) followed by Chlorophyceae (241.75±72.07) and minimum for Myxophyceae (59.75±29.40). At S2 diversity was recorded to be highest for Bacillariophyceae (677.25±264.53) followed by Chlorophyceae (226.91±106.59) and lowest for Myxophyceae (77.83±24.12). The diversity of phytoplankton was recorded to be maximum for Bacillariophyceae (897.6±327.68) at S3 followed by Chlorophyceae (289.7±95.87) and Myxophyceae

(104.66±49.20). However the overall density was found to be highest at S3 (1291.96) followed by S1 (1114.25) and lowest at S2 (981.99) showing the trend (S3>S1>S2). The qualitative study of phytoplankton in River Yamuna of Doon Valley revealed that the family Chlorophyceae was represented by *Chlorella, Chlaymydomonas, Spirogyra, Ulothrix, Hydrodictyon, Cladophora, Cosmarium, Chlorococcum, Oedogonium, Microspora, Desmidium, Chara, Zygenema, Syndesmus, and Volvox.* The family Bacillariophyceae was represented by *Ceratoneis, Amphora, Caloneis, Fragilaria, Navicula, Synedra, Diatoms, Gomphonema, Pinnularia, Melosira, Tabellaria, Denticula, Cymbella, and Cyclotella.* The Myxophyceae was represented by *Nostoc, Anabaena, Oscillatoria, Rivularia, Coccochloris, Phormidium.*



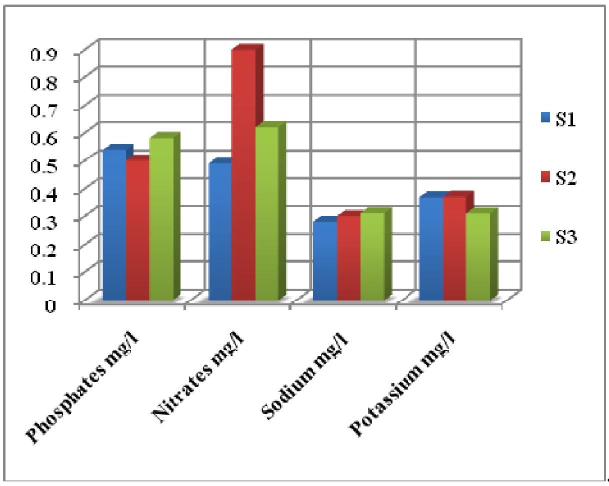
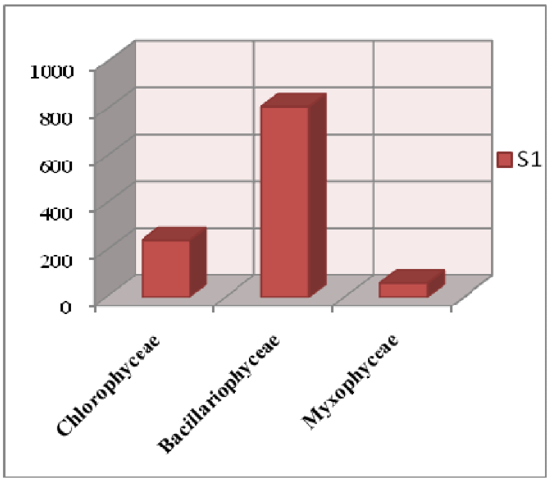




**Fig 5 Showing Free $CO_2$, DO, BOD and COD at S1, S2 and S3 of River Yamuna**

**Fig 6 showing phosphate, nitrate, sodium and potassium ay S1, S2 and S3 of River Yamuna**



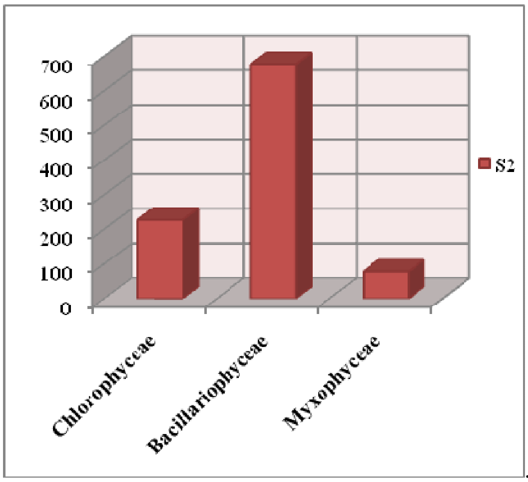
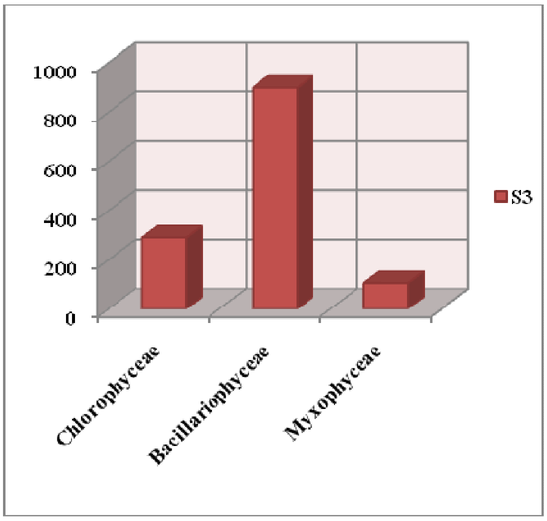




**Fig 7 showing average phytoplankton quantity in River Yamuna at S1 from August 2010 to July 2011**

**Fig 8 showing average phytoplankton quantity in River Yamuna at S2 from August 2010 to July 2011**

The Zooplankton inhabitating the River Yamuna at S1, S2 and S3 include 29 taxa out of which Protozoa consist of (10 genera), Rotifera (11 genera), Copepoda (6 genera) and Ostracoda (2 genera). Mean variation of all the three sites is shown in table 3. The diversity at S1 was found to be maximum for Rotifera (188.08±100.37) followed by Protozoa (119.75 ± 82.26), Copepoda (75.75±46.93) and Ostracoda (14.66±12.01). The diversity recorded at S2 was found to be maximum for Rotifera (136.0±80.31) followed by Protozoa (87.08 ± 60.07), Copepoda (57.16±30.91) and Ostracoda (10.50±7.21). At S3 the diversity was recorded to be highest for Rotifera (168.75±86.33) followed by

