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Monitoring wetland health in Dimoria: Insights from aquatic insect populations

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Abstract
A preliminary assessment of water quality of 3 selected sites of Jalisara beel and Bomani beel was carried out using aquatic insect community during March, 2023 to May, 2023. Aquatic insects were collected from the sites in replicates by 'Kick' method. The study revealed presence of 23 species of aquatic insects belonging to 16 families and 5 orders. Physico-chemical parameters of water were analyzed by standard methods. Spearman's correlation coefficient was applied to assess any significant variation in water quality parameters between the two selected wetlands. The Stream Invertebrate Grade Number – Average Level (SIGNAL 2) score, the Biological Monitoring Working Party ($BMWP^{THAI}$) score and the Average Score Per Taxon ($ASPT^{THAI}$) of the selected wetlands revealed severe, moderate and doubtful to probable moderate pollution, respectively. The findings of the study highlight the important role of aquatic insects as bioindicators in the two chosen wetlands of the Dimoria tribal region.

Keywords: Aquatic insects, water quality, biological indicator, SIGNAL 2 score, $BMWP^{THAI}$, $ASPT^{THAI}$ Score

Introduction
Wetlands are crucial ecosystems where water predominates, significantly influencing the environment and associated biota. They are highly productive and biodiverse, providing essential ecological services such as water purification, flood mitigation, and habitat for various species. Despite their importance, wetlands are increasingly threatened by human activities and development pressures [1-2]. In India, wetlands cover approximately 15.3 million hectares, representing about 4.7% of the total geographical area [3]. These ecosystems are vital for biodiversity conservation and offer significant socio-economic benefits. However, India's dense population exacerbates pressures on wetlands, contributing to their degradation [4].

Freshwater ecosystems are especially vulnerable to pollution from industrial, agricultural, and domestic sources. This pollution alters water chemistry and impacts biological communities, threatening the ecological balance and health of these systems [5-6]. Early inventories of Indian wetlands revealed substantial variation in area estimates due to differing definitions and classifications. Aquatic insects serve as effective bio-indicators for monitoring environmental health due to their sensitivity to changes in water quality. The presence and diversity of these insects provide insights into pollution levels and ecosystem health [7-8]. Biological methods, such as bio-monitoring using aquatic insects, offer a comprehensive assessment of water quality and are essential for informed environmental management [9-10].

Materials and Method
Study Area
The study focuses on two sites within the Dimoria Development Block in Kamrup Metro district, Assam. The block is situated southeast of Guwahati on the southern bank of the Brahmaputra River, bordered by Meghalaya to the south, Morigaon district to the northeast, and Greater Guwahati to the west, between 26° to 26°14′ N latitude and 91°51′ to 92°10′ E longitude, with a sub-tropical monsoon climate averaging 27°C and 200 cm of annual rainfall. Site I, Bomani Beel, is situated 38 km from Guwahati, within the block's 323.18 sq. km area, with coordinates between 26° N and 26° 11′ N latitudes and 91° 45′ E to 92° 0′ E longitudes, near the Digaru and Kalong rivers, and surrounded by villages such as Gomoria Pathar and Bejini. Site II, Jalisara Beel, is 49 km from Guwahati, with coordinates at 26°09′20.29″ N latitude and 92°04′43.15″ E longitude, serving as a significant floodplain wetland connected to the Kapili River during the monsoon and surrounded by Maloibari, Golab, Dapata, and Rewa Maheswar villages.

Aquatic insects and Water quality
In the periods the water samples were collected monthly from March to May 2023, from sub-surface layer (20 cm) of each 3 selected sites of Bomani beel and Jalisara beel. Aquatic insects were collected by a net having mesh size of 500 um following Kick' method where the net was dragged through the vegetation for a unit of time [11-12]. Three such drags represented a sample [13]. Subsequently, the organisms were separated, enumerated, and preserved in 70% ethyl alcohol. Identification up to the species level was carried out using an Almicro Microscope (DSZ-88) with the help of standard taxonomic references [14-17]. Water samples were collected in replicates from the same sites, and parameters such as air temperature (AT), water temperature (WT), transparency (TRAN), pH, total dissolved solids (TDS), total alkalinity (TA), dissolved oxygen (DO), biological oxygen demand (BOD), and free carbon dioxide (F-CO_2) were measured using standard analytical procedures.

