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Monitoring of Water Quality Using Aquatic Insects as Biological Indicators in Bhosga Reservoir, Karnataka, India

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Abstract Aquatic insects are the utmost generally employed macroinvertebrates in freshwater monitoring and assessment worldwide. However, aquatic insects have received far less attention for the objectives of health and water quality bioassessment, particularly in Kalaburagi, Karnataka. This study examined the abundance of aquatic insects in the Bhosga reservoir and their relationship to physicochemical factors. Water ecosystem health had been assessed using the BMWP, ASPT, and FBI scoring systems from October 2020 to September 2021. Samples were collected monthly by using the sweep net and dip net methods. There were 5964 aquatic insects recorded and divided into 23 families and 6 orders. Hemiptera (53%) was the most dominated aquatic insect family, followed by Coleoptera (16%), Diptera (15%), Odonata (8%), Ephemeroptera (6%), and Trichoptera (2%). Water quality falls under the class 2 category attributing "Good" water quality based on biotic indices. According to the PTI index, moderately sensitive to pollution group was abundant (74.11%) followed by sensitive to pollution (16.88%), and insensitive to pollution represented (9.00%) of the total abundance of aquatic insects. The compile of indices results indicated that the presence of moderately pollution sensitive families was higher than the insensitive to pollution families indicating that the aquatic habitat has not been significantly altered, nor is it very clean. The current study lays the groundwork for appropriate water management by using aquatic insects as bioindicators for assessing the water quality of the Bhosga reservoir.

Keywords Aquatic Insect, Biological Indicators, Bhosga Reservoir, Physicochemical, Water Quality

1. Introduction

Water pollution is a universal anxiety, as it affects water quality and confines water use for various purposes [1,2]. Anthropogenic activities and agricultural runoff that run directly into the catchment region and pass into the water bodies are the primary sources of water pollution [3]. Biomonitoring is a way to assess the environmental changes caused by anthropogenic factors through the use of indicator species. Aquatic insects are well-suited to ecological impact assessment and have a long history of monitoring water quality [4,5]. Aquatic insects have been used as bioindicators and are one of the commonly used groups in biological water quality assessment around the world [6,7]. The number and variety of aquatic insect species found in specific water bodies reflect the quality of the sites from which they are collected [8,9]. According to specific research, aquatic insects are incredibly effective at detecting anthropogenic disturbances and habitat quality [10].

Various studies have demonstrated that physicochemical analysis, maybe more accurate, but it only reflects the conditions in the water body at the time of sampling [11], whereas biological groups deliver a more precise image of environmental conditions because of their constant exposure and are less expensive to work with physicochemical analysis [12,13]. Biotic indices are numerical terms that categorize water quality based on the environmental sensitivity and diversity of the organisms present. Many biotic indicators have been developed using aquatic insects because they play an essential role in the aquatic ecosystem as a significant food source for other aquatic invertebrates, fishes, and some birds [14,15]

Our goal in the current study was to use aquatic insects as biological indicators to assess the present status of the water quality of the Bhosga reservoir. Physicochemical analysis and several biological indices, such as biological monitoring working party (BMWP), average per taxon (ASPT), and family biotic index (FBI) were used to assess the reservoir water quality. The results of this study may provide insight into the baseline data required for water management in Bhosga reservoir, Karnataka, India.

2. Materials and Methods

2.1. Study Area

Bhosga reservoir is located in the district of Kalaburagi in the state of Karnataka (76°-04" to 77°-42" Longitude and 16°-12" to 17°-46" Latitude) at the height of 454 meters above mean sea level. The reservoir covers an area of 756 sq km. The eastern boundary is with an earthen bund of about 10.66 meters in height (Figure 1).

2.2. Methodology

2.2.1. Environmental Variables

Physicochemical water quality assessment is carried out based on the following parameters including water temperature, pH, carbon dioxide, dissolved oxygen, nitrate, electrical conductivity, total dissolved solids, total alkalinity, total hardness, chloride, sulfate, and phosphate. All the parameters had been analyzed in the following protocol by APHA [16] and Trivedi and Goel [17].