Protozoa (139.91 ± 74.65), Copepoda (99.91±48.53) and lowest for Ostracoda (25.08±15.25). However the overall density was found to be highest for S3 (433.65), followed by S1 (398.24) and lowest for S2 (290.74) showing a trend (S3>S1>S2). The qualitative analysis of Zooplankton in River Yamuna in Doon Valley revealed that the Protozoans were represented by *Actinophrys, Actinosphaerium, Euglena, Paramecium, Peridinium, Campenella, Epistylis, Vorticella, Arcella and Diffugia*. The Rotifera was represented by *Keratella, Nolthoca, Rotaria, Testudinella, Ascomorpha, Polyarthra, Philodina, Asplanchna, Pompholix, Brachionus and Trichocera.* The Copepoda was represented by *Cyclops, Diaptomus, Daphnia, Bosmina, Helobdella and Nauplius Stages*. The Ostracoda was represented by *Cypris and Stenocypris*.



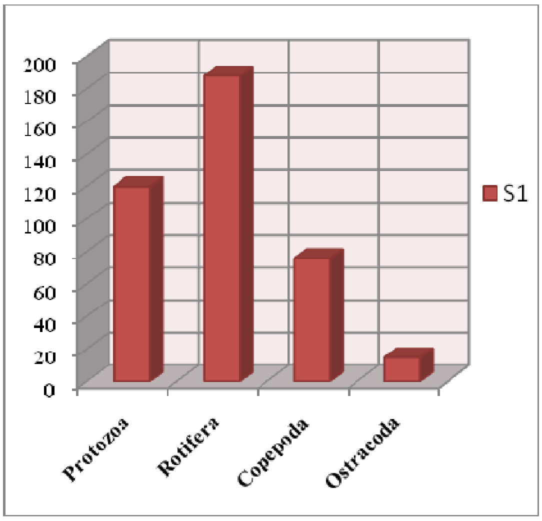
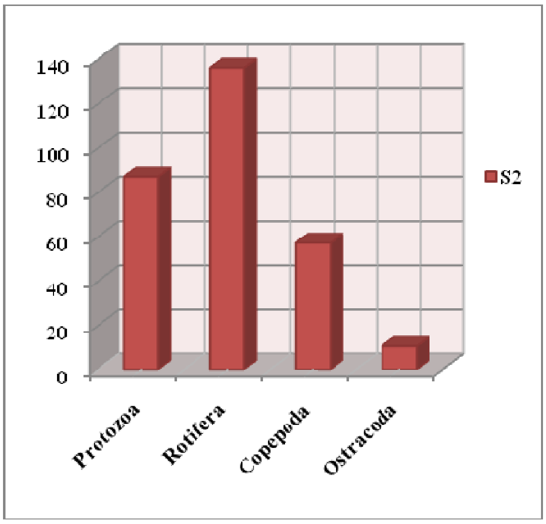




**Fig 9 showing average phytoplankton quantity in River Yamuna at S3 from August 2010 to July 2011**

**Fig 10 showing average zooplankton quantity in River Yamuna at S2 from August 2010 to July 2011**



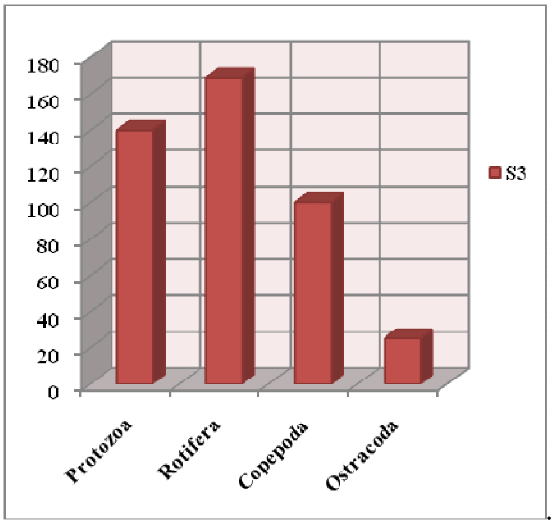




**Fig 11 showing average zooplankton quantity in River Yamuna at S2 from August 2010 to July 2011**

**Fig 12 showing average zooplankton quantity in River Yamuna at S3 from August 2010 to July 2011**

**Table 1 showing average (Mean ± SD) variation of physico-chemical parameters of River Yamuna at S1, S2 and S3 for the year August 2010-July 2011**

| Sites | S1 | S2 | S3 |
|---|---|---|---|
| | Avg ± S.D | Avg ± S.D | Avg ± S.D |
| **Parameter** | | | |
| **Temperature (°C)** | 17.25 ±2.45 | 18.0 ±2.59 | 18.58±2.31 |
| **Transparency (cm)** | 28.8 ±22.77 | 33.60 ±26.29 | 52.7±38.11 |
| **Velocity (m/s)** | 1.68 ±0.67 | 1.71 ±0.50 | 0.392±0.10 |
| **Turbidity (JTU)** | 336.66 ±382.54 | 307.91 ±366.63 | 253.33±330.72 |
| **Conductivity ( μmhocm$^{-1}$)** | 0.214 ±0.059 | 0.160 ±0.037 | 0.145±0.018 |
| **T.S (mg/l)** | 541.66 ±242.93 | 641.66 ±317.54 | 658.33±284.31 |
| **TDS (mg/l)** | 241.66 ±90.03 | 325.0 ±142.22 | 366.66±123.09 |
| **TSS (mg/l)** | 300.0 ±170.56 | 316.66 ±203.75 | 291.66±183.19 |
| **pH** | 8.27 ±0.25 | 8.40 ±0.284 | 8.0±0.148 |
| **Total alkalinity (mg/l)** | 156.16 ±29.60 | 150.75 ±22.34 | 171.83±24.29 |
| **Total Hardness (mg/l)** | 84.58 ±10.73 | 78.33 ±9.15 | 73.66±15.72 |
| **Calcium (mg/l)** | 38.70 ±10.52 | 39.47 ±14.50 | 33.35±8.32 |
| **Magnesium (mg/l)** | 11.37 ±3.93 | 9.47 ±3.20 | 9.83±3.20 |
| **Chloride (mg/l)** | 30.81 ±5.99 | 30.12 ±10.16 | 29.42±4.55 |
| **Free $CO_2$ (mg/l)** | 1.16 ±0.25 | 1.20 ±0.292 | 1.52±0.234 |
| **D.O (mg/l)** | 11.21 ±1.21 | 11.24 ±0.710 | 10.18 ±0.830 |
| **B.O.D (mg/l)** | 2.59 ±0.40 | 2.51 ±0.284 | 2.54±0.239 |
| **C.O.D (mg/l)** | 4.60 ±1.07 | 4.51 ±0.993 | 5.22±0.512 |
| **Phosphates (mg/l)** | 0.54 ±0.17 | 0.501 ±0.049 | 0.582±0.099 |
| **Nitrates (mg/l)** | 0.49 ±0.10 | 0.900 ±1.393 | 0.620±0.103 |
| **Sodium (mg/l)** | 0.28 ±0.04 | 0.301 ±0.050 | 0.311±0.071 |
| **Potassium (mg/l)** | 0.37 ±0.05 | 0.372 ±0.034 | 0.310 ±0.084 |