Three diversity indices including Shannon Diversity Index (H'), Evenness Index (J') and Berger Parker Index of Dominance (d) were calculated for aquatic insects collected

during each site visit using Biodiversity Professional Version 2 software. The biological monitoring scores utilized were SIGNAL 2 (Stream Invertebrate Grade Number-Average Level), BMWP [THAI] (The Biological Monitoring Working Party [THAI]) and ASPTA [THAI] (The Average Score per Taxon [THAI]) [18-19]. As the raw data were not normally distributed, the variations in correlation among the physico-chemical parameters and aquatic insect density (ID) and species richness (SR) of Bomani beel and Jalisara beel during the study period were determined by estimating Spearman's rank correlation coefficient (r) using Statistical Program for Social Sciences (SPSS version 21.0).

Fig 1: Map of Assam showing location of Bomani beel and Jalisara beel following all the sampling site

Results and Discussion

Physico-Chemical Properties of Water

During the study period, comprehensive water quality assessments were conducted at Jalisara Beel and Bomani Beel. pH levels at Jalisara Beel ranged from 5.55 to 7.62, while at Bomani Beel, values ranged from 6.38 to 6.67. These values are within the acceptable range of 5.0 to 9.5 as stipulated by WHO (2011) and BIS (2012), indicating satisfactory water quality. Total alkalinity (TA) was observed between 1.67 and 6 mg/l at both beels, categorizing them as less productive according to Schaeperclaus *et al*. (1990), who classify aquatic systems with TA below 15 mg/l as less productive. The flux of CO2 (F-CO2) varied from 1.33 to 2.67 mg/l, with higher values suggesting elevated pollution levels. Dissolved oxygen (DO) concentrations ranged from 1.50 to 9.50 mg/l at Jalisara Beel and from 1.63 to 9.53 mg/l at Bomani Beel. These DO levels align with findings from previous studies in Assam, including Bordoloi *et al*. (2012), Deka (2013), and Sonowal and Baruah (2017), indicating generally healthy aquatic conditions. Biological oxygen demand (BOD) ranged from 1.37 to 3.27 mg/l at Jalisara Beel and 1.47 to 3.50 mg/l at Bomani Beel, reflecting low organic pollution levels as values above 5 mg/l are considered undesirable (Patel *et al*, 1983). Air temperatures fluctuated between 25°C and 30°C, while water temperatures ranged from 23.67°C to 29.33°C at Jalisara Beel and 27.67°C to 29.33°C at Bomani Beel. These temperatures are within the optimal range for aquatic organisms (5-25°C), suggesting suitable habitat conditions. Transparency (TRAN) varied from 30.50 cm to 74.27 cm at Jalisara Beel and 44.77 cm to 95.27 cm at Bomani Beel, with higher TRAN values observed at specific sites and times, likely influenced by varying turbidity levels. Total dissolved solids (TDS) were consistently recorded between 200 mg/l and 300 mg/l at both beels. Overall, the data demonstrate that both Jalisara and Bomani Beels exhibit satisfactory water quality with minimal pollution and favorable environmental conditions.

Table 1: Physico-chemical properties of water of Jalisara *Beel* during March,2023-May,2023

Water variables	March			April			May		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
AT (°C)	27±0	27±0	27±0	30±0	30±0	30±0	25±0	25±0	25±0
WT (°C)	23.67±0.58	24±1	24.33±0.58	29.33±0.58	29±0	29.33±0.58	27.67±0.58	27.67±1.15	27.33±0.58
TRAN (cm)	31.23±5.24	32.35±2.40	30.50±7.82	39.77±5.25	34.30±5.27	33.13±6.67	66.10±18.14	74.27±17.80	57.30±7.66
pH	6.60±0.07	6.27±0.12	6.53±0.14	7.21±0.59	7.34±0.35	7.62±0.56	5.75±0.07	5.55±0.14	5.60±0.24
TDS (mgl $^{[-1]}$)	266.67±57.74	300±100	266.67±57.74	300±100	233.33±57.74	233.33±57.74	266.67±57.74	200±0	266.67±57.74
TA (mgl $^{[-1]}$)	2.33±0.58	1.67±0.58	2.33±0.58	2±0	2.33±0.58	2.67±0.58	5.33±0	6±0	5.67±0
DO (mgl $^{[-1]}$)	5.43±0.25	5.43±0.15	5.50±0.30	8.53±0.45	9.50±1.15	8.60±0.90	1.63±0.15	1.70±0.20	1.50±0.26
BOD (mgl $^{[-1]}$)	3.07±0.15	3.27±0.25	3.10±0.10	1.50±0.20	1.67±0.74	2±0.36	1.50±0. 10	1.57±0.15	1.37±0.29
F-CO_2 (mgl $^{[-1]}$)	2±0	1.67±0.58	2.33±0.58	1.33±0.58	1.67±0.58	1.33±0.58	2±0	2.33±0.58	2.67±0.58

