Macrobenthic Invertebrate assemblage along gradients of the river Basantar (Jammu, J&K) in response to industrial wastewater

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Abstract— *A limnological investigation was carried out in River Basantar in the Jammu province of Jammu & Kashmir (India) during the period from December, 2009 to November, 2011 in order to analyse the effect of industrial pollution on the diversity and population density of Macrobenthic invertebrate fauna along the longitudinal profile of the river. A total of 27 macrobenthic invertebrate taxa inhabited the river; among these Arthropoda dominated the macrobenthic community (81.48%, 22 species) followed by Annelida (11.11%, 3 species) and Mollusca (7.41%, 2 species). The Discharge Zone (St II) had the highest mean standing crop of macrobenthic population while the lowest species number. Oligochaetes (Annelida) and Dipterans (Arthropoda) exhibited their abundance at polluted sites whereas Odonates, Ephemeropterans, Hemipterans, Coleopterans (Arthropoda) and Molluscs were abundant at least polluted sites. Tubifex tubifex, Branchiura sowerbyi, Limnodrillus hoffmeisteri, Chironomus, Tubifera, Psychoda and Physa acuta were identified as pollution indicator taxa while Progomphus, Cloeon, Baetis and Gyraulus as sensitive taxa.*

Keywords*— *Pollution, Diversity, Macrobenthic Invertebrate, Indicator taxa.

I. INTRODUCTION

Aquatic ecosystem is one of the most productive ecosystems in the world that inhabits a large proportion of the earth's biodiversity (McAllister et al., 1997 and Groombridge and Jenkins, 1998). Numerous plants and animals, ranging from microscopic algae to large plants, from protozoan to mammals, exhibit a variety of adaptations which allow them to survive and grow in water (Gopal and Chauhan, 2001). In the past, 'Water' the basic amenity for living organisms was pure, virgin, undisturbed, uncontaminated and basically most hospitable for living organisms but the situation is just the reverse today because progress in science and technology is also leading to pollution of environment and serious ecological imbalance which in the long run, may prove disastrous for mankind (Chauhan, 2008), thereby affecting its ecological integrity to a greater extent**.**

Macrobenthic invertebrates refer to the organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes, filamentous algae etc.) of aquatic habitats, for at least part of their life cycle. The density of aquatic macrobenthic invertebrate species and communities is controlled by a variety of environmental factors such as habitat characteristics (Hynes, 1970; Peeters and Gardeniers, 1998), sediment quality (Chapman and Lewis, 1976), sediment grain size (Tolkamp, 1980), and by biological factors such as competition and predation (Kohler, 1992; MacKay, 1992; Macneil et al., 1999; Bhat et al., 2011). Stream flow, nature of substratum and organic pollution generally regulates the species composition and dominance of different taxa in various stretches of rivers (Negi and Singh, 1990; Bhat et al., 2011) and thus, macrobenthic invertebrates constitute the most popular and commonly used group of freshwater organisms in assessing water quality (Rosenberg and Resh, 1993). Benthic invertebrates have been favoured in environmental effects monitoring because they are sessile or limited in their range of movement and therefore cannot avoid pollution (Gaufin, 1973). They are generally abundant and can be found year round so are easily sampled. Since many aquatic species have a life span in water of approximately a year, they provide an indication of water quality conditions over that period. Thus, benthic invertebrate monitoring data provides a link between the effects of human activities on the physical and chemical properties of water and aquatic ecosystem health (Norris and Hawkins, 2000).

River Basantar (the present study site) is a tributary of river Ravi and is an important water body of Jammu and Kashmir State of India. It flows through the district Samba of Jammu region and is one of the main sources of drinking water for its inhabitants. The establishment of an Industrial Growth Centre with large number of industrial units along the side of this river causes direct discharge of the industrial waste into the river through drainage thereby severely deteriorating the water quality of the river and thus drastically affected the overall ecology of river Basantar. In order to assess the impact of pollution load on the diversity and distribution pattern of macrobenthic invertebrate fauna of river Basantar, a study was carried out for a period of two years i.e. from December, 2009 to November, 2011 at four pre-designated stations of river Basantar *viz.* St I, II, III and IV (Fig 1). St I lie near the National Highway Bridge and is under continuous stress of anthropogenic influences in the form of Cattle-bathing, washing of vehicles, fishing, drawing of water using electric motor and mining of sand. St II is about 2.2 km downstream from the Station I near Railway Bridge. It receives industrial effluents from industrial drainage. St III lies 1 km downstream from Station II. Sand mining, cattle bathing and drawing of water using electric motor (by Gujjar community residing at the bank of the river) are the common activities at this station. St IV is about 3.5 km downstream from Station III.

FIG 1: SATELLITE VIEW OF RIVER BASANTAR-THE STUDY AREA (FROM GOOGLE).

Thus, the present study describes the response of macrobenthic fauna to the industrial pollution with regard to its species composition and distribution in river Basantar so as to utilize the information so generated to devise proper strategies regarding the monitoring and conservation of river Basantar.

II. MATERIAL AND METHOD

2.1 Physico-chemical Parameters

Some important physico-chemical parameters *viz.* Water temperature, Dissolved Oxygen and Biological Oxygen Demand were analyzed by having monthly samples of sub-surface water at four pre-designated stations during the period from December, 2009 to November, 2011. The water temperature and Dissolved Oxygen (DO) were recorded at the sampling sites by mercury bulb thermometer and sodium azide modification of Winkler's method respectively while Biological Oxygen Demand (BOD) was analyzed by 3-day BOD test performed in the laboratory following Adoni (1985) and A.P.H.A. (1985).

2.2 Sampling of Macrobenthic Invertebrates

Macrobenthic invertebrate samples were collected monthly by using Ekmann's dredge from the preselected stations. Four bottom samples were taken from each station to minimize the sampling error. Samples collected were then sieved through sieve no. 40 having 256 meshes per sq. cm (Edmondson and Winberg, 1971) and packed in labelled polythene bags. Samples were washed in the laboratory; organisms were sorted and then preserved in 5% formalin or 90% ethylalcohol for further identification.

