Assessment of Ecosystem Health of an Effluent Receiving Wetland Etila beel (Assam) India using Aquatic Insect as Bioindicator

Mrigangka Malakar, Sanchita Boruah

ABSTRACT

An assessment of ecosystem health of an effluent receiving floodplain wetland, Etila *beel* (26º08/-26º10/ N and 92º08/ - 92º11/ E) of Kamrup Metro district, Assam, India was carried out using aquatic insects as bioindicator during September, 2013 to August 2016. Insects were collected from five sites (S1, S2, S3, S4, and S5) in four different season's viz., Post-Monsoon (PM1): September, October and November and Winter (W): December, January, and February. Pre-Monsoon (PM2): March, April, and May, Monsoon (M): June, July, and August. Aquatic insects were collected from the selected sites by Kick Sampling method. From the investigation, higher FBI values, lower BMWP^{THAI} score, lower ASPT score in the sampling stations of Etila *beel* had observed, which indicates poor ecosystem health status of the wetland. These indices can be used as measuring

tools for evaluating the ecosystem health status of any aquatic ecosystem suffering from environmental pollution. The harmful pollutants of the nearby paper industry, which were directly discharged in the wetland adversely impacted the entire *beel* ecosystem. However, it needs to be mentioned that, the aforesaid paper mill is in a non-functional state since March 2017, it is hoped that the water condition of Etila *beel* has improved since then.

INTRODUCTION

Aquatic insects are ideal indicators of ecosystem diversity and health and play an important role in ecosystem stability (El Alami *et al.* 2022). Since, aquatic insects are feasible indicators of water quality, both aquatic insects and water quality are interrelated (Vian *et al.* 2018). Aquatic insects are considered as ideal bioindicators of water quality because they are sensitive to environmental changes and their presence or absence determines clean or polluted state of water. Kamrup Metro district is amongst the 35 districts of Assam and situated between 25°43′ –26°51′ N and 90°36′ –92°12′ E. Kolong and Digaru are two main tributaries that are connected to River Brahmaputra. The district has several smaller and medium sized

Mrigangka Malakar[1]*

[1]District Environment Coordinator (DEC)
ARIAS Society (An autonomous body of Govt. of Assam), Guwahati, Assam, India

Sanchita Boruah[2]
[2] Associate Professor
Department of Zoology, D.H.S.K College, Dibrugarh, Assam, India

Email: mrigangka.malakar@gmail.com
*Corresponding author

wetlands, some of which are connected to the two river tributaries, Kolong and Digaru. The study was conducted to assess the ecosystem health status of the effluent receiving wetland Etila *beel* by using aquatic insects as bioindicators.

Several studies have been carried out on aquatic insects as bioindicator worldwide. Barman and Gupta (2015) conducted a study on aquatic insects as bio-indicator of water quality- on Bakuamari stream, Chakrashila Wildlife Sanctuary, Assam. Choudhury and Gupta (2015) observed the aquatic insect community of Deepor beel (Ramsar site), Assam, India. Saha and Gupta (2015) studied on aquatic and semi-aquatic Hemiptera of three oxbow lakes of Cachar District, Assam, N. E India and their role as bioindicator. Choudhury and Gupta (2017) conducted a rapid assessment study on water quality of Deepor *beel*

(Ramsar site), North East India using aquatic insects.

Study Area

Etila *beel*, a floodplain wetland (26º08/- 26o10/ N and 92º08/ - 92º11/ E) is situated in the Kamrup Metro district of Assam at about 40 km east of the state capital Guwahati and connected to the R. Kolong, a tributary on the south bank of R. Brahmaputra (Fig 1). Etila *beel* was an effluent receiving wetland from the nearby paper industry during the period of the study from September 2013 to August 2016. However, it needs to be mentioned that, the aforesaid paper mill is in a non-functional state since March 2017.