Table 2: Physico-chemical properties of water of Bomani *Beel* during March,2023-May,2023

Water variables	March			April			May		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
AT (°C)	30±0	30±0	30±0	26±0	26±0	26±0	28±0	28±0	28±0
WT (°C)	28.33±0.58	28.67±0.58	29±0	27.67±0.58	28.33±0.58	28.67±0.58	29.33±0.58	29.67±0.58	29.33±0.58
TRAN (cm)	47.87±8.06	44.77±11.14	54.13±5.40	58.47±2.10	67.97±32.51	68.07±17.57	91±8.35	68.14±20.50	95.27±6.52
pH	6.40±0.20	6.46±0.24	6.47±0.19	6.54±0.14	6.50±0.11	6.57±0.27	6.42±0.27	6.38±0.27	6.67±0.21
TDS (mgl $^{[-1]}$)	233.33±57.74	300±0	266.67±57.74	266.67±57.74	200±0	266.67±57.74	233.33±57.74	300±0	266.67±57.74
TA (mgl $^{[-1]}$)	2.67±0.58	2.33±0.58	2.67±0.58	2±0	2.33±0.58	1.67±0.58	6±2	3.67±0.58	5.67±2.52
DO (mgl $^{[-1]}$)	5.53±0.25	4.87±0.31	5.33±0.21	9.53±0.25	9.50±0.56	8.87±0.29	1.63±0.15	1.63±0.25	1.87±0.15
BOD (mgl $^{[-1]}$)	3.50±0.53	3.50±0.36	3.43±0.47	3±0.10	2.60±0.30	3.07±0.25	1.50±0.17	1.47±0.31	1.73±0.21
F-CO_2 (mgl $^{[-1]}$)	2.33±0.58	2.67±0.58	2±1	1.33±0.58	2±0	1.67±0.58	1±0	1.67±0.58	1.33±0.58

Diversity indices, biomonitoring scores and dominance status

The study identified a total of 5 orders, 16 families, and 20 species across both Jalisara Beel and Bomani Beel. The orders observed include Hemiptera, Ephemeroptera, Coleoptera, Odonata, and Diptera. Specifically, Jalisara Beel harbored 16 families and 20 species, while Bomani Beel contained 16 families and 15 species. In Jalisara beel, during the visits, distinct patterns of dominance among species were observed. In Visit 1, the dominant species included Micronecta sp, Paraplea frontalis, Anisops sp, Cleon inscriptum, and Canthydrus laetabilis. In Visit 2, the dominance shifted to Micronecta sp, Paraplea frontalis, and Cleon inscriptum. By Visit 3, the dominant species had changed to Micronecta haliploides, Neurothemis sp, and Urothemis signata. These variations highlight shifts in species dominance over time. Meanwhile, in Bomani beel, during Visit 1, the dominant species were Paraplea frontalis, Anisops sp, and Hydrovatus sp. In Visit 2, Microvelia sp. and Neurothemis sp. were dominant, with Cleon inscriptum being classified as eudominant. By Visit 3, the dominance was noted for Diplonychus rusticus and Cleon inscriptum.