**P*=0.98, **Significant at* 0.05

A total of 24 taxa of fishes belonging to 6 families and 4 orders were recorded during the present study are shown in table 4. Cyprinidae family was found abundantly at S3 follwed by S1 and S2 with 13 taxa including *Barilius bendelisis* (Hamilton-Buchanan), *Barilius vagra* (Hamilton-Buchanan), *Rasbora daniconius* (Hamilton-Buchanan), *Channa gauchua* (Bloch and Schneider), *Danio rerio* (Hamilton-Buchanan), *Danio devario* (Hamilton-Buchanan), *Garra gotyla* (Gray), *Puntius ticto* (Hamilton-Buchanan), *Puntius sarana sarana* (Hamilton-Buchanan), *Laboe gonius* (Hamilton-Buchanan), *Labeo boga* (Hamilton-Buchanan), *Tor putitora* (Hamilton-Buchanan) and *Tor tor* (Hamilton-Buchanan). Family Schizothoracinae was found abundantly at S3 with 3 taxa including *Raimas bola* (Hamilton-Buchanan), *Schizothorax plagiostomus* (Heckel) and *Schizothorax progastus*(Heckel) whereas family Belonidae was recorded with only one taxa *Xenentodon cancila* (Hamilton-Buchanan) and was not found at S2. The family Cobitidae was recorded with 4 taxa including *Botia dario* Hamilton-Buchanan), *Nemachelius savona* Hamilton-Buchanan), *Nemachelius botia* Hamilton-Buchanan) and *Crossocheilus latius latius* Hamilton-Buchanan). Family Mastacembellidae was found with one taxa *Mastacembelus armatus* (Lacepede) and family Sisoridae with two taxa *Bagarius bagarius* Hamilton-Buchanan) and *Glyptothorax pectinoptrus* (McClelland).

**Relation between physico-chemical parameters**

Karl Pearson correlation (r-values) calculated for the quantification of relationship between various physical and chemical parameters (table 5) revealed that transparency was positively correlated with temperature ($r$ = 0.91, $p$ > 0.01). Velocity was negatively correlated with temperature and transparency ($r$ = -0.81, $p$ > 0.01) and ($r$ = -0.97, $p$ > 0.01). Turbidity was negatively correlated with temperature and transparency but positively correlated with velocity ($r$ = 0.93, $p$ > 0.01). Conductivity was negatively correlated with transparency ($r$ = -0.79, $p$ >0.05) and positively correlated with turbidity ($r$ = 0.88, $p$ > 0.01). Total Solids were positively correlated with transparency ($r$ = 0.74, $p$ > 0.05) but negatively correlated with velocity ($r$ = -0.59, $p$ > 0.05).

Both TDS and TSS was positively correlated with Total Solids ($r$ = 0.98, $p$ > 0.01) and ($r$ = 0.05, $p$< 0.05). pH was negatively correlated with temperature ($r$ = -0.60, $p$ > 0.05) and positively correlated with conductivity ($r$ = 0.39, $p$< 0.05). Total alkalinity was positively correlated with temperature and TDS ($r$ = 0.66, $p$> 0.05) and ($r$ = 0.57, $p$> 0.05). Total hardness was positively correlated with conductivity, TDS, TSS and pH but negatively correlated with total alkalinity ($r$ = -0.65, $p$> 0.05). Calcium and magnesium was positively correlated with total hardness ($r$ = 0.75, $p$>0.01) and ($r$ = 0.81, $p$ > 0.01). Chloride was positively correlated with conductivity ($r$ = 0.94, $p$ > 0.01) and negatively correlated with total alkalinity ($r$ = -0.71, $p$ > 0.01). Free CO2 was positively correlated with temperature ($r$ = 0.87, $p$ > 0.01) and negatively correlated with total hardness ($r$ = -0.87, $p$ >0.010). DO was positively correlated with velocity and pH (*r* = 0.99, *p* >0.01) and (*r* = 0.95, *p* >0.01) but negatively correlated with Free CO2 (*r* = -0.91, *p* >0.01). BOD was positively correlated with DO (*r* = 0.11, *p*< 0.05) and negatively correlated with Free CO2 (*r* = -0.24, *p* <0.05). COD was positively correlated with temperature and Free CO2 but negatively correlated with DO (*r* = -0.99, *p* > 0.01). Phosphate and nitrate was positively correlated with Total Solids and TDS but negatively correlated with hardness (*r*= -0.44, *p* <0.05) and (*r* = -0.38, *p*< 0.05). Sodium was negatively correlated with pH but positively correlated with total alkalinity (*r* = -0.49, *p* <0.05) and (*r*= 0.56, *p*> 0.05). Potassium was positively correlated with conductivity (r = 0.64, p >0.05) and negatively correlated with sodium (r = -0.72, p >0.01).