MATERIALS AND METHODS

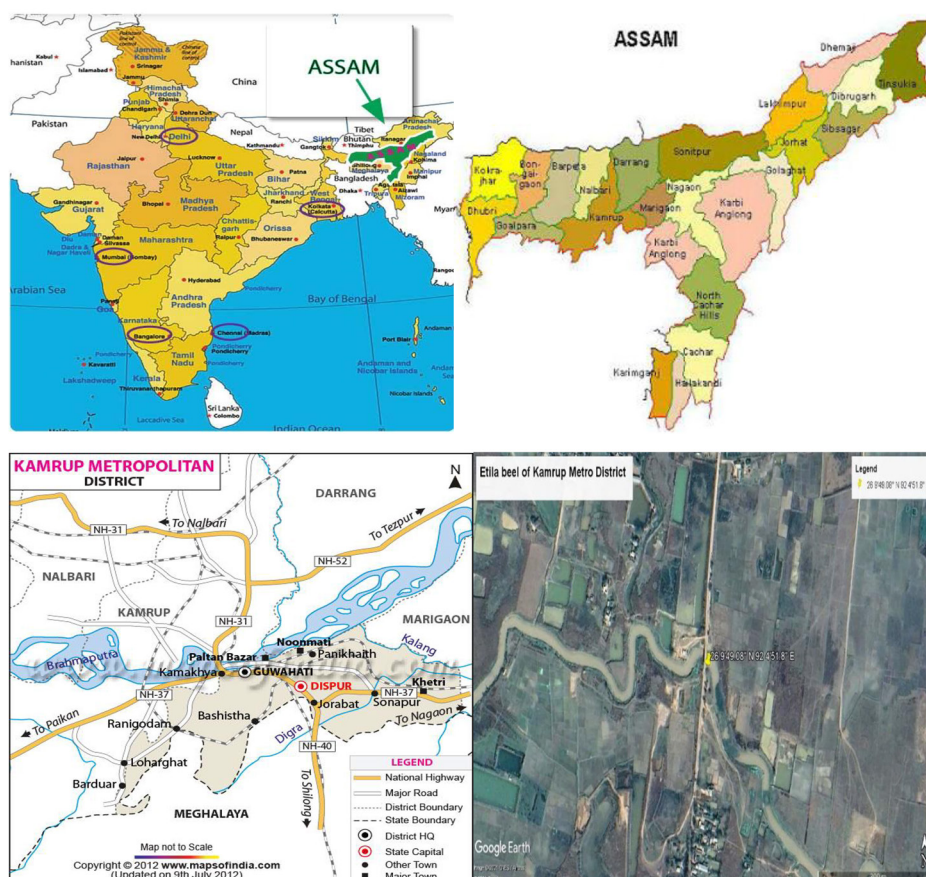Insects were collected from five sites (S1, S2, S3,

Fig. 1. Locational map of the study area.

S4, and S5) of Etila *beel* in four different season's viz., Post-Monsoon (PM1): September, October and November and Winter (W): December, January, and February. Pre-Monsoon (PM2): March, April, and May, Monsoon (M): June, July, and August of the three consecutive years including 2013-14, 2014-15 and 2015-16. Aquatic insects were collected from the selected sites by Kick Sampling method using a net of mesh size 500 μm whereby the vegetation was disturbed, and the net was dragged around the vegetation for a minute, placing the net in the direction of flow, with an open net mouth facing upstream. Three such drags constituted a sample. Three replicate samples were collected, and the insects were then sorted, counted, and then preserved in 70% ethyl alcohol.

To evaluate the water quality and diversity in the wetland, three biotic indices were calculated from the data collected.

Family Biotic Index-FBI: Family Biotic Index (FBI) value was used following Hilsenhoff 1988, Plafkin *et al.*1989, Barbour *et al.*1999 using the equation:

$$FBI=\Sigma xi.ti /n,$$

Where

xi = no. of individuals in the "i^{th}" taxon.
t^i = tolerance value of the "i^{th}" taxon.
n = total no of organisms in the sample.