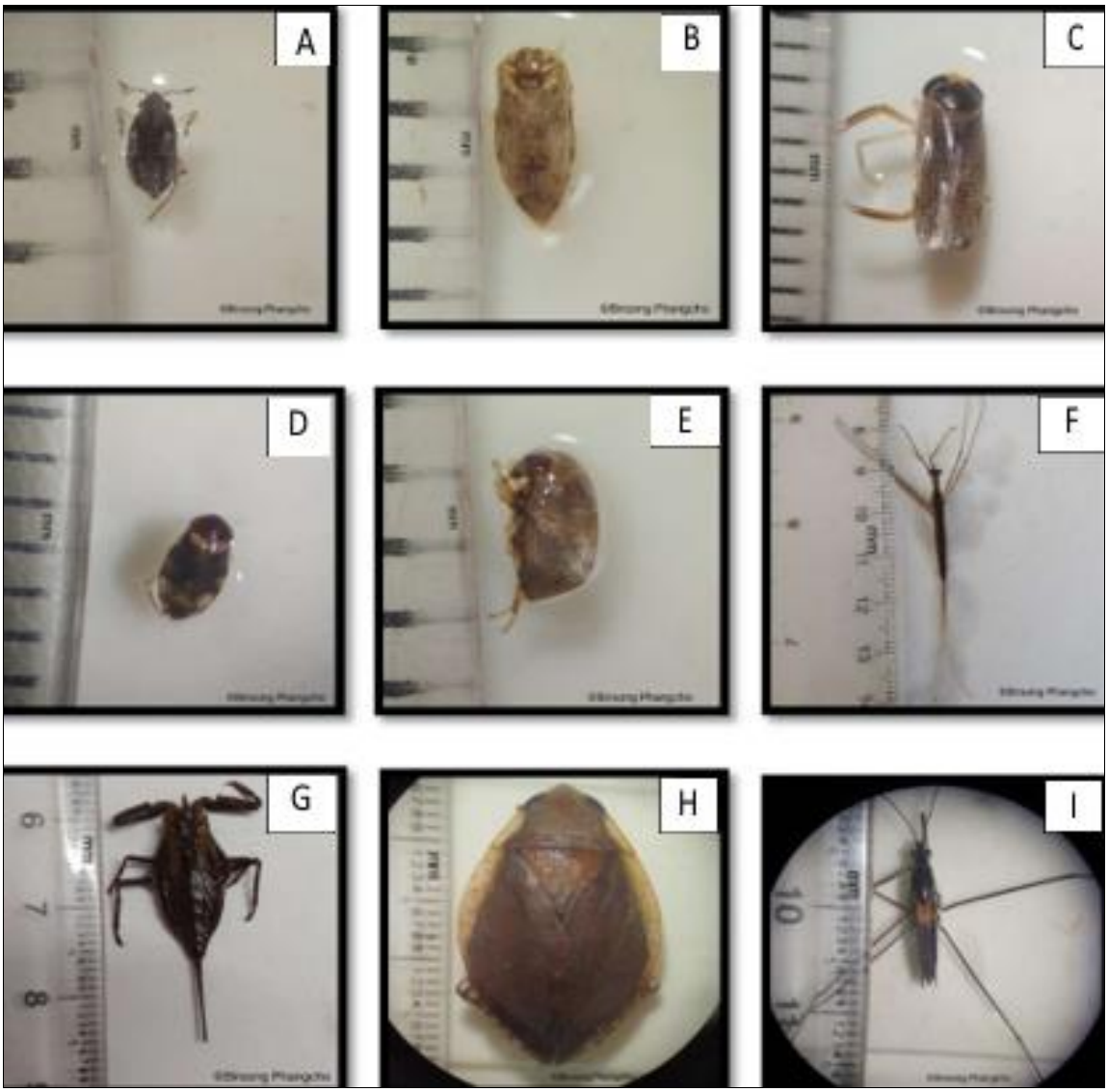


Fig 2: Images of A- Microvelia sp.; B- Micronecta haliploides; C- Micronecta sp.; D- Sigara sp.; E- Paraplea frontalis; F- Ranatra sp.; G- Laccotrephes sp.; H- Diplonychus rusticus; I-Aquarius sp