**Table 2 Average (Mean ± SD Values) spatial qualitative and quantitative distribution of phytoplankton (Unit/l) at S1, S2 and S3 of River Yamuna from August 2010 to July 2011**

| Sites | S1 | S2 | S3 |
|---|---|---|---|
| **Phytoplankton** | **Avg±SD** | **Avg±SD** | **Avg±SD** |
| ***Chlorophyceae*** | | | |
| *Chlorella* | 25.66±18.64 | 42.0±23.83 | 24.41±8.02 |
| *Chlaymydomonas* | 26.75±9.61 | 25.75±8.69 | 20.58±5.93 |
| *Spirogyra* | 19.33±6.51 | 22.50±6.33 | 24.25±9.82 |
| *Ulothrix* | 15.41±4.31 | 15.83±9.07 | 27.91±12.16 |
| *Hydrodictyon* | 13.33±10.22 | 6.50±7.11 | 15.08±7.36 |
| *Cladophora* | 17.75±4.39 | 15.25±13.49 | 31.75±13.39 |
| *Cosmarium* | 14.0±7.96 | 21.33±15.88 | 29.66±12.45 |
| *Chlorococcum* | 10.91±6.92 | 11.50±11.71 | 15.33±6.74 |
| *Oedogonium* | 11.66±6.54 | 7.66±5.78 | 15.08±7.52 |
| *Microspora* | 14.50±8.41 | 10.83±8.14 | 19.5±10.18 |
| *Desmidium* | 12.75±7.92 | 6.33±6.06 | 10.08±7.26 |
| *Chara* | 14.0±7.49 | 10.66±5.89 | 14.0±5.93 |
| *Zygenema* | 11.08±7.85 | 4.33±4.53 | 7.41±6.05 |
| *Syndesmus* | 14.58±7.50 | 8.33±5.67 | 10.16±5.60 |
| *Volvox* | 20.0±9.65 | 18.08±12.02 | 24.5±13.16 |
| **Total** | **241.75±72.07** | **226.91±106.59** | **289.7±95.87** |
| ***Bacillariophyceae*** | | | |
| *Ceratoneis* | 15.33±8.34 | 24.41±11.09 | 17.0±8.65 |
| *Amphora* | 14.66±6.93 | 12.08±8.30 | 27.08±13.30 |
| *Caloneis* | 15.0±12.43 | 2.58±2.50 | 7.50±4.66 |
| *Fragilaria* | 112.5±87.26 | 146.75±82.79 | 149.4±41.93 |
| *Navicula* | 171.0±64.80 | 138.33±48.43 | 160.1±68.26 |
| *Synedra* | 42.66±27.63 | 45.75±22.24 | 36.91±17.08 |
| *Diatoms* | 124.33±56.36 | 76.33±33.24 | 151.1±57.23 |
| *Gomphonema* | 82.58±39.03 | 33.75±21.42 | 29.66±16.52 |
| *Pinnularia* | 25.08±11.02 | 10.41±8.08 | 22.5±10.44 |
| *Melosira* | 15.66±11.61 | 4.41±5.24 | 11.25±7.30 |
| *Tabellaria* | 61.16±30.59 | 89.25±45.70 | 68.03±30.50 |
| *Denticula* | 30.08±15.28 | 17.08±13.22 | 45.33±18.38 |
| *Cymbella* | 87.58±43.22 | 68.75±33.65 | 152.0±65.92 |
| *Cyclotella* | 15.08±12.99 | 7.33±4.88 | 19.5±10.80 |
| **Total** | **812.75±351.51** | **677.25±264.53** | **897.6±327.68** |
| ***Myxophyceae*** | | | |
| *Nostoc* | 10.83±5.60 | 9.91± 6.65 | 16.75±11.00 |
| *Anabaena* | 9.25±5.78 | 9.25±4.35 | 16.66±7.57 |
| *Oscillatoria* | 10.83±6.56 | 23.83±9.26 | 21.5±8.74 |
| *Rivularia* | 8.75±6.21 | 13.0±7.94 | 22.83±13.12 |
| *Coccochloris* | 8.33±5.63 | 2.25±2.70 | 6.08±6.20 |
| *Phormidium* | 11.75±3.79 | 19.58±7.73 | 20.83±12.69 |
| **Total** | **59.75±29.40** | **77.83±24.12** | **104.66±49.20** |

**Relationship between Plankton diversity and hydrological parameters**

Pearson correlation coefficient (r values) calculated between physico-Chemical variables and Plankton population (table 6) inhabitating River Yamuna revealed that Chlorophyceae was positively correlated with temperature and transparency (*r* = 0.67, *p* > 0.05) and (*r* = 0.91, *p* > 0.01) but negatively correlated with velocity and total hardness (*r* = -0.97, *p* > 0.01) and (*r* = -0.67, *p* > 0.05). Bacillariophyceae was negatively correlated with turbidity (*r* = -0.53, *p* < 0.05) and positively correlated with total alkalinity (*r* = 0.91, *p* >0.01). Myxophyceae was positively correlated with temperature (*r* = 0.98, *p* >0.01) and negatively correlated with chloride (*r* = -0.99, *p* >0.01). Protozoa was positively correlated with TDS (*r* = 0.19, *p* <0.05) and phosphate (*r* = 0.98, *p* > 0.01). Rotifera was negatively correlated with transparency (*r* = -0.04, *p* <0.05) and positively correlated with turbidity (*r* = 0.19, *p*<

0.05).Copepoda was positively correlated with temperature ($r$ = 0.50, $p$< 0.05) and negatively correlated with total hardness ($r$ = 0.98, $p$> 0.01). Ostracoda was positively correlated with total alkalinity ($r$= 0.99, $P$> 0.010 and negatively correlated with nitrates ($r$ = -0.47, $p$ <0.05).