2.2.2. Aquatic Insect Sampling

A sampling of aquatic insects was conducted at five sites from October 2020 to September 2021. Sampling had been usually done at a monthly interval. Sweep net and dip net methods were adopted to collect the insects at five locations within the study sites. Three replicate samples were collected from each station during the sampling period. All of the sorted samples were placed in white trays for sorting. The sample contents were transferred into properly labeled vials preserved in 75% ethanol and carried to the laboratory. Under the stereo zoom microscope, aquatic insects were sorted, examined, and identified to the family level using the taxonomic keys by Subramanian and Sivaramkrishnan [18] Dudgeon [19], and Thirumalai [20].

2.2.3. Biotic Indices

1. BMWP - The Biological Monitoring Working Party index gives each aquatic insect taxon a score from 1 to 10 depending on their sensitivity to organic pollution, with the highest values going to the most sensitive species. Lakes with a BMWP greater than 100 are considered clean, while lakes with a BMWP less than 15 are considered extremely contaminated as shown in Table 2, given by Mason [21], and Armitage *et al*. [22].
2. ASPT – To calculate the Average Score Per Taxon, divide the BMWP index score by the number of families in the sample. A high ASPT score indicates a clean site with numerous high-scoring taxa. This index is used to assess the impact of organic pollution by Armitage *et al*. [22]. Results of BMWP and ASPT scores were then divided into six groups to assess water quality status, as indicated in Table 1. Equation (1) is used to calculate the ASPT.

$$\text{ASPT} = \text{BMWP Score/ Number of Families} \quad (1)$$

3. The FBI – Based on the tolerance levels of aquatic insect families to various levels of dissolved oxygen, the Family Biotic Index was developed by Hilsenhoff [25]. FBI index gives each aquatic insect taxon a score from 1 to 10 depending on their sensitivity to organic pollution, with the lowest values going to be the most sensitive species as indicated in Table 4. Generally, lower FBI values correspond to higher water quality. The equation (2) is used to calculate the FBI.

$$\text{FBI} = \sum xi * ti/ n \quad (2)$$

This formula substitutes xi for the number of individuals in a family and ti for its tolerance value. Results of FBI scores were then divided into eight groups to assess water quality status, as indicated in Table 3.

4. PTI- the Pollution Tolerance Index is based on the concept of indicator species and sensitive levels. It is designed to be done quickly and easily and helps to detect the water quality, given by Lewis [26].

3. Results and Discussions

3.1. Physicochemical Variables

The outcomes of the examined physicochemical parameters of water in the Bhosga reservoir are represented in Table 5. The average value of the temperature varied from 22.3±1.56 ℃ minimum in winter and 29.37±0.92 ℃ maximum in the pre-monsoon season. The lowest pH value was recorded in the winter at 7.4±0.173, and the highest in the pre-monsoon season at 7.83±0.113. The EC varied from 210±19.43 µS/cm in post-monsoon and highest 309.12±7.54 µS/cm in pre-monsoon season. The winter presented low values of TDS 131.5±4.18 mg/l, while high values of 163.44±16.39 mg/l were noted in the pre-monsoon season. Dissolved oxygen was higher in the winter of value 11.924±0.972 mg/l and reached the lowest level at 6.90±0.75 mg/l in monsoon. Total alkalinity acquired the highest in the pre-monsoon season at 146.06±9.112 mg/l and lowest at 101.0±5.25 mg/l in the post-monsoon season. Total hardness values varied between 222.86±12.52 mg/l in the pre-monsoon and 176.6±8.96 mg/l in the post-monsoon season. Carbon-dioxide ranged from the lowest of 2.14±0.60 mg/l in the pre-monsoon season to the highest of 5.79±1.13 mg/l in the post-monsoon season. Chloride values were minimum at 32.75±2.61 mg/l in the post-monsoon season and gained a maximum of 79.32±8.65 mg/l in the pre-monsoon season. Phosphate value was lowest at 1.80±0.113 mg/l in monsoon and highest at 2.25±0.123 mg/l in the winter season. Sulfate values are lowest at 4.05±0.24 mg/l in monsoon and highest at 4.50±0.22 mg/l in the winter season. Nitrate values were highest at 2.26±0.126 mg/l in winter and lowest at 1.64±0.159 mg/l in the post-monsoon season. Entirely the parameters were below the acceptable limits of the BIS standards [27].