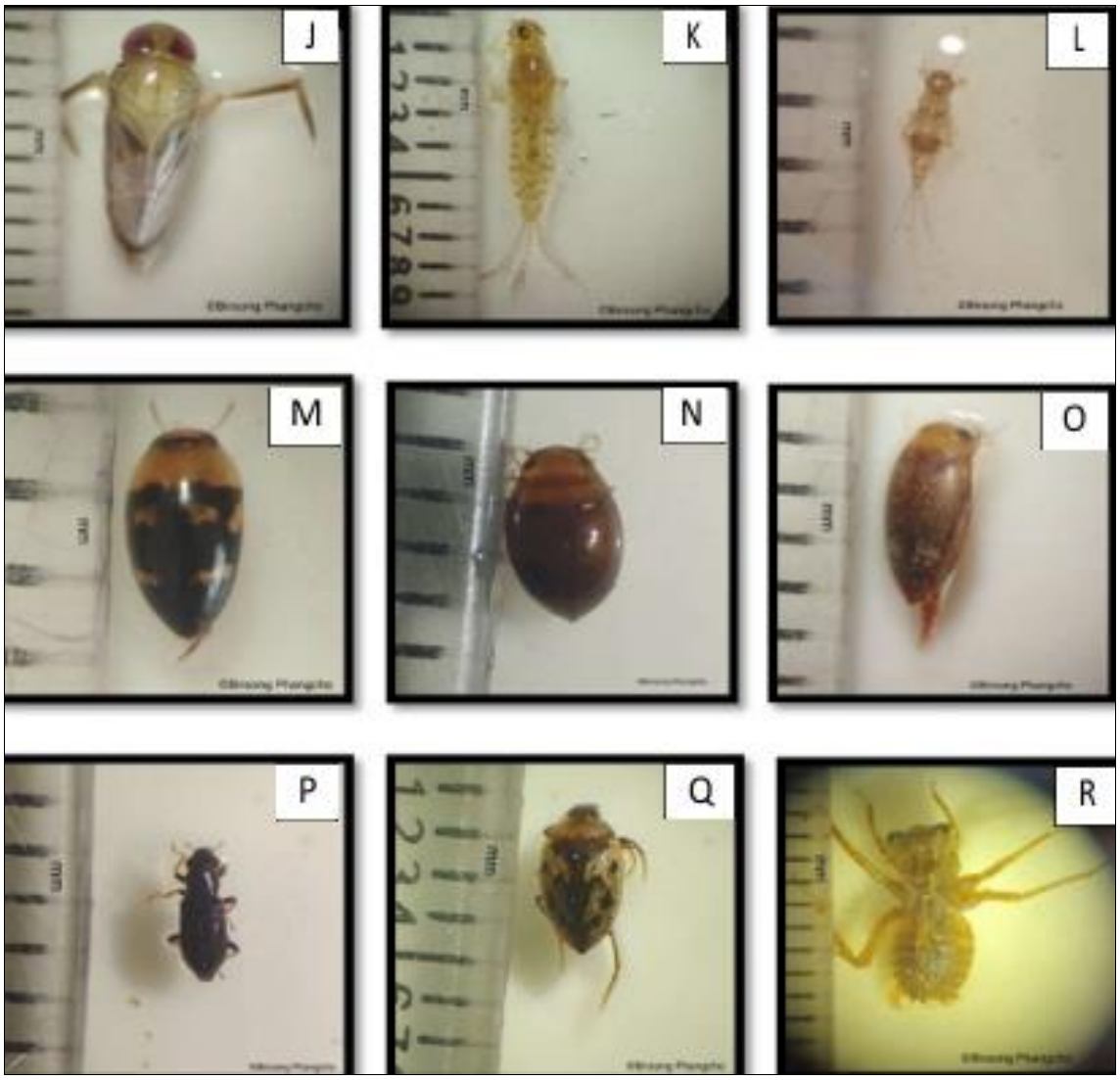


Fig 3: Images of J- Anisops sp.; K- Cleon inscriptum; L- Caenis sp.; M- Canthydrus laetabilis; N- Hydrovatus sp.; O- Laccophilus parulus; P- Hydrochus sp.; Q- Haliplus sp.; R- Rhodothemis rufa

Fig 4: Images of S- Neurothemis sp.; T- Urothemis signata; U- Pseudagrion australasiae; V- Ischnura senegalensis; W- Aedes sp

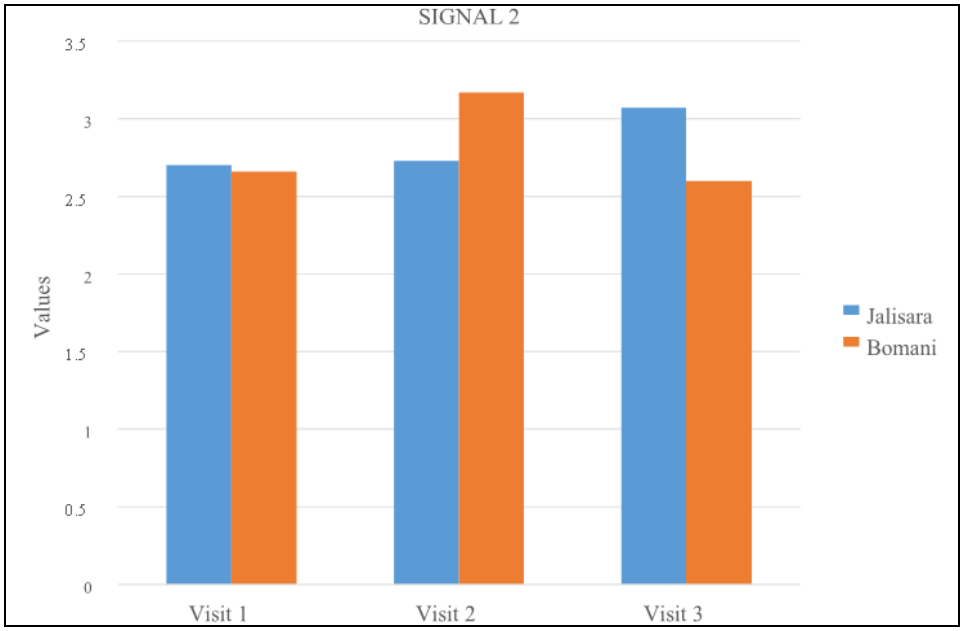
Table 3: The relative abundance and dominance status of aquatic insect's species recorded from Jalisara beel during Visit 1 (March), Visit 2 (April) and visit 3 (May), 2023 (Engelmann, 1978).