2.3 Qualitative analysis

The qualitative analysis of preserved samples of macrobenthic invertebrate fauna was done by following Ward and Whipple (1959), Needham and Needham (1962), Macan (1964), Tonapi (1980), Adoni (1985) and Pennak (1989).

2.4 Quantitative analysis

Preserved samples of macrobenthic invertebrate fauna were subjected to quantitative analysis applying the formula: $n = O/a.s\ (10{,}000)$, where n is the number of macrobenthic invertebrates per meter square, O is the number of organisms counted, a is the area of metallic sampler in square meter and s is the number of samples taken at each station (Welch, 1948).

III. RESULTS AND DISCUSSION

3.1 Physico-chemical Parameters

The water temperature of river Basantar was recorded to be 19.17 ºC ± 5.20 & 20.33 ºC ± 6.21 at St I, 22.33 ºC ± 5.57 & 23.50 ºC ± 6.36 at St II, 23.75 ºC ± 5.42 & 25.00 ºC ± 6.57 at St III and 25.83 ºC ± 7.05 & 25.58 ºC ± 6.79 at St IV during the year 2009-10 & 2010-11 respectively. Dissolved oxygen content of river Basantar recorded during the present study indicated that the annual mean Dissolved Oxygen at St I, St II, St III & St IV during the first year was 6.55 mg/l ± 1.53, 1.83 mg/l ± 1.68, 3.97 mg/l ± 1.34 and 6.42 mg/l ± 1.69 respectively while during the second year it was found to be 8.77 mg/l ± 2.61 at St I, 5.13 mg/l ± 2.02 at St II, 6.80 mg/l ± 2.56 at St III and 9.13 mg/l ± 2.80 at St IV. At the confluence point (St II), a drastic decline, sometimes reaching to zero (the limit which is far below the tolerance level of aquatic organisms) was recorded which may be attributed to the inorganic reducing agents such as H_2S, ammonia, nitrite, ferrous ion and certain oxidizable substances which tended to decrease dissolved oxygen in the water. Moreover, it can be rapidly removed from the wastewaters by the discharge of oxygen demanding waste (Verma and Saksena, 2010). St III too had low DO concentration as compared to St I & IV. Another important physico-chemical parameter studied was Biological Oxygen Demand (BOD) which exhibited wide variations at different stations. The annual mean BOD concentration was recorded to be highest at St II (240.49 mg/l 229.50 & 185.60 mg/l 172.42) followed by St III (68.82 mg/l ± 44.35 & 49.41 mg/l ± 34.70), St IV (3.38 mg/l ± 1.36 & 2.74 mg/l ± 1.26) and the least concentration at St I (2.35 mg/l ± 0.92 & 1.99 mg/l ± 1.01) during both the years respectively. The higher concentration of BOD at St II (the discharging point) & St III may be due to the consumption of oxygen for the oxidation of large amount of industrial effluents. Mathur et al. (1991), Singh et al. (1999), Sharma et al. (2000), Mishra and Tripathi (2003), Chavan et al. (2005), Rajaram et al. (2005), Jayalakshmi et al. (2011), Shinde et al. (2011), Srivastava and Srivastava (2011) and Sujitha et al. (2011) also suggested such higher values of BOD at the stations receiving industrial waste.

3.2 Macrobenthic Invertebrate Fauna

Present investigations on macrobenthic invertebrate fauna of river Basantar revealed the presence of three major Phyla Annelida, Arthropoda, and Mollusca. In total, 27 macrobenthic invertebrate taxa were identified, of which 3 taxa belonged to Annelida, 22 taxa to Arthropoda and 2 taxa to Mollusca (Table 1). Arthropoda dominated the macrobenthic community (81.48%) whereas remaining phyla exhibited the lower percentages *viz.* Annelida (11.11%) and Mollusca (7.41%). Dominance of Arthropoda among macrobenthic invertebrate community has also been observed by Coimbra et al. (1996), Silviera et al. (2006) and Verma and Saksena (2010).

Maximum species (26 & 23) were found at St IV followed by 22 & 17 species at St I, 21 & 19 species at St III and a minimum of 14 & 12 species at St II during the first and second year of study respectively. The least number of species observed at the discharge point (St II) may be associated with the pollution load and decline in the concentration of dissolved oxygen at this site. Abu-hilal et al. (1994), Hassan et al. (1995), El-sammak (2001) and Tabatabaie and Amiri (2010) also observed lower diversity of macrobenthic invertebrates at polluted sites of the water bodies they studied. Singh (1997) also registered a decline in the species number at polluted site reflecting that the sensitive species were gradually eliminated as the pollution load increased. Johansson (1997), Flemer et al. (1999) and Wu (2002) noticed decreased species diversity in response to decreasing dissolved oxygen; and the species composition was largely determined by differences in the tolerance of the different species to oxygen deficiency.

Quantitatively, annual macrobenthic invertebrate population of river Basantar during both the years was highest at St II (22995 ind.m^{-2} & 18401 ind.m^{-2}) followed by St III (3852 ind.m^{-2} & 3744 ind.m^{-2}), St I (2196 ind.m^{-2} & 1629 ind.m^{-2}) and St IV (1602 ind.m^{-2} & 1494 ind.m^{-2}) respectively (Table 1, Fig. 2). The highest mean annual abundance followed the similar trend during both the years i.e. the highest at St II (1916.25 ind.m^{-2} ± 1310.92 & 1533.42 ind.m^{-2} ± 1633.59) and the lowest at St IV (133.5 ind.m^{-2} ± 76.88 & 124.5 ind.m^{-2} ± 81.65). St III had the mean annual abundance of 321.0 ind.m^{-2} ± 265.11 & 312.0 ind.m^{-2} ± 282.45 while St I had 183.0 ind.m^{-2} ± 104.59 & 135.75 ind.m^{-2} ± 104.79 during the first and second year of study period respectively.