3.2. Aquatic Insect Diversity

A total of 5964 aquatic insects belonging to 6 orders and 23 families were collected and recorded in Bhosga reservoir as presented in Table 6. Identified order Hemiptera was highest represented by ten families including Gerridae (Pond skater), Veliidae (Riffle bug), Hebridae (Velvet water bug), Mesoveliidae (Water treader), Corixidae (Water boatman), Belostomatidae (Giant water bugs), Hydrometridae (Pond skater), Notonectidae (Backswimmer), Nepidae (Water scorpions), and Pleidae (Pygmy backswimmer). The predatory aquatic bug families of Nepidae and Belostomatidae are regarded as effective predators of mosquito larvae [28]. The Order Diptera included four families that were Chironomidae (Non-biting midge), Culicidae (Mosquito larvae), Stratiomyidae (Soldier fly), and Ceratopogonidae (Biting midge). The order Odonata represented three families of Libellulidae (Skimmer-dragonfly), Aeshnidae (Darners-dragonfly), and Coenagrionidae (Pond-damselfly). The richness of the Odonata community can be an indicator of good water quality [29]. The order Coleoptera represented three families of Dytiscidae (Diving beetle), Hydrophilidae (Water scavenger beetle), and Gyrinidae (Whirlgig beetle). The order Ephemeroptera represents two families of Baetidae (Small minnow mayfly), and Caenidae (Square-gilled mayfly). The order Trichoptera represented one family of Lepidostomatidae (Caddisfly). The order Ephemeroptera and Trichoptera are one of the sensitive species presences of those families that are measured as an indicator for good water quality [30]. Similar observations were observed by Wakid *et al*. [31], who recorded a total of 6868 aquatic insects belonging to 28 families and 7 orders, collected from Bogor Lake, Indonesia. Rao *et al*. [32] reported 3647 individuals categorized under 22 families and 7 orders collected from Jedarpalayam dam, Tamil Nadu, India.