			Jalisara beel			Bomani beel		
Order	Family	Species	Visit 1 RA (%) DS	Visit 2 RA (%) DS	Visit 3 RA (%) DS	Visit 1 RA (%) DS	Visit 2 RA (%) DS	Visit 3 RA (%) DS
Hemiptera	Vellidae	Microvelia sp. (Westwood, 1834)	6.58 (SD)	-	-	-	17.7 (D)	-
	Corixidae	Micronecta haliploides (Horvath, 1904)	-	-	11.42 (D)	-	-	-
		Micronecta sp. (Horvath, 1904)	14.37 (D)	25.53 (D)	3.57 (SD)	-	-	5.35 (SD)
	Pleidae	Paraplea frontalis (Esaki and China, 1928)	11.37 (D)	13.47 (D)	2.85 (R)	13.44 (D)	8.33 (SD)	-
	Nepidae	Ranatra sp. (Stål, 1861)	0.59 (SR)	--	10 (SD)	-	-	3.57 (SD)
	Belastomatidae	Diplonychus rusticus (Fabricius,1781)	-	7.09 (SD)		4.20 (SD)	3.12 (SD)	21.42 (D)
	Gerridae	Aquarius sp. (Fabricius, 1775)	-	-	2.14 (R)	-	-	-
	Notonectidae	Anisops sp. (Kirkaldy, 1904)	20.35 (D)	-	3.57 (SD)	23.52 (D)	-	-
Ephemeroptera	Baetidae	Cleon inscriptum (Leach, 1815)	11.37 (D)	18.44 (D)	5.71 (SD)	6.72 (SD)	35.41 (ED)	17.85 (D)
	Caenidae	Caenis sp. (Stephens, 1835)	-	-	8.57 (SD)	-	7.29 (SD)	-
Coleoptera	Noteridae	Canthydrus laetabilis (Walker,1858)	17.96 (D)	5.67 (SD)	1.42 (R)	10.08 (SD)	3.12 (R)	8.92 (SD)
	Dytiscidae	Hydrovatus sp. (Motschulsky,1853)	-	-	1.42 (R)	15.12 (D)	-	5.35 (SD)
	Hydrochidae	Hydrochus sp. (Leach,1817)	-	-	5 (SD)	-	-	-
	Haliplidae	Haliplus sp (Latreille, 1802)	-	-	4.28 (SD)	-	-	-
Odonata	Libellulidae	Rhodothemis rufa (Rambur, 1842)	2.39 (R)	2.12 (R)	6.42 (SD)	10.08 (SD)	-	1.78 (R)
		Neurothemis sp. (Brauer, 1867)	-	-	12.85 (D)	8.4 (SD)	12.5 (D)	-
		Urothemis signata (Rambur, 1842)	3.59 (SD)	1.41 (R)	12.85 (D)	-	--	-
	Coenagrionidae	Pseudagrion australasiae (Seyls,1876)	-	2.12 (R)	-	5.04 (SD)	8.33 (SD)	-
		Ischnura senegalensis (Rambur, 1842)	8.38 (SD)	4.25 (SD)	7.85 (SD)	3.36 (SD)	1.04 (SR)	-
Diptera	Culicidae	Aedes sp. (Meigen, 1818)	2.99 (R)	-	-	-	3.12 (SD)	3.57 (SD)

Note: RA= Relative abundance; DS= Dominance status; RA<1%= Subrecedent (SR); 1.1-3.1%= Recedent (R); 3.2-10%= Subdominant (SD); 10.1-31.6%= Dominant (D); and >31%= Eudominant (ED).

Stream Invertebrate Grade Number Average Level version 2 (SIGNAL 2)

During the study period of Jalisara beel the highest value of SIGNAL 2 was recorded 3.07 during third visit, Bomani beel the highest value of SIGNAL 2 was recorded 3.17 during second visit which is considered as 'severe pollution' according to Gooderham and Tsyrlin, 2002. The lowest value of SIGNAL 2 of Jalisara beel was recorded 2.7 during first visit, Bomani beel the lowest value was recorded 2.6 during first visit which is considered as 'severe pollution' according to Gooderham and Tsyrlin, 2002.