TABLE 1
ANNUAL ABUNDANCE (IND.M^{-2} ± SD) OF MACROBENTHIC INVERTEBRATE COMMUNITY IN THE SAMPLING STATIONS. IN PARENTHESES IS THE MEAN ANNUAL ABUNDANCE VALUE.

Macrobenthic Taxa	Year	St I	St II	St III	St IV
Phylum Annelida Class Oligochaeta					
Tubifex tubifex	2009-10	9 (0.75 ± 2.49)	10989 (915.75 ± 757.47)	2088 (174 ± 185.37)	45 (3.75 ± 6.83)
	2010-11	-	7416 (618 ± 407.33)	1863 (155.25 ± 171.24)	36 (3 ± 5.61)
Branchiura sowerbyi	2009-10	-	684 (57 ± 72.96)	36 (3 ± 5.61)	9 (0.75 ± 2.49)
	2010-11	-	279 (23.25 ± 29.27)	-	9 (0.75 ± 2.49)
Limnodrillus hoffmeisteri	2009-10	-	243 (20.25 ± 25.75)	63 (5.25 ± 5.76)	9 (0.75 ± 2.49)
	2010-11	-	99 (8.25 ± 12.97)	-	-
Total Annelids	2009-10	9 (0.75 ± 2.49)	11916 (993 ± 814.55)	2187 (182.25 ± 187.14)	63 (5.25 ± 7.76)
	2010-11	-	7794 (649.5 ± 436.58)	1863 (155.25 ± 171.24)	45 (3.75 ± 5.76)
Phylum Arthropoda Order Ephemeroptera					
Caenis sp.	2009-10	18 (1.5 ± 3.35)	9 (0.75 ± 2.49)	117 (9.75 ± 13.48)	18 (1.5 ± 3.35)
	2010-11	36 (3 ± 4.24)	-	99 (8.25 ± 10.69)	18 (1.5 ± 4.97)
Baetis sp.	2009-10	225 (18.75 ± 26.10)	-	27 (2.25 ± 3.90)	207 (17.25 ± 17.80)
	2010-11	144 (12 ± 9.95)	-	36 (3 ± 5.61)	18 (1.5 ± 3.35)
Cloeon sp.	2009-10	369 (30.75 ± 25.31)	-	-	72 (6 ± 7.65)
	2010-11	153 (12.75 ± 11.30)	-	-	162 (13.5 ± 20.95)
Total Ephemeropterans	2009-10	612 (51 ± 49.34)	9 (0.75 ± 2.49)	144 (12 ± 16.97)	297 (24.75 ± 20.50)
	2010-11	333 (27.75 ± 21.88)	-	135 (11.25 ± 15.20)	198 (16.5 ± 20.40)
Order Diptera					
Chironomus sp.	2009-10	54 (4.5 ± 5.81)	7380 (615 ± 409.46)	522 (43.5 ± 50.22)	153 (12.75 ± 15.35)
	2010-11	36 (3 ± 6.71)	9347 (778.92 ± 1259.51)	954 (79.5 ± 59.91)	297 (24.75 ± 25.49)
Pentanura sp.	2009-10	54 (4.5 ± 6.87)	1575 (131.25 ± 142.37)	144 (12 ± 14.39)	54 (4.5 ± 6.87)
	2010-11	-	675 (56.25 ± 54.88)	153 (12.75 ± 25.04)	36 (3 ± 4.24)
Tabanus sp.	2009-10	9 (0.75 ± 2.49)	189 (15.75 ± 15.20)	63 (5.25 ± 10.69)	27 (2.25 ± 3.90)
	2010-11	9 (0.75 ± 2.49)	99 (8.25 ± 15.35)	90 (7.5 ± 10.28)	27 (2.25 ± 5.36)
Chrysops sp.	2009-10	81 (6.75 ± 8.32)	162 (13.5 ± 14.47)	27 (2.25 ± 5.36)	36 (3 ± 5.61)
	2010-11	99	-	-	90

		(8.25 ± 10.69)			(7.5 ± 10.28)
Culicoides sp.	2009-10	27 (2.25 ± 3.90)	567 (47.25 ± 49.31)	90 (7.5 ± 10.92)	45 (3.75 ± 5.76)
	2010-11	18 (1.5 ± 3.35)	90 (7.5 ± 10.92)	72 (6 ± 7.65)	27 (2.25 ± 3.90)
Tubifera sp.	2009-10	27 (2.25 ± 3.90)	153 (12.75 ± 12.44)	126 (10.5 ± 13.16)	63 (5.25 ± 5.76)
	2010-11	-	63 (5.25 ± 6.83)	36 (3 ± 5.61)	27 (2.25 ± 5.36)
Psychoda sp.	2009-10	9 (0.75 ± 2.49)	135 (11.25 ± 18.05)	18 (1.5 ± 3.35)	27 (2.25 ± 7.46)
	2010-11	-	144 (12 ± 14.85)	18 (1.5 ± 3.35)	-
Pseudolimnophila sp.	2009-10	117 (9.75 ± 12.97)	-	-	54 (4.5 ± 8.62)
	2010-11	99 (8.25 ± 10.69)	-	-	27 (2.25 ± 5.36)
Brachydeutera sp.	2009-10	-	774 (64.5 ± 79.22)	117 (9.75 ± 18.17)	-
	2010-11	-	135 (11.25 ± 12.79)	63 (5.25 ± 9.34)	-
Limnophora sp.	2009-10	-	72 (6 ± 10.61)	180 (15 ± 17.36)	18 (1.5 ± 3.35)
	2010-11	-	27 (2.25 ± 5.36)	72 (6 ± 10.61)	9 (0.75 ± 2.49)
Total Dipterans	2009-10	378 (31.5 ± 24.23)	11007 (917.25 ± 562.98)	1287 (107.25 ± 102.18)	477 (39.75 ± 39.31)
	2010-11	261 (21.75 ± 17.80)	10580 (881.67 ± 1293.52)	1458 (121.5 ± 100.59)	540 (45 ± 45.60)
Order Odonata					
Perithemis sp.	2009-10	288 (24 ± 17.75)	-	27 (2.25 ± 3.90)	36 (3 ± 5.61)
	2010-11	135 (11.25 ± 12.79)	-	45 (3.75 ± 5.76)	126 (10.5 ± 10.28)
Plathemis sp.	2009-10	216 (18 ± 19.09)	-	-	117 (9.75 ± 10.69)
	2010-11	117 (9.75 ± 13.97)	-	27 (2.25 ± 5.36)	72 (6 ± 7.65)
Progomphus sp.	2009-10	126 (10.5 ± 10.28)	-	9 (0.75 ± 2.49)	180 (15 ± 12.37)
	2010-11	315 (26.25 ± 31.70)	-	-	243 (20.25 ± 15.64)
Total Odonates	2009-10	630 (52.5 ± 39.88)	-	36 (3 ± 4.24)	333 (27.75 ± 23.08)
	2010-11	567 (47.25 ± 51.19)	-	72 (6 ± 6.71)	441 (36.75 ± 24.50)
Order Hemiptera					
Laccotrephes maculates	2009-10	72 (6 ± 8.49)	-	63 (5.25 ± 10.69)	18 (1.5 ± 3.35)
	2010-11	45 (3.75 ± 4.44)	-	9 (0.75 ± 2.49)	36 (3 ± 4.24)
Micronecta sp.	2009-10	54 (4.5 ± 6.87)	-	9 (0.75 ± 2.49)	27 (2.25 ± 3.90)
	2010-11	90 (7.5 ± 8.08)	-	9 (0.75 ± 2.49)	45 (3.75 ± 5.76)
Total Hemipterans	2009-10	126 (10.5 ± 12.64)	-	72 (6 ± 12.90)	45 (3.75 ± 5.76)
	2010-11	135 (11.25 ± 8.32)	-	18 (1.5 ± 3.35)	81 (6.75 ± 8.32)