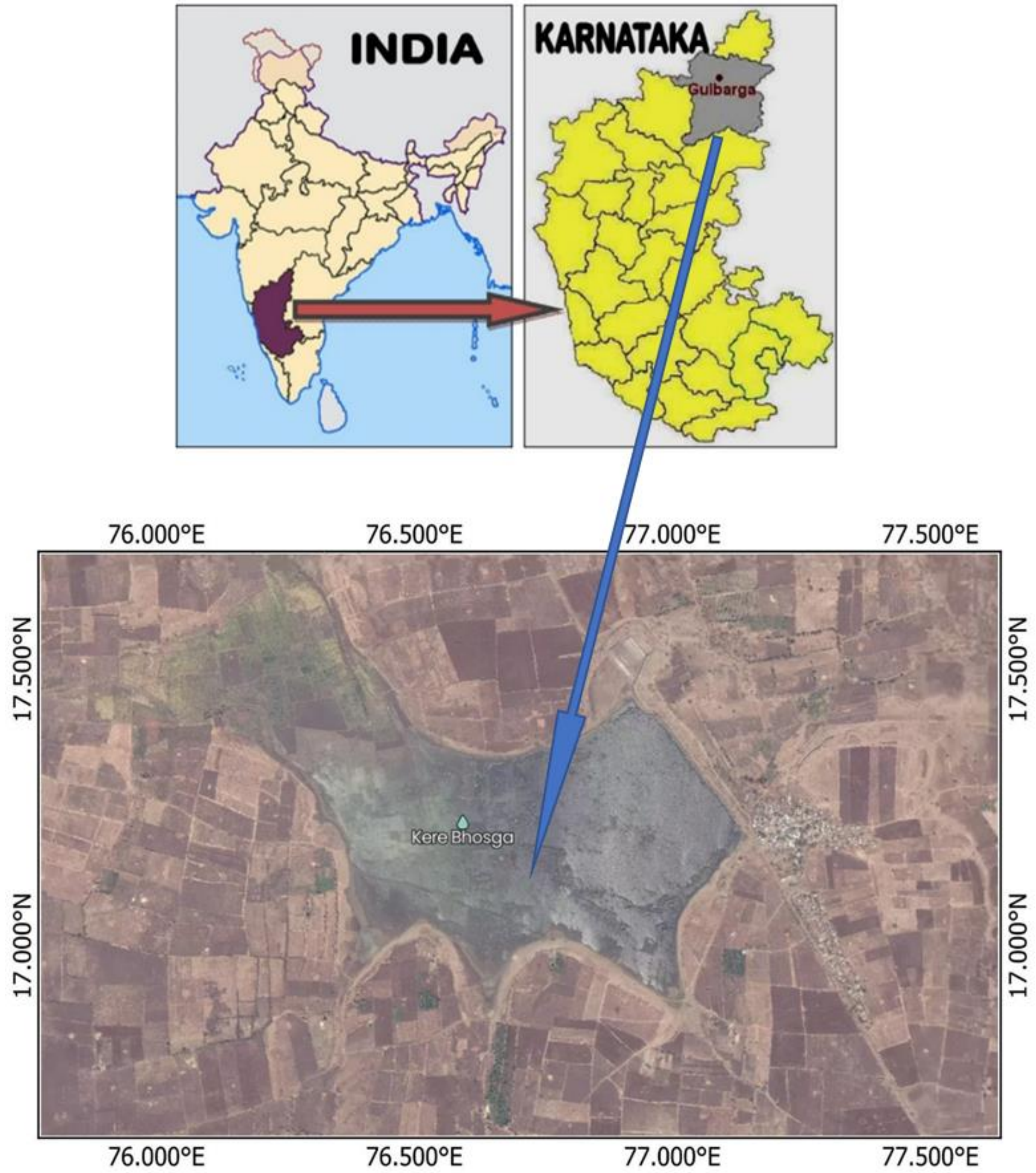

Figure 1. Map of India showing Bhosga reservoir in Kalaburgi District in Karnataka state

Table 1. Values for interpreting the results of BMWP (Biological Monitoring Working Party) – ASPT (Average Score Per Taxon) Armitage *et al*. [22], Alba-Tercedor and Sanchez-Ortega [23] and Ganguly et al [24]

Class	BWMP score	ASPT score	Water quality category
1	>120	>5.4	Excellent quality
2	101-120	4.8-5.4	Good quality
3	61-100	4.3-4.8	Regular quality
4	36-60	3.6-4.3	Contaminated
5	16-35	3.0-3.6	Very contaminated
6	<15		Extremely contaminated

Table 2. BWMP scores of families Armitage *et al* [22]

Slno	Order	Family	BMWP scores
1	Hemiptera	Corixidae	05
		Gerridae	05
		Hebridae	05
		Notonectidae	05
		Pleidae	05
		Veliidae	10
		Hydrometridae	05
		Belostomidae	05
		Mesoveliidae	05
		Nepidae	05
2	Coleoptera	Dytiscidae	05
		Hydrophilidae	05
		Gyrinidae	05
3	Odonata	Libellulidae	08
		Aeshnidae	08
		Coenagrionidae	06
4	Diptera	Chironomidae	02
		Ceratopogonidae	06
		Culicidae	02
		Stratiomyidae	05
5	Ephemeroptera	Baetidae	06
		Caenidae	07
6	Trichoptera	Lepidostomatidae	10

Table 3. Evaluation of water quality using the Family-level biotic index (FBI) Hilsenhoff [25]