Water quality of the studied wetland was evaluated by using family biotic index values ranges between 0.00 – 10.00, water quality grade ranges from very poor to excellent and on the basis of degree of organic pollution, taken from standard protocols provided by Hilsenhoff 1988 (Table 1).

Table 1. Evaluation of water quality using the family-level biotic index (Hilsenhoff 1988).

Family biotic	Water quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.0	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 likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 2. Tolerance values for aquatic insects to calculate FBI (Hilsenhoff 1988).

Taxonomic families	Tolerance value
(1) Nepidae	5
(2) Belostomatidae	5
(3) Corixidae	5
(4) Veliidae	5
(5) Gerridae	5
(6) Mesoveliidae	5
(7) Libellulidae	2
(8) Coenagrionidae	8
(9) Dytiscidae	5
(10) Hydrophilidae	5

Tolerance which has been used in the calculation of FBI is a listing of tolerance values that range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant of organic wastes. These values have been taken from standard protocols provided by Hilsenhoff 1988 (Table 2).

BMWP^THAI score

The biological monitoring working party (BMWP) is a procedure for measuring water quality using families of macroinvertebrates as biological indicators (Hawkes 1998). The method is based on the principle that different aquatic invertebrates have different sensitivity/tolerance to organic pollution (i.e., nutrient enrichment that can affect the availability of dissolved oxygen). The BMWP^THAI score is obtained by summing the individual scores of all families present. Score values for individual families reflect their pollution tolerance. In this study, BMWP^THAI

Table 3. BMWP^THAI tolerance values of aquatic insects (Mustow 2002).

Taxonomic families	Tolerance value
(1) Nepidae	5
(2) Belostomatidae	5
(3) Corixidae	5
(4) Veliidae	5
(5) Gerridae	5
(6) Mesoveliidae	5
(7) Libellulidae	6
(8) Coenagrionidae	6
(9) Dytiscidae	5
(10) Hydrophilidae	5
(11) Notonectidae	5

tolerance values have been taken from standard protocols provided by Mustow 2002 (Table 3).

Average Score Per Taxon -ASPT score: The Average Score Per Taxon (ASPT) represents the average tolerance score of all taxa within the community and is calculated by dividing the BMWP^{THAI} by the number of families represented in the sample.

ASPT score = Total of BMWP^{THAI} score / Total number families represented.

RESULTS AND DISCUSSION

BMWP^{THAI} (Biological Monitoring Working Party) score, ASPT (Average Score Per Taxon) score and FBI (Family Biotic Index) were used to assess the water quality of the Etila *beel*. BMWP^{THAI} (Biological

Monitoring Working Party) score system is one of the most commonly used biotic index score which has been applied to various wetlands and rivers throughout India and the world. This index allocates some scores to the benthic macroinvertebrates like insects at the family level which represent family's tolerance level towards water pollution. The lower their tolerance to water pollution, the greater the BMWP score and vice-versa.

During 2013-14, the overall BMWP^{THAI} score was ranged from 32 at S1 in the pre-monsoon, which shows Moderate (M) class water quality to overall maximum score 47 at S2 during monsoon season which also shows Moderate (M) class water quality. The minimum ASPT score was recorded as 2.9 at S1 in the pre-monsoon season which shows PS (Probable Severe Pollution) class water quality and maximum ASPT score was recorded as 4.27 at S4, S5 in the

Table 4. Seasonal Variation in BMWP^{THAI} and ASPT score at 5 stations of Etila *beel* (2013-2014).