Order Coleoptera					
Cybister tripunctatus	2009-10	18 (1.5 ± 3.35)	-	-	27 (2.25 ± 5.36)
	2010-11	18 (1.5 ± 3.35)	-	9 (0.75 ± 2.49)	-
Paederus extraneus	2009-10	-	-	-	18 (1.5 ± 3.35)
	2010-11	-	-	-	9 (0.75 ± 2.49)
Dubiraphia sp.	2009-10	81 (6.75 ± 6.50)	-	63 (5.25 ± 6.83)	36 (3 ± 5.61)
	2010-11	126 (10.5 ± 10.92)	-	18 (1.5 ± 4.97)	27 (2.25 ± 3.90)
Helichus sp.	2009-10	36 (3 ± 4.24)	-	-	45 (3.75 ± 6.83)
	2010-11	36 (3 ± 5.61)	-	-	27 (2.25 ± 5.36)
Total Coleopterans	2009-10	135 (11.25 ± 9.09)	-	63 (5.25 ± 6.83)	126 (10.5 ± 11.52)
	2010-11	180 (15 ± 16.97)	-	27 (2.25 ± 5.36)	63 (5.25 ± 5.76)
Total Arthropods	2009-10	1881 (156.75 ± 101.12)	11016 (918 ± 563.41)	1602 (133.5 ± 109.97)	1341 (111.75 ± 74.53)
	2010-11	1476 (123 ± 97.16)	10580 (881.67 ± 1293.52)	1710 (142.5 ± 115.07)	1323 (110.25 ± 71.64)
Phylum Mollusca **Class Gastropoda**					
Gyraulus parvus	2009-10	279 (23.25 ± 20.61)	-	45 (3.75 ± 5.76)	171 (14.25 ± 15.79)
	2010-11	153 (12.75 ± 13.48)	-	9 (0.75 ± 2.49)	108 (9 ± 10.39)
Physa acuta	2009-10	27 (2.25 ± 5.36)	63 (5.25 ± 5.76)	18 (1.5 ± 3.35)	27 (2.25 ± 5.36)
	2010-11	-	27 (2.25 ± 3.90)	162 (13.5 ± 23.67)	18 (1.5 ± 3.35)
Total Molluscs	2009-10	306 (25.5 ± 24.87)	63 (5.25 ± 5.76)	63 (5.25 ± 5.76)	198 (16.5 ± 14.62)
	2010-11	153 (12.75 ± 13.48)	27 (2.25 ± 3.90)	171 (14.25 ± 24.22)	126 (10.5 ± 10.28)
Total Macrobenthic Invertebrates	2009-10	2196 (183 ± 104.59)	22995 (1916.25 ± 1310.92)	3852 (321 ± 265.11)	1602 (133.5 ± 76.88)
	2010-11	1629 (135.75 ± 104.79)	18401 (1533.42 ± 1633.59)	3744 (312 ± 282.45)	1494 (124.5 ± 81.65)

-Depicted “Absent”