Family biotic index	Water quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution
7.26-10.00	Very poor	Severe organic pollution likely

Table 4. FBI (Family Biotic Index) scores of families Hilsenhoff [25]

Slno	Order	Family	FBI scores
1	Hemiptera	Corixidae	08
		Gerridae	00
		Hebridae	00
		Notonectidae	00
		Pleidae	00
		Veliidae	01
		Hydrometridae	05
		Belostomidae	05
		Mesoveliidae	00
		Nepidae	06
2	Coleoptera	Dytiscidae	05
		Hydrophilidae	05
		Gyrinidae	04
3	Odonata	Libellulidae	02
		Aeshnidae	03
		Coenagrionidae	08
4	Diptera	Chironomidae	09
		Ceratopogonidae	06
		Culicidae	08
		Stratiomyidae	07
5	Ephemeroptera	Baetidae	04
		Caenidae	02
6	Trichoptera	Lepidostomatidae	01

Table 5. Mean physicochemical parameters from October 2020 to September 2021 of Bhosga reservoir

Parameters	Post-monsoon	Winter	Pre-monsoon	Monsoon
Water temperature (℃)	25.41±1.135	22.3±1.565	29.37±0.925	27.398±0.947
pH	7.80±0.197	7.4±0.173	7.83±0.118	7.71±0.169
Electrical conductivity (μS/cm)	210.3±19.42	252.86±4.53	309.72±7.57	292.48±22.01
Total dissolved solids (mg/l)	158.28±6.91	131.5±4.18	163.44±6.38	144.94±8.43
Dissolved oxygen (mg/l)	7.73±0.859	11.92±0.97	7.68±0.93	6.904±0.75
Total hardness (mg/l)	176.56±8.96	202.05±10.71	222.86±12.52	194.56±2.94
Total alkalinity (mg/l)	101±5.256	124.64±4.408	146.06±9.112	122.45±4.02
Carbon-dioxide (mg/l)	5.79±1.132	5.12±1.015	2.14±0.60	4.21±0.84
Chloride (mg/l)	32.75±2.61	49.19±4.55	79.32±8.65	50.06±2.16
Phosphate (mg/l)	1.96±0.08	2.25±0.123	1.88±0.22	1.80±0.11
Sulfate (mg/l)	4.25±0.11	4.50±0.22	4.14±0.26	4.05±0.24
Nitrate (mg/l)	1.64±0.15	2.26±0.12	1.95±0.19	1.82±0.08

3.3. Percentage Composition of Aquatic Insects

The percentage composition of aquatic insect orders collected from the Bhosga reservoir is illustrated in Figure 2. The most diverse family was Hemiptera (53%), the most dominated aquatic insect family, followed by Coleoptera (16%), Diptera (15%), Odonata (8%), Ephemeroptera (6%), and Trichoptera (2%). The similar observations explaining the number and percentage composition of taxa by Amaravati *et al*. [33] recorded that the order Hemiptera was the dominant family with (37%) followed by the order Coleoptera, Ephemeroptera, and Odonata each contributed to (14.82%), order Diptera and Trichoptera (7.41%) and Megaloptera (3.70%). Murugesan *et al*. [34] reported that Hemiptera was dominated order contributed (34%) followed by the order Diptera contributed (20%), Odonata (19%), Coleoptera (15%), Ephemeroptera and Trichoptera contributed (3%), Collembola (2%) and Plecoptera (1%).