Orders/Families of collected insects	Post-Monsoon					Winter					Pre-Monsoon					Monsoon				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Hemiptera																				
Nepidae	5	5	5	5	5	-	-	5	5	5	5	-	-	5	5	5	5	5	5	5
Belostomatidae	5	5	5	5	5	5	5	-	5	5	5	-	5	5	-	5	5	5	5	5
Corixidae	5	5	5	-	-	-	5	5	5	5	-	5	5	-	5	5	-	5	-	5
Veliidae	5	-	-	5	-	5	5	5	-	-	5	-	5	5	5	5	5	5	5	5
Notonectidae	5	-	5	-	-	-	5	-	5	-	-	5	-	5	-	5	5	5	5	5
Gerridae	-	-	5	-	5	5	-	5	5	5	-	5	-	5	5	5	5	5	-	5
Mesoveliidae	-	5	5	5	-	5	5	-	-	5	5	-	5	5	5	-	-	5	5	-
Odonata																				
Libellulidae	-	-	-	6	6	-	6	6	-	-	6	6	6	6	6	-	6	-	6	-
Coenagrionidae	-	6	6	6	6	6	6	6	6	-	6	6	6	6	6	6	6	6	6	6
Coleoptera																				
Dytiscidae	5	5	-	5	5	5	-	5	5	5	-	5	5	-	5	5	5	5	5	5
Hydrophilidae	5	5	-	5	5	5	5	-	5	5	-	5	-	5	5	5	5	-	5	5
Total BMWP score	35	36	36	42	37	36	42	37	41	35	32	37	37	47	47	46	47	46	47	46
Interpretation	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
ASPT score	3.18	3.27	3.27	3.81	3.36	3.27	3.81	3.36	3.72	3.18	2.9	3.36	3.36	4.27	4.27	4.18	4.27	4.18	4.27	4.18
Interpretation	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PM	PM	PM	PM	PM	PM	PM

Note: BMWP score and their quality index are 0-16= Poor water quality (P), 17-50= Moderate water quality (M), 51-100= Good water quality (G), 101-150= High water quality (H), 151+ = Very high water quality (VH) (Chesters, 1980), ASPT score and index of organic pollution are > 6= Clean water (C), 5-6 = Doubtful quality (D), 4-5 = Probable moderate pollution (PM), <4 = Probable severe pollution (PS) (Mandaville 2002). Abbreviations: BMWP = Biological monitoring working party, ASPT = Average score per taxon.

Table 5. Seasonal Variation in BMWP^{THAI} and ASPT score at 5 stations of Etila *beel* (2014-2015).

Orders/Families of collected insects	BMWP score																			
	Post-Monsoon					Winter					Pre-Monsoon					Monsoon				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Hemiptera																				
Nepidae	5	5	-	-	5	-	-	5	5	5	5	-	-	5	5	5	5	5	5	5
Belostomatidae	5	5	5	5	-	5	5	-	-	-	5	-	5	5	-	5	5	5	5	5
Corixidae	5	5	5	-	-	-	5	5	5	5	-	5	5	-	5	5	-	5	-	5
Veliidae	5	-	-	5	-	5	5	-	-	-	5	-	5	5	5	-	5	5	5	5
Gerridae	-	-	5	-	5	5	-	5	5	5	5	5	-	5	-	5	5	5	-	5
Notonectidae	-	5	5	5	-	-	5	5	5	-	-	-	5	-	5	-	5	5	5	-
Mesoveliidae	-	5	5	5	-	5	5	-	-	5	5	5	5	5	-	-	-	5	5	-
Odonata																				
Libellulidae	6	6	6	6	6	-	-	6	6	6	6	6	6	6	6	6	-	-	6	-
Coenagrionidae	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Coleoptera																				
Dytiscidae	5	5	-	5	5	5	-	5	5	5	5	5	5	-	-	-	5	5	5	5
Hydrophilidae	-	-	-	5	5	5	5	-	5	-	-	5	-	5	5	5	5	-	5	5
Total BMWP score	37	42	37	42	32	36	36	37	42	37	42	37	42	42	37	37	41	46	47	41
Interpretation	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
ASPT score	3.36	3.81	3.36	3.81	2.90	3.27	3.27	3.36	3.81	3.36	3.81	3.36	3.81	3.81	3.36	3.36	3.72	4.18	4.27	3.72
Interpretation	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PM	PM	PS

pre-monsoon season and at S2, S4 in the monsoon season which shows PM (Probable Moderate Pollution) class water quality (Table 4).