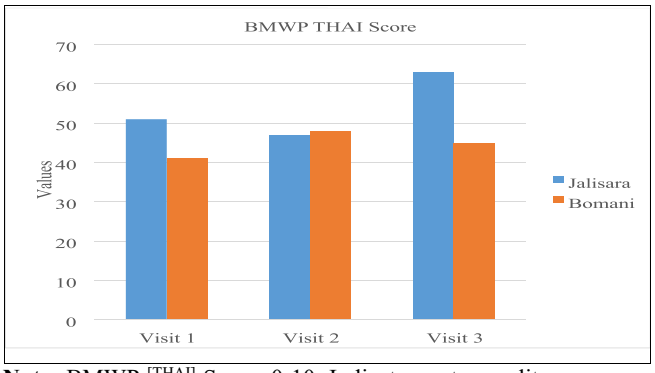


Note: Signal Grade, 10-8; Indicates a greater sensitivity to pollution, 7-5- sensitivity to pollution, 4-3; tolerance to pollution, 2-1; greater tolerance to pollution (Chessman, 2003).

Fig 5: Signal 2 to score of Jalisara beel and Bomani beel during first to third visit (March, 2023 to May, 2023)

Biological Monitoring Working Party (BMWP [THAI]) Score

During the study period of Jalisara beel the highest value BMWP [THAI] Score of was recorded 63 during third visit, Bomani beel the highest value was recorded 48 during second visit which is considered as 'moderate quality' according to Mason, 2002. The lowest value of BMWP [THAI] Score of Jalisara beel was recorded 47 during first visit, Bomani beel the lowest value was recorded 41 during third visit which is considered as 'moderate quality' according to Mason (2002). From the findings of Barman and Gupta (2016) it has been found that different biological monitoring scores based on tolerance values of different Coleoptera and Hemiptera species and their density could be of great value in determining the health of the ecosystems and suggested that species richness and density of aquatic insect may indicate the conservation value of the habitats because of their significant responses to environmental factors.

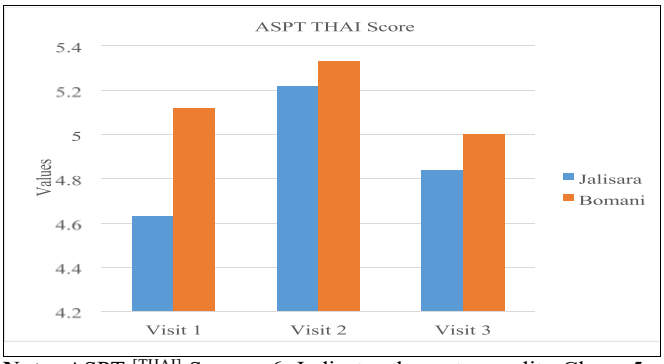


Note: BMWP [THAI] Score, 0-10; Indicates water quality very poor and heavy polluted, 11-40; Poor and polluted or impacted, 41-70; Moderate and moderately impacted, 71-100; Good and clean but slightly impacted, >100; Very good and unpolluted or impacted (Mason, 2002).

Fig 6: BMWP [THAI] score of Jalisara beel and Bomani beel during first to third visit (March, 2023 to May, 2023)

Average Score Per Taxon (ASPT [THAI]) Score

During the study period of Jalisara beel the highest value ASTP [THAI] Score of was recorded 5.22 during second visit, Bomani beel the highest value was recorded 5.33 during second visit which is considered as 'doubtful quality' according to Mandaville, 2002. The lowest value of ASTP [THAI] Score of Jalisara beel was recorded 4.63 during first visit, Bomani beel the lowest value was recorded 5 during third visit which is considered as 'probable moderate pollution' according to Mandaville (2002).



Note: ASPT [THAI] Score, >6; Indicates the water quality Clean, 5-6; Doubtful quality, 4-5; Probable moderate pollution, <4; Probable severe pollution (Mandaville, 2002).

Fig 7: ASPT [THAI] score of Jalisara beel and Bomani beel during first to third visit (March, 2023 to May, 2023)

Diversity Indices

The biological indices were evaluated at Jalisara Beel and Bomani Beel across three visits. The Shannon Diversity Index (H′) showed equal diversity at both beels during the first visit (0.93), with Jalisara Beel exhibiting higher diversity (0.91) in the second visit and Bomani Beel showing the lowest (0.69). In the third visit, Jalisara Beel again had higher diversity (1.09), while Bomani Beel recorded the lowest (0.89). For the Evenness Index (J′), Bomani Beel had higher evenness (0.93) in the first visit, while Jalisara Beel recorded the lowest (0.89). In the second visit, Jalisara Beel showed higher evenness (0.87), and Bomani Beel had the lowest (0.77). The trend continued in the third visit with Jalisara Beel at 0.93 and Bomani Beel at 0.89. The Berger-Parker Dominance Index (d) revealed that Bomani Beel exhibited higher dominance in the first (0.24) and second (0.45) visits, while Jalisara Beel had lower values (0.20 and 0.26, respectively). In the third visit, Bomani Beel remained dominant (0.21), and Jalisara Beel showed the lowest (0.13).