**Table 3 Average (Mean ± SD Values) spatial qualitative and quantitative distribution of Zooplankton (Unit/l) at S1, S2 and S3 of River Yamuna from August 2010 to July 2011**

| Sites | S1 | S2 | S3 |
|---|---|---|---|
| **Zooplankton** | **Avg.± SD** | **Avg. ±SD** | **Avg. ±SD** |
| ***Protozoans*** | | | |
| *Actinophrys* | 13.16 ±7.13 | 10.08 ± 6.85 | 12.83 ± 6.60 |
| *Actinosphaerium* | 10.16 ± 8.52 | 8.33 ± 8.70 | 13.16 ± 7.38 |
| *Euglena* | 6.50 ± 5.58 | 9.00 ± 7.63 | 12.83 ±7.00 |
| *Paramecium* | 8.00 ± 8.93 | 7.58 ± 7.25 | 15.41 ±8.56 |
| *Peridinium* | 12.50 ± 8.56 | 7.91 ± 5.94 | 11.16 ±8.25 |
| *Campenella* | 17.16 ± 11.23 | 7.00 ± 4.53 | 6.16 ±4.64 |
| *Epistylis* | 11.91 ± 8.25 | 4.50 ± 4.25 | 12.75± 7.60 |
| *Vorticella* | 9.75 ± 8.78 | 11.41 ± 7.22 | 17.58 ±8.57 |
| *Arcella* | 12.16 ±7.68 | 6.91 ± 4.31 | 15.58 ±7.22 |
| *Diffugia* | 18.41 ± 11.0 | 14.33 ± 7.38 | 22.41 ± 11.09 |
| **Total** | **119.75 ± 82.26** | **87.08 ± 60.07** | **139.91 ± 74.65** |
| ***Rotifera*** | | | |
| *Keratella* | 13.0 ±9.21 | 14.41±7.27 | 8.50±4.27 |
| *Nolthoca* | 15.16 ±7.92 | 9.66 ±6.32 | 16.16±8.12 |
| *Rotaria* | 14.08±7.39 | 10.75±9.15 | 18.50±9.85 |
| *Testudinella* | 17.25±11.29 | 12.16±8.11 | 10.16±6.91 |
| *Ascomorpha* | 15.08±12.78 | 16.08±9.40 | 20.33±8.94 |
| *Polyarthra* | 9.50±5.83 | 7.25±6.45 | 9.58±6.48 |
| *Philodina* | 14.08±10.25 | 8.75±7.20 | 9.91±7.21 |
| *Asplanchna* | 34.5±18.15 | 21.08±10.79 | 23.41±11.23 |
| *Pompholix* | 12.91±6.17 | 8.25±10.43 | 13.50±7.42 |
| *Brachionus* | 34.08±14.68 | 21.08±11.66 | 27.58±12.77 |
| *Trichocera* | 8.41±4.98 | 6.50±5.95 | 11.08±7.87 |
| **Total** | **188.08±100.37** | **136.0±80.31** | **168.75±86.33** |
| ***Copepoda*** | | | |
| *Cyclops* | 24.50±14.93 | 15.33±7.81 | 28.41±11.98 |
| *Diaptomus* | 15.25±8.34 | 9.08±5.51 | 13.33±6.40 |
| *Daphnia* | 14.50±6.51 | 11.25±6.63 | 14.00±8.81 |
| *Bosmina* | 6.25±5.49 | 4.16±3.37 | 11.91±7.93 |
| *Helobdella* | 5.83±5.04 | 4.00±3.07 | 11.91±6.94 |
| *Nauplius Stages* | 9.41±8.77 | 13.33±6.56 | 20.33±8.45 |
| **Total** | **75.75±46.93** | **57.16±30.91** | **99.91±48.53** |
| ***Ostracoda*** | | | |
| *Cypris* | 6.41±5.94 | 5.00±2.76 | 14.33±9.14 |
| *Stenocypris* | 8.16±6.22 | 5.50±4.88 | 10.75±6.52 |
| **Total** | **14.66±12.01** | **10.50±7.21** | **25.08±15.25** |

The Physico-Chemical variables are important environmental factors of water in which all the biological communities live in association with each other [36]. The most common physical assessment of water quality is measurement of temperature. Infact no other single factor has so intense influence and direct as well as indirect effect on biota of an ecosystem [37]. During the present study the temperature recorded in River Yamuna ranged from 17.25 ±2.45 0C to 18.58±2.310C respectively. However the values of temperature recorded at all the sites varies monthly as well as seasonally but overall the temperature was found to be slightly higher which had a strong effect on the chemical and biological parameters of water. The total alkalinity recorded in River Yamuna was relatively higher. The highly alkaline nature of river water was revealed by the elevation of pH from 8.0 ±0.14 to 8.4 ± 0.28. The increase in pH could be due to either increased concentration of carbonates or increased photosynthetic activities of producers [38]. The higher carbonate and bicarbonate levels may have contributed to the alkalinity of water samples. The conductivity, Total Solids TDS and TSS were observed relatively in higher levels during monsoon period which may be attributed to the heavy rainfall resulting in soil erosion and several fold concentration of elements and minimum in winters due to minimum velocity which favoured effective sedimentation and low level of water causing minimum silt. Hardness is an important parameter in decreasing the toxic effect of poisonous element [39]. The values of total hardness ranged from 73.66±15.72 mg/l to 84.58 ±10.73 mg/l. Hardness values may be attributed to presence of high calcium and magnesium levels in aquatic ecosystems. In River Yamuna DO

(Dissolved Oxygen) concentration was almost high ranged from 10.18 ±0.830 mg/l to 11.24 ±0.710 which indicated the better conditions of water quality. The monthly and seasonal values vary and showed high DO concentration in River Yamuna. Levels of BOD ranging from 2.51±0.28 mg/l to 2.59±0.40 mg/l and COD ranging from 4.51±0.99 mg/l to 5.22±0.51mg/l may be due to addition of organic content. Further slightly higher values of BOD and COD in this river were observed during the summer and may be attributed to the seasonal effect at high temperature. However in River Yamuna water at all the sites is suitable for various uses. Most of the people residing along the bank of River Yamuna at S1, S2 and S3 still used its water for drinking and other purposes. The transparency was minimum in monsoon while as turbidity was maximum during this period and vice-versa. The reason for this was heavy rainfall during monsoon period which brings soil and other sediments resulting in less penetration of light, hence decreasing the photosynthetic activity of aquatic flora and resulting in low concentration of DO during monsoon period [40]. The velocity was higher in River Yamuna during summer and monsoon months as it is a glacier fed river resulting in more and more water due to melting of ice and snow and also heavy rainfall results in maximum runoff hence increasing its velocity. In River Yamuna the concentration level of phosphate and nitrate varied between 0.50 ±0.04 mg/l to 0.58±0.09 mg/l and 49±0.10 mg/l to 0.90±1.39 mg/l. The observed values of phosphate and nitrate in river Yamuna reflect addition of phosphate and nitrate from anthropogenic sources. Further phosphate and nitrate at S1, S2 and S3 may be accounted to runoff from feedlot or heavily fertilized fields. The relatively low concentration of Chloride in River Yamuna may be due to dilution effect. The levels of Sodium and Potassium in River Yamuna ranged from 0.28±0.04 mg/l to 0.31±0.07 mg/l. The overall monthly mean values of Sodium and Potassium were relatively lower in River Yamuna.