During 2014-15, minimum BMWP^{THAI} score was recorded as 32 at S5 in post-monsoon season which shows M (Moderate) class water quality and maximum BMWP score was recorded as 47 at S4 in monsoon season which shows M (Moderate) class water quality. The minimum ASPT score was recorded in the post-monsoon season at S5 with the score value 2.9 which shows PS (Probable Severe Pollution) class water quality and maximum ASPT score was recorded as 4.27 at S4 in monsoon season which shows PM (Probable Moderate Pollution) class water quality (Table 5).

During 2015-16, minimum BMWP^{THAI} score was recorded as 36 at S5 in the post-monsoon season which shows M (Moderate) class water quality, and maximum BMWP^{THAI} score value was recorded as 47 at S1 in the monsoon season which shows M (Mod-

erate) class water quality: while the minimum ASPT score was recorded as 3.27 at S5 in post-monsoon season which shows PS (Probable Severe Pollution) class water quality and maximum ASPT score was recorded as 4.27 at S1 in the monsoon season which shows PM (Probable Moderate Pollution) class water quality (Table 6).

During 2013-14, in the post-monsoon, mean FBI value of all the stations were recorded as 5.60 ± 0.55 which shows "Fair" (F) water quality, in winter, mean FBI value was recorded as 5.52 ± 0.58 which became "Fair" (F) class water quality, in pre-monsoon, water quality was "Fair" (F) with mean FBI value 5.67 ± 0.22, in the monsoon season, mean FBI value of all the stations were recorded as 5.36 ± 0.38 which shows "Fair" (F) water quality. During this year, maximum annual mean FBI value was recorded at S1 with 5.72 ± 0.50 which shows "Fair" (F) water quality and degree of organic pollution was "Fairly substantial pollution likely", at S2 the annual mean FBI value was recorded as 5.60 ± 0.59 which shows "Fair" (F)

Table 6. Seasonal variation in BMWP^THAI and ASPT score at 5 stations of Etila *beel* (2015-16).

Orders/Families of Collected Insects	Post-Monsoon					Winter					Pre-Monsoon					Monsoon				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Hemiptera																				
Nepidae	5	-	5	-	5	5	5	5	5	-	5	-	-	5	5	5	5	5	5	5
Belostomatidae	5	5	-	5	5	5	5	5	-	-	5	5	5	-	-	5	5	-	-	5
Corixidae	5	5	5	-	5	-	-	5	5	5	-	5	5	-	5	5	-	5	5	-
Veliidae	5	-	-	5	-	5	5	-	-	-	5	-	-	5	5	5	5	5	5	5
Gerridae	5	5	5	-	-	5	-	5	5	5	5	5	-	5	5	5	5	5	5	5
Notonectidae	-	5	5	-	5	-	5	-	5	5	-	5	5	5	-	5	5	5	5	5
Mesoveliidae	5	-	-	5	-	5	5	-	-	5	-	5	5	5	-	-	5	5	5	5
Odonata																				
Libellulidae	6	6	6	6	-	6	6	6	6	6	6	6	6	-	6	6	-	-	-	-
Coenagrionidae	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Coleoptera																				
Dytiscidae	-	5	-	5	5	-	-	-	5	5	-	5	5	5	-	-	5	5	5	5
Hydrophilidae	-	5	5	5	5	5	-	5	5	5	5	-	-	5	5	5	5	-	5	5
Total BMWP score	42	42	37	37	36	42	37	37	42	42	37	42	37	41	37	47	46	41	46	46
Interpretation	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
ASPT score	3.81	3.81	3.36	3.36	3.27	3.81	3.36	3.36	3.81	3.81	3.36	3.81	3.36	3.72	3.36	4.27	4.18	3.72	4.18	4.18
Interpretation	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PM	PM	PS	PM	PM