Table 1 & Fig. 2 indicated that the annual abundance of annelids was highest at St II (11916 ind.m^{-2} in the first year & 7794 ind.m^{-2} in the second year) as compared to other stations that was mainly contributed by oligochaetes (11673 ind.m^{-2} in the first year & 7695 ind.m^{-2} in the second year) and may be attributed to the heavy pollution load at this station. St III also had higher annual abundance of annelida among all other phyla and it was found to be 2187 ind.m^{-2} during the first year and 1863 ind.m^{-2} during the second year of study. Oligochaetes, the main contributor to this peak, were reported to have their annual abundance at this station to be 2124 ind.m^{-2} & 1863 ind.m^{-2} during the Year 2009-10 & 2010-11 respectively. The present observation corroborates with the findings of Hawkes (1979), Callisto et al. (2005) and Cupsa et al. (2009) who reported that oligochaetes are dominant in severely polluted conditions. Aston (1973), Kaniewska-Prus (1983), Kulshrestha et al. (1991), Heller and Ehrlich (1995) well opined that oligochaetes are very resistant and able to survive under oxygen deficit conditions. Sinha et al. (1989) also linked the high BOD and low concentration of DO with the abundance of oligochaetes owing to the higher bacterial activities which in turn become the food of the oligochaetes and thus forming the base of their dominance at such sites. Arimoro et al. (2007) reported that high nutrient enrichment and sedimentation at polluted sites are known to favour the oligochaetes abundance. Slepukhina (1984), Yap et al. (2003), Gupta and Sharma (2005), Moretti and Callisto (2005), Yoshimura (2008), Barquin and Death (2011) and Chowdhary and Sharma (2013) confirmed that there existed inverse relationship of oligochaetes with dissolved oxygen and thus, the anoxic conditions at St II & least dissolved oxygen content at St III of river Basantar favoured the growth of oligochaetes. Contribution to the peak of annelids by oligochaetes has also been shown by Sawhney (2008). Fig. 3 indicated that among Oligochaetes, *Tubifex tubifex* registered its highest abundance at St II and III (polluted sites). Its mean annual abundance at St II was found to be 915.75 ind.m^{-2} ± 757.47 (2009-10) & 618.0 ind.m^{-2} ± 407.33 (2010-11) and at St III it was observed to be 174.0 ind.m^{-2} ± 185.37 (2009-10) & 155.25 ind.m^{-2} ± 171.24 (2010-11). On the contrary, St I & IV had least density of this species (Table 1). Verma and Saksena (2010) also reported highest density of *Tubifex* in anoxic and polluted waters and thus considered it as pollution indicator species. According to Slepukhina (1984), Lang (1985) and Barbour et al. (1996), the order Oligochaeta has a high tolerance to a variety of stresses and its high abundance is a good indicator of pollution. Oligochactes, particularly *Tubifex* are considered as the pollution indicator taxon (Howmiller and Beeton, 1971; Singh, 1997; Sturmbauer et al., 1999; Qadri and Yousuf, 2004). Reddy and Rao (1987), Sinha et al. (1989) and Xiong et al. (2003) reported that the density of oligochaetes, particularly Tubificidae (Brinkhurst and Jamieson, 1971; Fusari and Fonseca-Gessner, 2006) increased significantly with increasing trophic state. Other taxa, *Branchiura sowerbyi* and *Limnodrillus hoffmeisteri* were also found abundant at discharge point (St II) owing to its tolerance to pollution load (Fig 3). *Limnodrillus* is known to be able to tolerate unfavourable conditions such as low DO and high pollutant concentrations (Brinkhurst and Kennedy, 1965; Brinkhurst, 1967; Harrel and Smith, 2002). Richardson (1928), Singh (1997) and Yap et al. (2003) suggested that *Limnodrillus* is a potential bioindicator for a polluted river ecosystem.

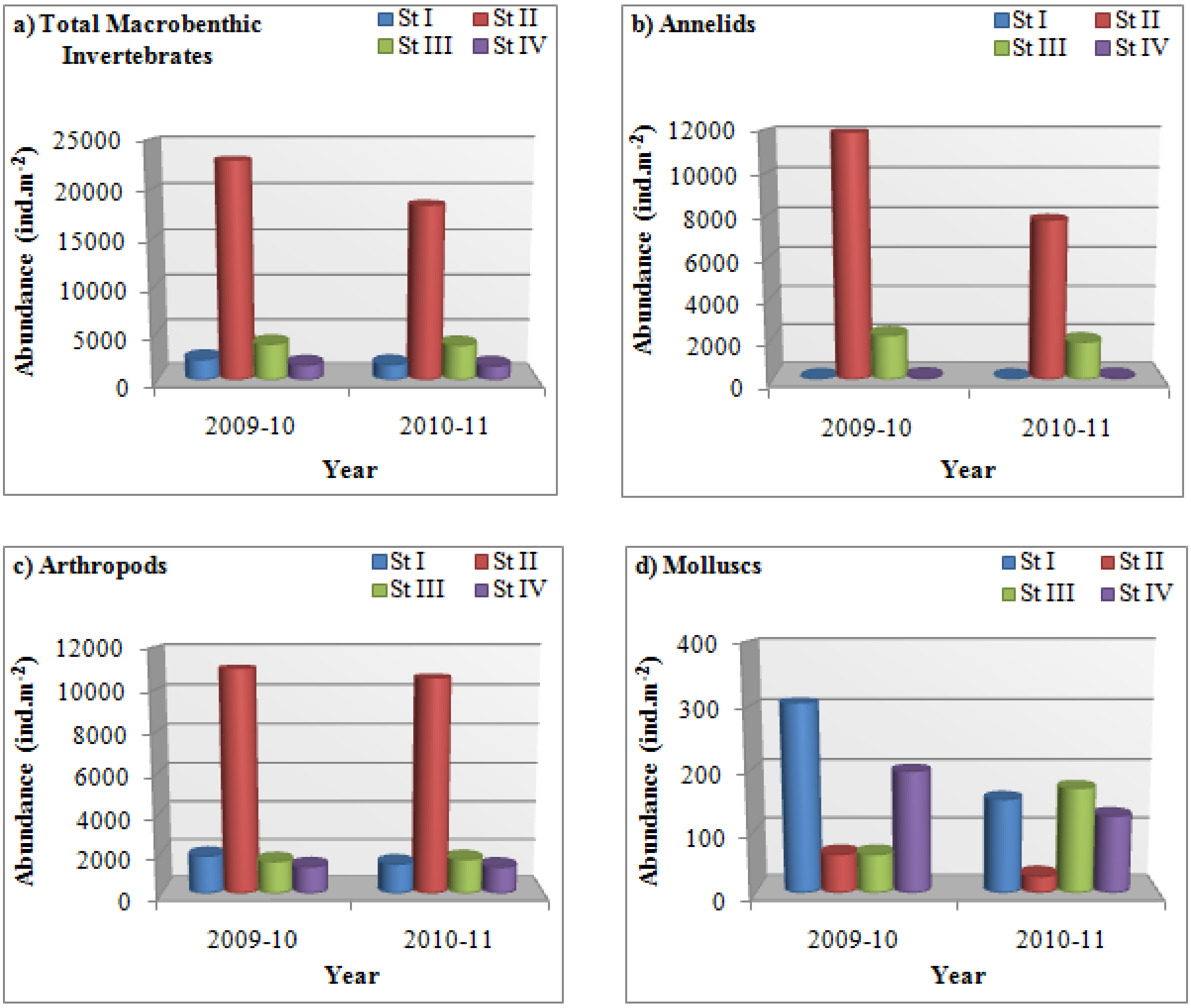

FIG 2: ANNUAL ABUNDANCE (IND.M^{-2}) OF MACROBENTHIC INVERTEBRATE COMMUNITY OF RIVER BASANTAR.