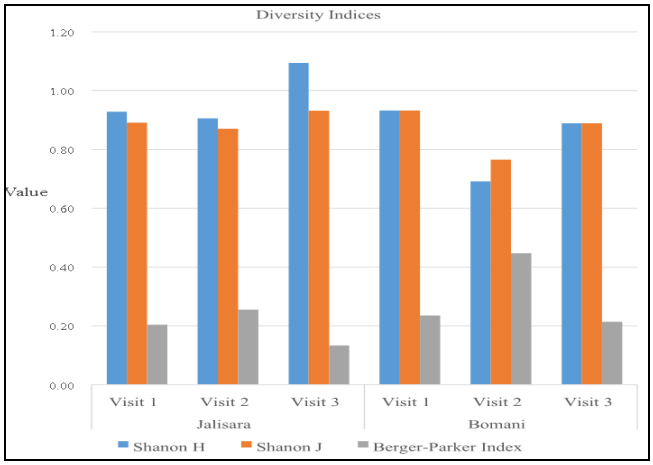


Fig 8: Bar diagram showing Diversity Indices values of Jalisara beel and Bomani beel during first to third visit (March, 2023 to May, 2023)

During the study period (March to May 2023), various environmental variables in Jalisara Beel and Bomani Beel showed significant correlations. Atmospheric Temperature (AT) positively correlated with Water Temperature (WT) ($rs=0.603$, $p<0.1$) and pH ($rs=0.506$, $p<0.5$). Water Temperature (WT) had a positive correlation with AT ($rs=0.603$, $p<0.1$) but a negative correlation with Free Carbon Dioxide (F-CO2) ($rs=-0.561$, $p<0.5$). Transparency (TRAN) positively correlated with Total Alkalinity (TA) ($rs=0.549$, $p<0.5$). pH positively correlated with AT ($rs=0.506$, $p<0.5$) and Dissolved Oxygen (DO) ($rs=0.675$, $p<0.1$), and negatively correlated with F-CO2 ($rs=-0.531$, $p<0.5$). TA positively correlated with TRAN ($rs=0.549$, $p<0.5$) and negatively correlated with DO ($rs=-0.740$, $p<0.1$) and Biological Oxygen Demand (BOD) ($rs=-0.504$, $p<0.5$). DO showed a positive correlation with pH ($rs=0.675$, $p<0.1$), while BOD had a negative correlation with TA ($rs=-0.504$, $p<0.5$). F-CO2 exhibited negative correlations with WT ($rs=-0.561$, $p<0.5$) and pH ($rs=-0.531$, $p<0.5$). Spearman correlation analysis indicated that most environmental variables had significant relationships with insect density (ID) and species richness (SR). The study found that the aquatic insects present were tolerant and semi-tolerant, capable of surviving in moderate to low dissolved oxygen levels in the water.

Table 4: Significant Spearman's correlation among physico-chemical parameters in Jalisara beel and Bomani beel during study period (March-May, 2023)

	AT	WT	TRA N	pH	TDS	TA	DO	BOD	F- CO2
AT	1.000	.603**	-.331	.506*	.141	-.124	.225	.322	-.245
WT		1.000	.421	.326	.010	.245	.024	-.314	-.561*
pH			1.000	-.321	-.236	.549*	-.373	-.449	-.225
DO				1.00 0	-.039	-.435	.675**	.147	-.531*
TDS					1.000	-.396	-.220	.072	-.030
TA						1.00 0	-.740**	-.504*	.123
DO							1.000	.424	-.269
BOD								1.000	.296
F-CO_2									1.000
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).									

Note: **Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed) n= number of samples.

Conclusion

A preliminary assessment of water quality at Jalisara Beel and Bomani Beel was conducted using aquatic insects as bioindicators. The results from various bio-monitoring scores and diversity indices indicated that the water quality at Jalisara Beel is severely polluted, while Bomani Beel is moderately polluted. The study highlighted key physico-chemical parameters influencing the water quality at both locations. The insect populations at the three sites of Jalisara Beel and Bomani Beel were found to be low, likely due to reduced dissolved oxygen (DO) levels. This suggests that the aquatic insect species present are either tolerant or semi-tolerant, capable of surviving in low DO conditions. Ideally, both beels should support high DO concentrations and host more sensitive orders, such as Ephemeroptera, Plecoptera, and Trichoptera. However, only Ephemeroptera was recorded during the study. The absence of the other two orders may be attributed to human activities, including agricultural runoff, nearby cement factory operations, and infrastructure developments like the railway overbridge. These findings underscore the need for heightened environmental awareness and conservation efforts. The data gathered serves as a baseline for future research on freshwater ecosystems.

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