class water quality and degree of organic pollution was "Fairly substantial pollution likely", at S3 and S5, minimum annual mean FBI value was recorded with 5.45 ± 0.35 and 5.45 ± 0.31 and both stations shows "Fair" (F) class water quality and degree of organic pollution were "Fairly substantial pollution likely", at S4, annual FBI value was recorded as 5.46 ± 0.57 which shows " Fair" (F) class water quality and indicate "Fairly substantial pollution likely". In this year, a greater number of pollution tolerant species were recorded in the wetland. Among which Coenagrionidae (tolerance value 8) were recorded in highest number, which ultimately contributed to the higher FBI values indicating the poor water quality status of the wetland. During 2014-15, in the post-monsoon season, mean FBI score of all the stations was recorded as 5.41 ± 0.26 which shows "Fair" (F) class water quality, in winter season, mean FBI score was recorded as 5.47 ± 0.44 which again shows "Fair" (F) class water quality, in the pre-monsoon season, mean FBI score was recorded as 5.52 ± 0.29 which indicate "Fair" (F) class water quality, and during monsoon season, it was recorded as 5.43

± 0.33 which shows the same "Fair" (F) class water quality. During this year, the annual mean FBI score of different stations were also evaluated. At S1, annual mean FBI score was recorded as 5.42 ± 0.39 which shows " Fair" (F) class water quality and degree of organic pollution was recorded as "Fairly substantial pollution likely", at S2, annual mean FBI score value was recorded as 5.48 ± 0.33 which shows " Fair" (F) class water quality and indicates pollution level "Fairly substantial pollution likely", at S3, it was recorded as 5.46 ± 0.17 which shows again "Fair" (F) class water quality and pollution level "Fairly substantial pollution likely", at S4, minimum annual mean FBI score was recorded with a value 5.37 ± 0.40 which shows "Fair" (F) class water quality and pollution level "Fairly substantial pollution likely", at S5 maximum annual mean FBI score was recorded with 5.55 ± 0.38 which shows again the "Fair" (F) class water quality and pollution level "Fairly substantial pollution likely". During 2015-16, in the post-monsoon, mean FBI score of all the stations was recorded as 5.26 ± 0.24 which shows "Fair" (F) class water quality, in winter season, mean FBI score was

Table 7. Seasonal and annual mean variations of FBI values and water qualities of Etila beel (2013-2016).