**Table 4: Ecological status and of diversity of Ichthyo – fauna of River Yamuna at S1, S2 and S3 from August 2010- July 2011**

| ***Ichthyo-Fauna*** | **River Yamuna** | | | ***Ecological Status*** |
|---|---|---|---|---|
| | **S1** | **S2** | **S3** | |
| **Order Cypriniformes** | | | | |
| ***Family Cyprinidae*** | | | | |
| *Barilius bendelisis* (Hamilton-Buchanan) | +++ | ++ | +++ | **Intermediate** |
| *Barilius vagra* (Hamilton-Buchanan) | +++ | +++ | +++ | **Rare** |
| *Rasbora daniconius* (Hamilton-Buchanan) | + | + | ++ | **Vulnerable** |
| *Channa gauchua* (Bloch and Schneider) | ++ | + | + | **Vulnerable** |
| *Danio rerio*(Hamilton-Buchanan) | +++ | ++ | +++ | **Rare** |
| *Danio devario*(Hamilton-Buchanan) | + | + | ++ | **Rare** |
| *Garra gotyla* (Gray) | + | + | + | **Vulnerable** |
| *Puntius ticto*(Hamilton-Buchanan) | ++ | ++ | +++ | **Rare** |
| *Puntius sarana sarana*(Hamilton-Buchanan) | + | + | ++ | **Vulnerable** |
| *Laboe gonius*(Hamilton-Buchanan) | +++ | ++ | +++ | **Intermediate** |
| *Labeo boga*(Hamilton-Buchanan) | ++ | + | ++ | **Intermediate** |
| *Tor putitora*(Hamilton-Buchanan) | +++ | +++ | +++ | **Vulnerable** |
| *Tor tor*(Hamilton-Buchanan) | ++ | ++ | +++ | **Vulnerable** |
| ***Family Schizothoracinae*** | | | | |
| *Raimas bola*(Hamilton-Buchanan) | + | + | + | **Endangered** |
| *Schizothorax plagiostomus* (Heckel) | +++ | ++ | +++ | **Intermediate** |
| *Schizothorax progastus*(Heckel) | ++ | ++ | +++ | **Intermediate** |
| **Order Beloniformes** | | | | |
| ***Family Belonidae*** | | | | |
| *Xenentodon cancila*(Hamilton-Buchanan) | + | - | + | **Rare** |
| ***Family Cobitidae*** | | | | |
| *Botia dario* Hamilton-Buchanan) | + | + | + | **Rare** |
| *Nemachelius savona* Hamilton-Buchanan) | ++ | + | ++ | **Vulnerable** |
| *Nemachelius botia* Hamilton-Buchanan) | + | + | + | **Intermediate** |
| *Crossocheilus latius latius* Hamilton-Buchanan) | ++ | + | ++ | **Rare** |
| **Order Mastacembeliformes** | | | | |
| ***Family Mastacembellidae*** | | | | |
| *Mastacembelus armatus* (Lacepede) | ++ | + | ++ | **Rare** |
| **Order Siluriformes** | | | | |
| ***Family Sisoridae*** | | | | |
| *Bagarius bagarius* Hamilton-Buchanan) | ++ | + | ++ | **Vulnerable** |
| *Glyptothorax pectinoptrus* (McClelland) | ++ | ++ | +++ | **Rare** |
| **Total number of taxa reported= 24** | **24** | **23** | **24** | |

*Abundant: (+++); Present (++); Common (+); Nil: (-)*

**Table 5 showing Pearson correlation coefficient between Physico-chemical parameters of River Yamuna at S1, S2 and S3 from August 2010-July 2011**