Among arthropods, the annual density of dipterans was found higher at polluted sites i.e. St II (11007 ind.m^{-2} & 10580 ind.m^{-2}) and St III (1287 ind.m^{-2} & 1458 ind.m^{-2}) as compared to that of St IV (477 ind.m^{-2} & 540 ind.m^{-2}) and St I (378 ind.m^{-2} & 261 ind.m^{-2}) during first and second year of study respectively (Table 1, Fig. 2). The abundance of dipterans at the polluted sites was mainly contributed by *Chironomus* sp. with the mean annual density of 615.0 ind.m^{-2} ± 409.46 & 778.92 ind.m^{-2} ± 1259.51 at St II and 43.5 ind.m^{-2} ± 50.22 & 79.5 ind.m^{-2} ± 59.91 at St III during both the years respectively. Dipterans are tolerant organisms (Lenat, 1993) and their abundance may indicate degraded conditions (Buckup et al., 2007) which justifies its highest density at St II, the discharge point. Henriques-Oliveira and Nessimian (2010) and Chowdhary and Sharma (2013) identified order Diptera constituting largest density owing to the most abundant group Chironomidae. Highest abundance of *Chironomus* sp. at St II & III may be attributed to the reduced flow of water and high nutrient load due to industrial effluents. Higher density of *Chironomus* sp. at polluted sites and least abundance or complete absence at less polluted sites is in line with the findings of Gaufin (1957), Curry (1962), Gopal and Sah (1993), Barbour et al. (1996), Marques et al. (1999), Arimoro et al. (2007), Buckup et al. (2007), Edokpayi et al. (2010), Verma and Saksena (2010), Chowdhary and Sharma (2013). Moreover, the above taxon also survived the anoxic conditions observed particularly at St II. In support to this, Lindeman (1942) has already advocated that some red Chironomidae containing erythrocruorin can exist in the complete absence of dissolved oxygen for a long period of time. Tudorancea et al. (1989), Heller and Ehrlich (1995) and Adeogun and Fafioye (2011) also linked the higher abundance of *Chironomus* sp. to their tolerance to anoxic conditions that existed at the discharge point (St II) during the present study period. This affinity with the anoxic conditions may be due to their possession of haemoglobin that transports dissolved oxygen (Tyokumbur et al., 2002) and this property may be advantageous for their proliferation and colonization at polluted sites effectively out-competing with other taxa (Adeogun and Fafioye, 2011). Moreover, due to their unique qualities like prolonged aquatic larval forms and their abundance in great concentrations amongst others, chironomids have been used as bio-indicators in aquatic ecosystems (Rotimi and Iloba, 2009). Other dipteran taxa viz. *Tubifera* and *Psychoda* showed their higher abundance at the polluted sites (St II & III) while their density was very low at the least polluted sites (St I & IV) (Fig. 3).

Odonates had its higher density at St I (630 ind.m^{-2} & 567 ind.m^{-2}) and St IV (333 ind.m^{-2} & 441 ind.m^{-2}) during the year 2009-10 & 2010-11 respectively as depicted in Table 1 & Fig. 2. On the contrary, odonates were reported entirely absent at St II and a very meager density was observed at St III (36 ind.m^{-2} & 72 ind.m^{-2}). Verma and Saksena (2010) observed odonate nymphs as inhabitants of freshwaters with rich oxygen and least/no pollution, thus, supporting the present results. Emere and Nasiru (2009) also associated odonates with clean water. Absence of odonate taxon *Progomphus* at St II & III (polluted stations) during both the years as depicted in Fig. 4 may be due to its association with sand substrate (Assis et al., 2004) as it burrows sand to obtain oxygen but the sedimentation of silt and organic material at these stations created a barrier and does not allow it to get oxygen (Couceiro et al., 2006). Moreover, the dissolved oxygen profile of these stations was very low which further restricted the abundance of this species at these stations.

Table 1 & Fig. 2 indicated that Ephemeropterans exhibited higher annual density at St I (612 ind.m^{-2} and 333 ind.m^{-2}) while least density at St II (0 ind.m^{-2} & 9 ind.m^{-2}) during first and second year of study respectively. Pollution sensitive ephemeropteran taxon *Cloeon* sp. was reported at St I (30.75 ind.m^{-2} ± 25.31 & 12.75 ind.m^{-2} ± 11.30) and St IV (6.0 ind.m^{-2} ± 7.65 & 13.5 ind.m^{-2} ± 20.95) but was found absent at St II & III (Fig 4). Another sensitive taxon *Baetis* sp. had its higher annual abundance at St I (18.75 ind.m^{-2} ± 26.10 & 12.0 ind.m^{-2} ± 9.95 & St IV (17.25 ind.m^{-2} ± 17.80 & 12.0 ind.m^{-2} ± 9.95) as compared to St II where it registered its absence and at St III where the mean density was found to be 2.25 ind.m^{-2} ± 3.90 & 3.0 ind.m^{-2} ± 5.61 during the first and second year respectively. Further, *Cloeon* sp. reappeared and *Baetis* sp. elevated its annual abundance at St IV thereby indicating the restoration of comparatively better habitat conditions at this station (Fig. 4). Arimoro et al. (2008) also found *Cloeon* sp. and *Baetis* sp. completely absent at polluted site and thus, identified them as pollution sensitive species. Edokpayi et al. (2000), Edema et al. (2002), Rueda et al. (2002), Walsh et al. (2002), Miserendino and Pizzolon (2003), Nelson and Roline (2003), Ikomi et al. (2005) and Arimoro et al. (2007) declared *Baetis* sp. sensitive to reductions in DO and associated its presence with the least polluted sites. Comparatively more number of ephemeropterans at St I as compared to other stations may be due to the increased oxygen concentration as also suggested by Chowdhary and Sharma (2013). Edema et al. (2002), Miserendino and Pizzolan (2003), Nelson and Rolin (2003), Arimoro et al. (2007), Edokpayi et al. (2010) and Sawhney (2008) related the abundance of ephemeropterans with the dissolved oxygen content. Merrit and Cummins (1978), Lenat (1983), Spanhoff et al. (2007), Mare-Rosca et al. (2008) and Emere and Nasiru (2009) stated that the members of ephemeroptera are considered to be sensitive to environmental stress and their presence signified relatively clean conditions. They prefer to live in unpolluted waters where they contribute to the secondary production (Williams and Feltmate, 1992; Olomukoro and Ezemonye, 2007).