| Years | Stations | Seasonal FBI values and Water Quality | | | | | | | | Annual Mean FBI and Water Quality | | |
| | | Post-Monsoon | | Winter | | Pre-Monsoon | | Monsoon | | | | |
		FBI	WQ	FBI	WQ	FBI	WQ	FBI	WQ	FBI	WQ	Degree of Organic Pollution
	S1	5.00	G	6.09	FP	6.03	FP	5.76	FP	5.72 ± 0.50	F	Fairly substantial pollution likely
	S2	6.36	FP	5.30	F	5.76	FP	5.00	G	5.60 ± 0.59	F	Fairly substantial pollution likely
2013-14	S3	5.86	FP	5.00	G	5.51	F	5.46	F	5.45 ± 0.35	F	Fairly substantial pollution likely
	S4	5.14	F	6.21	FP	5.60	F	4.91	G	5.46 ± 0.57	F	Fairly substantial pollution likely
	S5	5.66	F	5.00	G	5.47	F	5.68	F	5.45 ± 0.31	F	Fairly substantial pollution likely
Mean FBI		**FBI 5.60 ± 0.55**		**5.52 ± 0.58**		**5.67 ± 0.22**		**5.36 ± 0.38**				
	S1	5.30	F	6.02	FP	5.21	F	5.18	F	5.42 ± 0.39	F	Fairly substantial pollution likely
	S2	5.04	F	5.84	FP	5.55	F	5.52	F	5.48 ± 0.33	F	Fairly substantial pollution likely
2014-15	S3	5.66	F	5.37	FP	5.27	F	5.56	F	5.46 ± 0.17	F	Fairly substantial pollution likely
	S4	5.42	F	5.13	FP	5.93	FP	5.02	F	5.37 ± 0.40	F	Fairly substantial pollution likely
	S5	5.66	F	5.00	G	5.67	F	5.88	FP	5.55 ± 0.38	F	Fairly substantial pollution likely
Mean FBI		**5.41 ± 0.26**		**5.47 ± 0.44**		**5.52 ± 0.29**		**5.43 ± 0.33**				
	S1	5.51	F	5.41	F	5.20	F	5.08	F	5.30 ± 0.19	F	Fairly substantial pollution likely
	S2	5.05	F	5.06	F	5.14	F	5.70	F	5.23 ± 0.31	F	Fairly substantial pollution likely
2015-16	S3	5.00	G	5.13	F	5.04	F	4.78	G	4.98 ± 0.14	G	Some organic pollution probable
	S4	5.25	F	5.06	F	5.76	FP	5.56	F	5.40 ± 0.31	F	Fairly substantial pollution likely
	S5	5.51	F	5.27	F	5.29	F	5.63	F	5.42 ± 0.17	F	Fairly substantial pollution likely
Mean FBI		**5.26 ± 0.24**		**5.18 ± 0.15**		**5.28 ± 0.28**		**5.35 ± 0.40**				

Note: FBI ranges are 0.00 - 3.75 = Excellent (E), 3.76 - 4.25 = Very good (VG), 4.26 - 5.00 = Good (G), 5.01 - 5.75 = Fair (F), 5.76 - 6.50 = Fairly poor (FP), 6.51 - 7.25 = Poor (P), 7.26 - 10.00 = Very poor (VP).

recorded as 5.18 ± 0.15 which again shows "Fair" (F) class water quality, in the pre-monsoon season, mean FBI score was recorded as 5.28 ± 0.28 which indicate "Fair" (F) class water quality, in the monsoon season, it was recorded as 5.35 ± 0.40 which shows the "Fair" (F) class water quality. During this year, the annual mean FBI score of different stations were

also evaluated. At the S1, annual mean FBI score was recorded as 5.3 ± 0.19 which shows "Fair" (F) class water quality and degree of organic pollution was evaluated as "Fairly substantial pollution likely", at S2, annual mean FBI score value was recorded as 5.23 ± 0.31 which shows "Fair" (F) class water quality and indicates the pollution level "Fairly substantial

pollution likely", at S3, the minimum annual mean FBI score was recorded with 4.98 ± 0.14 which shows "Good" (G) class water quality and pollution level was evaluated as "Some organic pollution probable", at S4, annual mean FBI score was recorded as 5.40 ± 0.31 which shows "Fair" (F) class water quality and pollution level "Fairly substantial pollution likely", at S5 maximum annual mean FBI score was recorded with 5.42 ± 0.17 which shows again the "Fair" (F) class water quality and pollution level "Fairly substantial pollution likely" (Table 7).