| | Temp | Transparency | Velocity | Turbidity | Conductivity | Total Solids | TDS | TSS | pH | Total Alkalinity | Total Hardness | Calcium | Magnesium | Chloride | Free $CO_2$ | DO | BOD | COD | $PO_4$ | $NO_3$ | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temp** | 1 | | | | | | | | | | | | | | | | | | | | | |
| **Transparency** | 0.91* | 1 | | | | | | | | | | | | | | | | | | | | |
| **Velocity** | -0.81* | -0.97* | 1 | | | | | | | | | | | | | | | | | | | |
| **Turbidity** | -0.96* | -0.98* | 0.93* | 1 | | | | | | | | | | | | | | | | | | |
| **Conductivity** | -0.97* | -0.79** | 0.65** | 0.88* | 1 | | | | | | | | | | | | | | | | | |
| **Total Solids** | 0.95* | 0.74** | -0.59** | -0.84* | -0.99* | 1 | | | | | | | | | | | | | | | | |
| **TDS** | 0.99* | 0.86* | -0.74** | -0.93* | -0.99* | 0.98* | 1 | | | | | | | | | | | | | | | |
| **TSS** | -0.25** | -0.61** | 0.76* | 0.48** | 0.01** | 0.05** | -0.14** | 1 | | | | | | | | | | | | | | |
| **pH** | -0.60** | -0.87* | 0.95* | 0.78* | 0.39** | -0.32** | -0.50** | 0.92* | 1 | | | | | | | | | | | | | |
| **Total Alkalinity** | 0.66** | 0.90* | -0.97* | -0.82* | -0.46** | 0.39** | 0.57** | -0.89* | -0.99* | 1 | | | | | | | | | | | | |
| **Total Hardness** | -0.99* | -0.91* | 0.80* | 0.96* | 0.97* | -0.95* | -0.99* | 0.24** | 0.59** | -0.65** | 1 | | | | | | | | | | | |
| **Calcium** | -0.75* | -0.95* | 0.99* | 0.89* | 0.57** | -0.51** | -0.67** | 0.82* | 0.97* | -0.99* | 0.75* | 1 | | | | | | | | | | |
| **Magnesium** | -0.80* | -0.51** | 0.31** | 0.63* | 0.92* | -0.95* | -0.87* | -0.36** | 0.02** | -0.09** | 0.81* | 0.22** | 1 | | | | | | | | | |
| **Chloride** | -0.99* | -0.94* | 0.85* | 0.98* | 0.94* | -0.92* | -0.98* | 0.33** | 0.66* | -0.71* | 0.99* | 0.80* | 0.76* | 1 | | | | | | | | |
| **Free $CO_2$** | 0.87* | 0.99* | -0.99* | -0.97* | -0.74* | 0.68** | 0.81* | -0.68** | -0.91* | 0.93* | -0.87* | -0.97* | -0.43** | -0.91* | 1 | | | | | | | |
| **DO** | -0.81* | -0.97* | 0.99* | 0.93* | 0.64** | -0.59** | -0.73* | 0.77* | 0.95* | -0.97** | 0.80* | 0.99* | 0.31** | 0.85* | -0.99* | 1 | | | | | | |
| **BOD** | -0.67** | -0.32** | 0.12** | 0.47** | 0.83* | -0.87* | -0.75* | -0.54** | -0.18** | 0.10** | 0.68** | 0.02** | 0.98* | 0.61** | -0.24** | 0.11** | 1 | | | | | |
| **COD** | 0.75* | 0.95* | -0.99* | -0.89* | -0.58** | 0.51** | 0.67** | -0.82* | -0.97* | 0.99** | -0.74* | -0.99* | -0.22** | -0.80* | 0.97* | -0.99* | -0.03** | 1 | | | | |
| **$PO_4$** | 0.45** | 0.76* | -0.88* | -0.66** | -0.23** | 0.15** | 0.34** | -0.97* | -0.98* | 0.96* | -0.44** | -0.92* | 0.15** | -0.52** | 0.82* | -0.88* | 0.35** | 0.92* | 1 | | | |
| **$NO_3$** | 0.37** | -0.01** | 0.22** | -0.13** | -0.59** | 0.64** | 0.48** | 0.79* | 0.50** | -0.44** | -0.38* | 0.31** | -0.85* | -0.30** | -0.10** | 0.23** | -0.94* | -0.31** | -0.65** | 1 | | |
| **Na** | 0.99* | 0.86* | -0.73* | -0.92* | -0.99* | 0.98* | 0.99* | -0.13** | -0.49** | 0.56** | -0.99* | -0.66** | -0.87* | -0.97* | 0.81** | -0.73* | -0.76* | 0.66** | 0.33** | 0.49** | 1 | |
| **K** | -0.81* | -0.97* | 0.99* | 0.93* | 0.64** | -0.58** | -0.73* | 0.77* | 0.95* | -0.97* | 0.80* | 0.99* | 0.31** | 0.85* | -0.99* | 0.99* | 0.11** | -0.99* | -0.89* | 0.23** | -0.72* | 1 |

*Significant at 0.01* and 0.05***

**Table 6 showing Pearson correlation coefficient between Physico-chemical parameters and plankton diversity of River Yamuna at S1, S2 and S3 from August 2010-July 2011**

| | Temp. | Transparency | Velocity | Turbidity | EC | TS | TDS | TSS | pH | TALk | THD | Ca | Mg | Cl | Free $CO_2$ | DO | BOD | COD | $PO_4$ | $NO_3$ | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chlorophyceae** | 0.67* | 0.91** | -0.97* | -0.83* | -0.48** | 0.41** | 0.58** | -0.88* | -0.99* | 0.99* | -0.67** | -0.99* | -0.12** | -0.73* | 0.94* | -0.98* | 0.08** | 0.99* | 0.96* | -0.42** | 0.58** | -0.98 |
| **Bacillariophyceae** | 0.31** | 0.66** | -0.80* | -0.53** | -0.08** | 0.00054** | 0.20** | -0.99* | -0.94* | 0.91* | -0.30** | -0.86* | 0.31** | -0.39** | 0.72* | -0.81* | 0.49** | 0.86* | 0.98* | -0.76* | 0.19** | -0.81* |
| **Myxophyceae** | 0.98* | 0.97* | -0.90* | -0.99* | -0.91* | 0.87* | 0.95* | -0.43** | -0.74* | 0.78* | -0.98* | -0.86* | -0.69** | -0.99* | 0.95* | -0.91* | -0.53** | 0.86* | 0.61** | 0.20** | 0.95* | -0.90* |
| **Protozoa** | 0.30** | 0.66** | -0.80* | -0.53** | -0.07** | -0.0034** | 0.19** | -0.99* | -0.94* | 0.91* | -0.30** | -0.86* | 0.31** | -0.38** | 0.72* | -0.81* | 0.49** | 0.86* | 0.98* | -0.76* | 0.18** | -0.81* |
| **Rotifera** | -0.43** | -0.04** | -0.16** | 0.19** | 0.64** | -0.69** | -0.53** | -0.75* | -0.45** | 0.38** | 0.44** | -0.26** | 0.88* | 0.36** | 0.04** | -0.17** | 0.95** | 0.26** | 0.60** | -0.99* | -0.55** | -0.18** |
| **Copepoda** | 0.50** | 0.80* | -0.91* | -0.70* | -0.28** | 0.20** | 0.39** | -0.96* | -0.99* | 0.98* | -0.49** | -0.95* | 0.10** | -0.57** | 0.85* | -0.91* | 0.30** | 0.95* | 0.99* | -0.61** | 0.39** | -0.91* |
| **Ostracoda** | 0.63** | 0.89* | -0.96* | -0.81* | -0.44** | 0.36** | 0.54** | -0.90* | -0.99* | 0.99* | -0.63** | -0.99* | -0.06* | -0.70* | 0.92* | -0.97* | 0.13** | 0.99* | 0.97* | -0.47** | 0.54** | -0.97* |