3.4. Water Quality

The aquatic insects collected from the Bhosga reservoir and the biological scores allocated to each family of aquatic insects are presented in Table 7. The usability of the biological indices to detect water quality in freshwater ecosystems such as BMWP, ASPT, FBI, and PTI indices had been implemented and shown to be suitable tools for water quality assessment [35, 36]. The highest BMWP score of Bhosga reservoir was 122.4 in the winter, which indicates “Excellent” water quality and falls under class 1, whereas, in other seasons, it indicates “Good” water quality in post-monsoon, pre-monsoon, and monsoon seasons scores with 118.6, 112.6, and 109.2, falling under class 2, respectively. According to the ASPT index, “Excellent” water quality was 5.46 in winter falling within class 1, whereas in post-monsoon, pre-monsoon, and monsoon seasons with 5.28, 5.11, and 4.82, falling within class 2, which respectively showed “Good” water quality as represented in Table 1. The FBI biological scores revealed a 4.22 score in winter, which represents “Very good” water quality with possible slight organic pollution falling under class 2, whereas in post-monsoon, pre-monsoon, and monsoon seasons with 4.30, 4.54, and 4.75, falling under class 3, respectively, indicating “Good” water quality signifying that the water may have been degraded with some organic pollution, as showed in Table 3. The analysis of PTI was categorized into 3 groups as shown in Table 8. Group 1 consisted of sensitive to pollution (Baetidae, Caenidae, Lepidostomatidae, and Veliidae), group 2 represented by moderately sensitive to pollution (Gerridae, Hebridae, Mesoveliidae, Corixidae, Belostomatidae, Hydrometridae, Notonectidae, Nepidae, Pleidae, Libellulidae, Aeshnidae, Coenagrionidae, Dytiscidae, Hydrophilidae, Gyrinidae, Stratiomyidae, and Ceratopogonidae), and group 3 composed of (Chironomidae and Culicidae) [26]. Moderately sensitive to pollution group was abundant (74.11%) followed by sensitive to pollution (16.88%), and insensitive to pollution represented (9.00%) of the total abundance of aquatic insects. The present findings were in agreement with Azmi *et al*. [10], who observed that the water was categorized as “Excellent” to "Good water quality. Based on the overall biotic indices scores, it has been revealed that the presence of moderately pollution sensitive families was higher than the insensitive to pollution families indicating that the aquatic habitat has not been significantly altered, nor is it very clean.