In Etila *beel*, the tolerance value based on the BMWP[THAI] score (Mustow 2002) of all the 11 families ranged from 5 to 6. The overall BMWP score in Etila *beel* was ranged between 32 and 47. The overall BMWP[THAI] score of all the sites in Etila *beel* revealed moderate (M) water quality condition of this wetland. But, the ASPT score, ranged from 2.9 to 4.27, revealed poor water quality condition of this wetland. Mean seasonal FBI values found much higher (5.18 ± 0.15 to 5.67 ± 0.22) and accordingly tagged as Fair/ Fairly Poor and only at two stations, water quality was found as "Good". Hence, as per the FBI score, the water quality was polluted in Etila *beel*. FBI is different from BMWP[THAI] and ASPT score because in FBI, lower the score cleaner is the system. In Etila *beel,* mean seasonal FBI values were found very high (5.18 ± 0.15 to 5.67 ± 0.22) and accordingly tagged as Fair/ Fairly Poor and only at two stations, water quality was found as "Good". Hence, as per the FBI score, the water quality was polluted in Etila *beel.*

CONCLUSION

From the studies, It may be concluded that the higher FBI values, lower BMWP[THAI] score, lower ASPT score in the sampling stations of effluent receiving wetland Etila *beel* had the lower species diversity indices, and these indices can be used as measuring tools for evaluating the ecosystem health status of any aquatic ecosystem suffering from environmental pollution. The harmful pollutants of the nearby paper industry, which were directly discharged in the wetland, adversely impacted the entire beel ecosystem. However, it needs to be mentioned that, the aforesaid paper mill is in a non-functional state since March 2017, it is hoped that the water condition of Etila *beel* has improved since then.

REFERENCES

Barbour MT, Gerritsen J, Snyder BD, Stribling JB (1999) Rapid Bioassessment Protocols for Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish, (2nd edition). US. Environmental Protection Agency, Office of Water; Washington, DC.

Barman B, Gupta S (2015) Aquatic insects as bio-indicator of water quality- A study on Bakuamari stream, Chakrashila Wildlife Sanctuary, Assam, North East India. *Journal of Entomology and Zoology Studies* 3 (3): 178-186.

Chesters RK (1980) Biological Monitoring Exercise Party. The 1978 National Testing Exercise. Department of Environment, *Water Data Unit Technical Memorandum* 19: 1-37.

Choudhury D, Gupta S (2015) Aquatic insect community of Deepor beel (Ramsar site), Assam, India. *Journal of Entomology and Zoology Studies* 3 (1): 182-192.

Choudhury D, Gupta S (2017) Rapid Assessment on water quality of Deepor beel (Ramsar site), North East India using aquatic insects. *International Journal on Ecology and Environmental Sciences* 43(1): 35 – 46

El Alami M, Yaagoubi S, Gattolliat JL, Sartori M, Dakki M (2022) Diversity and Distribution of Mayflies from Morocco. *Ephemeroptera, Insecta* 14(6) : 498.

Hawkes HA (1998) Origin and development of the biological moni toring working party score system. *Water Research* 32 (3): 964-968.

Hilsenhoff WL (1988) Rapid field assessment of organic pollution with a family-level biotic. *Journal of the North American Benthological Society* 7(1): 65-68

Mandaville SM (2002) Benthic Macroinvertebrates in Freshwaters – Taxa Tolerance Values, Metrics, and Protocols. *Soil & Water Conservation Society of Metro Halifax* 18(1): 48-54

Mustow SE (2002) Biological monitoring of rivers in Thailand: use and adaptation of the BMWP score. *Hydrobiologia* 479: 191- 229.

Plafkin JL, Barbour MT, Porter KD, Gross SK, Hughes RM (1989) Rapid bioassessment protocols for use in Streams and Rivers: Benthic macroinvertebrate and Fish. U.S. Environmental Protection Agency Office of Water, Washington D.C.

Saha, A. Gupta S (2015) Aquatic and semi-aquatic Hemiptera of three oxbow lakes of Cachar District, Assam, N. E India and their role as bioindicator. *Journal of Entomology and Zoology Studies* 3 (3): 111-116.

Vian CV, Harun S, Hee KB, Hui AW.B, Fikri AH (2018) Aquatic Insects and Water Quality Study at Kimanis River, Crocker Range National Park, Saah, Malaysia. *Journal of Tropical Biology & Conservation (JTBC)*.15 : 223-245.