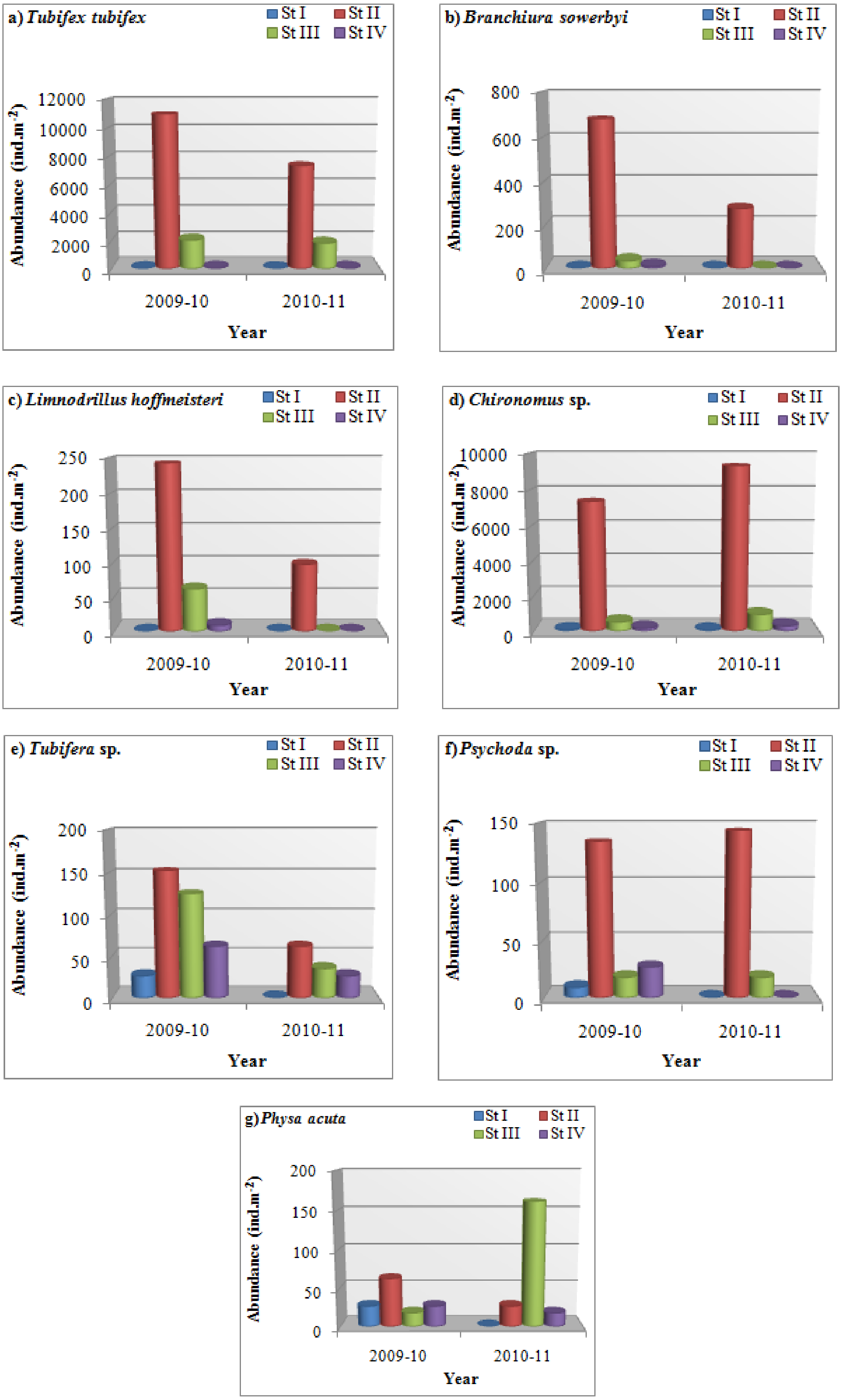

FIG 3: ANNUAL ABUNDANCE (IND.M^{-2}) OF PREDOMINANT POLLUTION INDICATOR MACROBENTHIC INVERTEBRATE TAXA OF RIVER BASANTAR.

The annual abundance of Hemipterans and Coleopterans revealed that it was highest at St I as compared to other stations during both the years and it was reported to be 126 ind.m^{-2} (2009-10) & 135 ind.m^{-2} (2010-11) and 135 ind.m^{-2} (2009-10) & 180 ind.m^{-2} (2010-11) at this station respectively (Fig. 2). On the contrary, both the orders recorded their complete absence at St II. Spanhoff et al. (2007) also recorded coleopterans at least polluted sites and Camargo (1992) found them absent at discharge point.