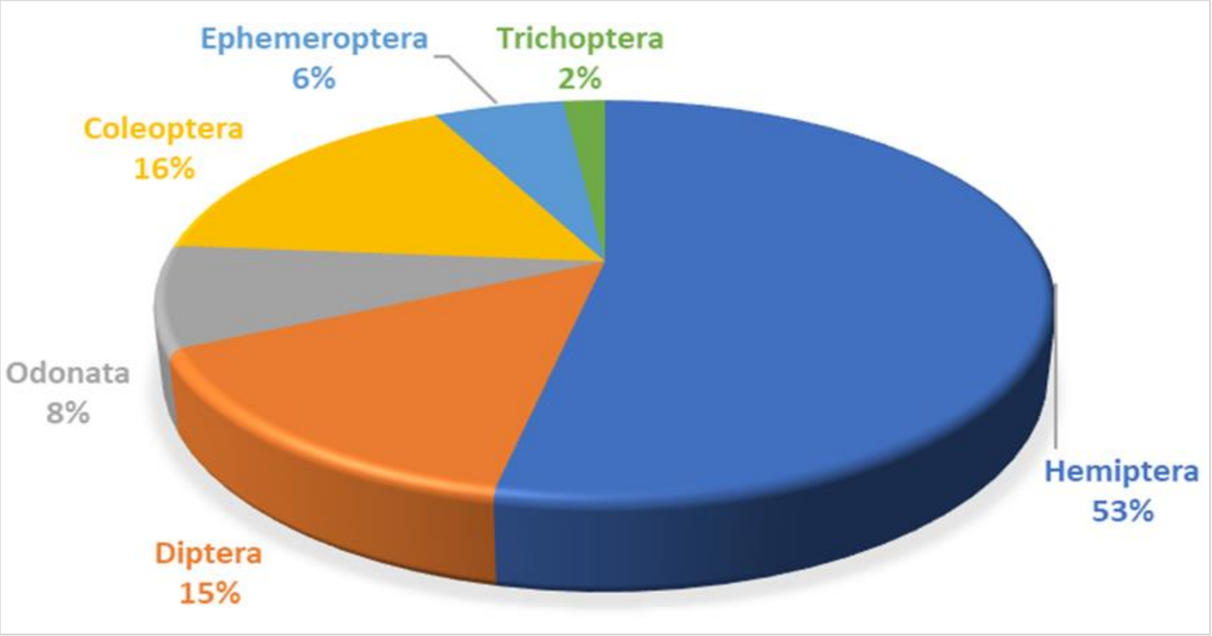

Figure 2. Percentage Composition of Aquatic Insects

Table 6. Diversity of aquatic insects of Bhosga Reservoir

Order	Family (Common name)	Abundance
Hemiptera	Gerridae (Pond skater)	250
	Veliidae (Riffle bug)	562
	Hebridae (Velvet water bug)	216
	Mesoveliidae (Water treader)	554
	Corixidae (Water boatman)	485
	Belostomatidae (Giant water bug)	61
	Hydrometridae (Pond skater)	82
	Notonectidae (Back swimmer)	357
	Nepidae (Water scorpion)	75
	Pleidae (Pygmy backswimmer)	536
Diptera	Chironmidae (Non-biting midge)	272
	Culicidae (Mosquito larva)	265
	Stratiomyidae (Soldierfly Larva)	175
	Ceratopogonidae (Biting midge)	164
Odonata	Libellulidae (Skimmer-dragonfly)	168
	Aeshnidae (Darners-dragonfly)	153
	Coenagrionidae (Pond-damselfly)	178
Coleoptera	Dytiscidae (Diving beetle)	348
	Hydrophilidae (Water scavenger beetle)	356
	Gyrinidae (Whirlgig beetle)	262
Ephemeroptera	Baetidae (Small minnow mayfly)	172
	Caenidae (Square-gilled mayfly)	165
Trichoptera	Lepidostomatidae (Caddisfly)	108
Total	23	5964

Table 7. The classification of water quality in Bhosga reservoir based on biological indices

Biotic indices	Post-monsoon	Winter	Pre-monsoon	Monsoon
BMWP	118.6	122.4	112.6	109.2
ASPT	5.28	5.46	5.11	4.82
FBI	4.30	4.22	4.54	4.75

Table 8. Pollution Load Index. Three groups of aquatic insects are categorized based on water Sensitive to pollution: Moderately sensitive to pollution and Insensitive to pollution Lewis [26]

Group	Collected aquatic insects	Total number of families	Abundance in %
Sensitive to pollution	Baetidae	172	2.88
	Caenidae	165	2.76
	Lepidostomatidae	108	1.81
	Veliidae	562	9.42
Total		**1007**	**16.88**
Moderately sensitive to pollution	Gerridae	250	4.19
	Hebridae	213	3.62
	Mesoveliidae	554	9.28
	Corixidae	485	8.13
	Belostomatidae	61	1.02
	Hydrometridae	82	1.37
	Notonectidae	357	5.98
	Nepidae	75	1.25
	Pleidae	536	8.98
	Straliomyidae	168	2.81
	Ceratopogonidae	153	2.56
	Libellulidae	178	2.98
	Aeshnidae	348	5.83
	Coenagrionidae	356	5.96
	Dytiscidae	262	4.39
	Hydrophilidae	175	2.93
	Gyrinidae	164	2.74
Total		**4420**	**74.11**
Insensitive to pollution	Chironmidae	272	4.56
	Culicidae	265	4.44
Total		**537**	**9.00**
Total number of aquatic insects		**5964**	

4. Conclusions

The current study was considered to have a good abundance of aquatic insects. A total of 5964 aquatic insects belonging to 23 families and 6 orders were reported. Water quality concerning physicochemical parameters was below the permissible limits of the BIS standards. Water quality falls under the class 2 category attributing “Good” water quality with the interpretation of a clean or not significantly altered aquatic environment based on biotic indices. However, the study states that the monitoring of the reservoir water quality using aquatic insects is an effective tool for better management and should be regularly conducted by relevant authorities.

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