*Significant at 0.01* and 0.05***

River Yamuna showed highest quantitative and qualitative composition of plankton and fish fauna from S1 to S3. A distinctive pattern of phytoplankton structure was observed at all the three sites. Maximum number of total phytoplankton during the study period indicates good physicochemical conditions. The Phytoplankton inhabitating River Yamuna comprises of 35 taxa out of which Chlorophyceae constitute (15 genera), Bacillariophyceae (14 genera) and Myxophyceae (6 genera). The diversity of Bacillariophyceae biomass was dominating the River Yamuna. The population dynamics of the phytoplankton is influenced by the climatic conditions as well as the physico-chemical characteristics of the river. A marked difference in the composition and in the abundance of various algal groups was observed in the river. The turbidity and the heavy water current will prevent the growth of phytoplankton during the monsoon period. During summer season, the river water turns to more lacustrine and the additions of nutrients favour the growth of planktons. Hydrological factors such as discharge or water residence time are thought to be of greater importance to planktonic development in rivers [41]. In the present investigation Bacillariophyceae formed the bulk of the algal population in river Yamuna. Diatoms (Bacillariophyceae) dominated the phytoplankton during the study period. In most large rivers, a bloom dominated by diatoms, occurs after the decrease of discharge in spring, where as mixed population of Chlorophyceae and diatoms comprises the summer phytoplankton [42]. Higher concentration of phytoplankton at S3 was mainly due to the increase in the quantity of nutrients. Bacillariophyceae was remarkably abundant than the other groups of planktons. The next prominent group was Chlorophyceae followed by the Myxophyceae. The phosphate and nitrate content at all the sites during the phytoplankton peaks were not always high. The low concentration of phosphates and nitrates during the months when quantity of phytoplankton was high may be due to the utilization of the nutrients by the phytoplankton.

The composition and occurrence of zooplankton recorded in the various stations during the period of the study is shown in Table 3. Qualitatively, the fauna of each sampling site was dominated by rotifers followed by protozoa, copepods, and ostracods in that order. The Zooplankton consists of 29 taxa out of which Protozoa include (10 genera), Rotifera (11 genera), Copepoda (6 genera) and Ostracoda (2 genera). However Rotifera was dominating the River with maximum diversity. Most of the zooplankton encountered in the study area appears to be normal inhabitants of natural lakes, ponds, streams and artificial impoundments in India and in tropics and sub trophics [43]. The rotifers constitute the largest group of zooplankton recorded in all the sites. The ability of rotifers to undergo vertical migration, which minimizes competition through niche exploitation and food utilization, could be probably the reason for their dominance [44]. Also, rotifer richness in the stream probably could be due to high microhabitat diversity especially at sites S1 and S3. The high population abundance of rotifer may also be attributed to their parthenogenetic reproductive pattern and short developmental rates under favourable conditions in most fresh water systems [45]. Pearson’s correlation coefficient indicated that several environmental variables exert a considerable influence on the zooplankton abundance especially dissolved oxygen, temperature, total alkalinity, phosphate and pH. Consistent with our findings Sarkar and Choudhary [46] reported significant multiple correlations between plankton abundance and several physical and chemical variables in their study. During the course of study Ichthyo fauna was more diverse in River Yamuna as shown in table 5. The river water is a natural medium for the growth of aquatic flora and the fluxing of the wastes by natural or anthropogenic factors cause a disturbance in its composition. Fish communities in riverine system typically follow a pattern of increasing species richness, diversity and abundance from upstream to downstream [47-48]. In the present study it was revealed that dissolved oxygen and pH are key habitat features and positively correlated with the fish assemblages and are the most important variables in shaping fish distributions. The variations in the habitat attributes like pH, turbidity, total dissolved solids and conductivity across different sites was attributed to differences in land use pattern, which was responsible for variation of species diversity and distribution [49]. Our study depicted the presence of 24 taxa belonging to 6 families and 4 orders. Though the fish diversity was profoundly present in the River Yamuna but there is great need of conservation strategies as far as the status of fish fauna is concerned. The velocity of water has a bearing effect upon the biological diversity. This causes the change in the optimum conditions favorable for the growth of the aquatic flora [50]. With the increase in velocity during rainy season, the aquatic flora and fauna gets washed off from the stones and other substratum. The turbidity had a negative correlation with plankton population as well as other aquatic organisms because with the increase in turbidity the photosynthesis is adequately effected due to less light penetration resulting in lower levels of DO and ultimately adverse effect on aquatic biodiversity [51].

The impact on physico-chemical and biological observations showed clear monthly and seasonal variation at different sites of River Yamuna. The river bears much diversified biodiversity especially at S3 as it is a lake ecosystem and its conditions are favourable for the growth of flora and fauna residing in it. The River Yamuna at S1, S2 and S3 originating from Yamunotri glacier has least pollution because of minimum anthropogenic activities. The bottom of the river is sandy and stony which is the indication of pollution free ecosystem. The altitudinal, geographical variations, mountain slopes, expansion of river valley and the vegetation cover has given rise to varying microclimatic conditions in the study area which affected the physico-biochemical properties of River Yamuna and all the abiotic and biotic factors were interrelated with each other [52]. Among physico-chemical parameters water temperature was influenced by velocity, gradient, river bed and impact of previous night weather. The transparency was affected by TSS, sand, plankton and rainfall in monsoon period. The velocity of the river increases with the melting of snow and again showed an increase during monsoon. The direct relationship between the amount of DO and aquatic flora and fauna was reported. The concentration of nitrates and phosphates were within the limits which proved to be helpful in plankton production in the river. The interaction of different environmental factors influences all the living organisms in each trophic level of this aquatic ecosystem [53]. The synchronization of the organisms and their environment is the basic rule of ecology. Hence freshwater resources are the life line of a community, it is essential that communities get involved and interlinked for their survival without changing their ecological niche [54]. The present study suggested that River Yamuna in Uttarakhand has to be preserved for its intended use, a sustainable and holistic management planning is necessary for conservation of this aquatic ecosystem. Habitat destruction, over exploitation and wanton destruction should be controlled and environmental awareness with regard to aquatic ecosystem in Himalayas be propagated among the prospective and inhabitance of the area for the general follow up.

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