Least abundance of Mollusca was observed at St II (the discharge point) i.e. 5.25 ind.m^{-2} ± 5.76 during the first year and 2.25 ind.m^{-2} ± 3.90 during the second year as shown in Table 1 which may be attributed to the pollution load at this station. Similarly, St III also had less density of Mollusca in the first year (5.25 ind.m^{-2} ± 5.76). On the contrary, during the second year, St III had higher molluscan abundance (14.25 ind.m^{-2} ± 24.22) during few months which were owing to the abundance of *Physa* sp., a pollution indicator species (Fig. 3). Arimoro et al. (2008) and Verma and Saksena (2010) also opined that the molluscan abundance was least at polluted sites but higher at the sites having rich dissolved oxygen content. Graf et al. (2011) recorded a decline in molluscan fauna attributing to the pollution load from commercial sources; and water abstraction as observed at St III. A pollution sensitive taxon *Gyraulus* sp. registered its abundance in accordance with the degree of pollution at different stations during both the years i.e. maximum abundance at St I followed by St IV, St III and St II (279, 171, 45 and nil during the first year and 153, 108, 9 and nil respectively during the second year of study) as indicated in Fig. 4. Verma and Saksena (2010) also identified the above genera at non-polluted sites rich in dissolved oxygen and good water quality.

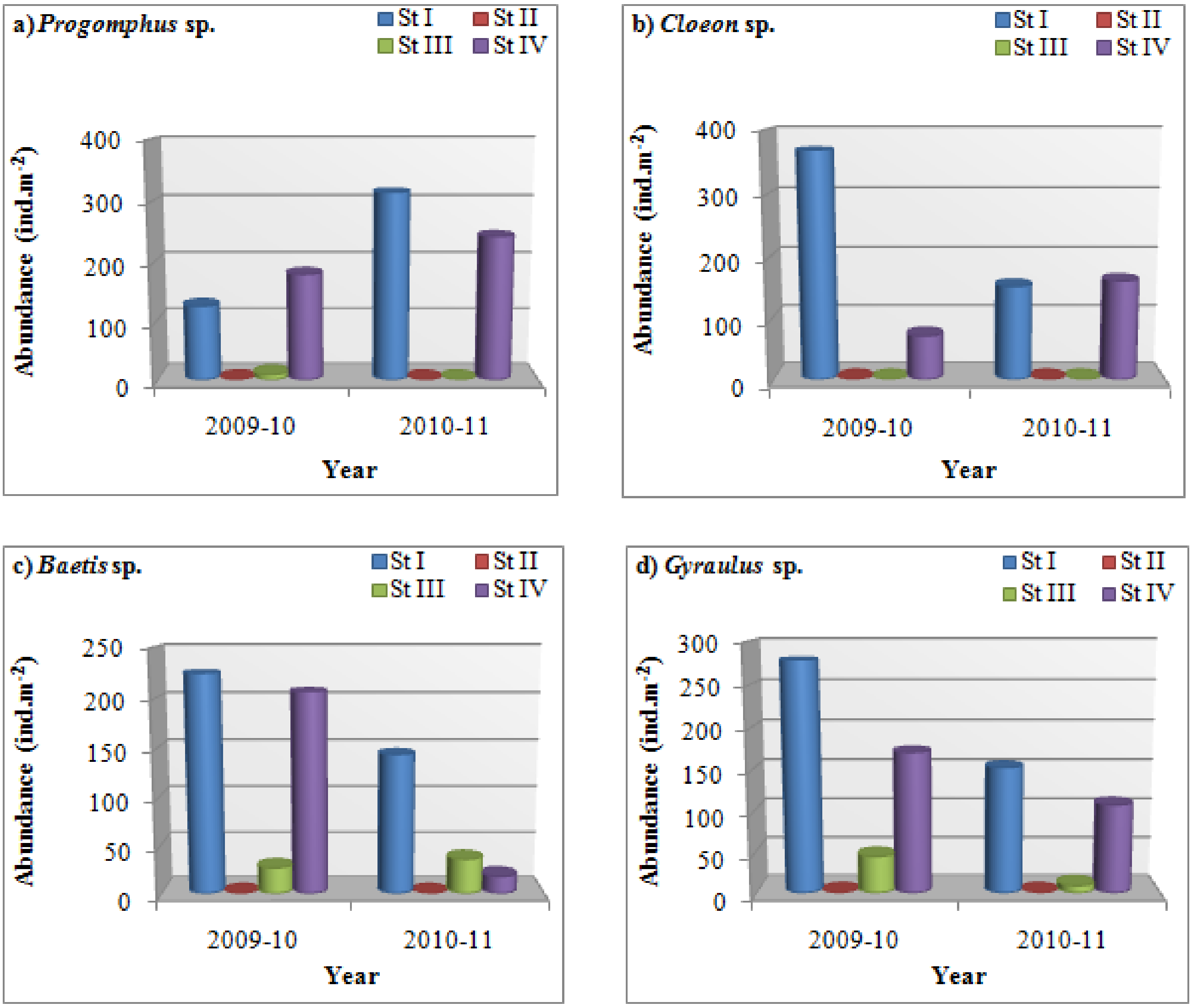

FIG 4: ANNUAL ABUNDANCE (IND.M^{-2}) OF PREDOMINANT SENSITIVE MACROBENTHIC INVERTEBRATE TAXA OF RIVER BASANTAR.

It is pertinent to mention here that species number of macrobenthic invertebrate was highest at St IV rather than St I because St IV exhibited the presence of species that were inhabiting St I (comparatively sensitive species) as well as St II & III (tolerant species) although their densities at this station were entirely different from rest of the stations. The abundance of pollution tolerant species declined at St IV while reappearance/increase in density of sensitive species as found at St I was evident at St IV. Such downstream spatial recovery of macrobenthic invertebrate fauna has also been confirmed by Camargo (1992).

IV. CONCLUSION

The macrobenthic invertebrates play an important role in the assessment of ecological status of aquatic systems. The results of present study revealed that the discharge of industrial effluents in to the river Basantar severely impacted the composition and distribution of macrobenthic fauna inhabiting the river. The higher abundance of pollution tolerant taxa and disappearance of sensitive taxa at the affected stretch of the river provided a clear picture depicting the deteriorating ecological condition of the river. This piece of work shall be utilized to formulate necessary conservatory strategies for the ecological restoration of the river.

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