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Research Article

COMPARISON OF FRESHWATER ALGAE TYPES IN JUNE AND SEPTEMBER 2019 AT MAE RAM STREAM, MAE RIM DISTRICT, CHIANG MAI PROVINCE, THAILAND

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ABSTRACT. The distribution of freshwater algae in Mae Ram Stream in Mae Rim District, Chiang Mai Province, Thailand was investigated in June and October of 2019. Benthic diatoms and macroalgae were collected from nine sampling sites located along a stream in the upstream to downstream areas. The physical and chemical water properties at each sampling sites were analysed and classified for the trophic status. The results show that the water temperature ranged between 22.0-30.0 °C, Velocity 0.28-0.79 m/s, Turbidity 2.98-182.33 NTU, pH 7.01-8.02, Total Dissolved Solids 91.93-162.01 mg/l, Conductivity 131.33-249.35 µs/cm^{-1}, DO 4.88-8.02 mg/l, BOD_5 0.27-3.47 mg/l, Nitrate 0.29-1.29 mg/l, Ammonium 0.09-0.61 mg/l and Soluble reactive phosphorus 0.27-0.96 mg/l. The trophic status of the water at each sampling site was classified as the oligotrophic to mesotrophic. A total of 111 benthic diatoms were found. The most abundant species were *Eolimna minima*, *Nitzschia* sp.1, *Achnanthes pusilla*, *Gomphonema lagenula* and *Nitzschia palea*, respectively. The highest species abundance was recorded for *Eolimna minima* which was found at all sampling sites, whereas *Nitzschia palea* was found as a majority group only at the downstream sampling sites. A total of 14 species of macroalgae were found and they were classified into four divisions, *Chlorophyta*, *Cyanophyta*, *Charophyta* and *Rhodophyta*. The most abundant group was *Chlorophyta* and the least abundant group was *Rhodophyta*. Furthermore, *Compsopogon* spp. (*Rhodophyta*) was found to be a common species at the downstream sites, whereas *Nitella* sp. and *Chara* sp. (*Charophyta*) were only found at the upstream sampling sites.

Keywords: *Benthic diatom, macroalgae, water quality.*

INTRODUCTION

Mae Rim District, Chiang Mai Province is located in an area comprising of mountains and valleys in Northern Thailand. In the greater watershed of this area and the surrounding areas are villages, intensive agriculture and famous ecotourism attractions such as the Mae Sa Waterfall, the Mae Sa Elephant Camp, the Tat Mok Waterfall, Doi Mon Jam and the Queen Sirikit Botanical Garden. Therefore, the watershed of this area has been affected by human inputs, such as anthropogenic nutrient-loading, which has been identified as one of the main drivers of biodiversity loss in recent decades. However, there have been a limited number of biodiversity studies conducted at this location and only a few have been published. The most recent studies have only focused on the terrestrial ecosystems with an emphasis on plants and birds [1, 2]. Studies on the aquatic ecosystem of this area have reported the presence of a number of animal parasites [3, 4]. In addition, the first and second reports addressing the aquatic ecosystem producers were published in the years 2000 and 2006. Several of these studies were conducted by Peerapornpisal et al. [5, 6], who studied the benthic diatoms and macroalgae at in Mae Sa Stream. In these studies, 69 species of benthic diatoms and 31 species of macroalgae were recorded as new to Thailand. Moreover, a high abundance of *Batrachospermum macrosporum* and *Batrachospermum vugum* were found at upstream sampling sites. Nevertheless, the downstream collection sampling sites reported a high abundance of *Sirodotia huillensis* and *Compsopogon coeruleus*, and the results indicated that the water quality plays a significant role in the distribution of the algae due to their small size and limited migration. Therefore, they respond quickly to stress and rapidly to environmental changes [7]. Moreover, reports on algae diversity have not been conducted in this area, especially in the Mae Ram Stream which runs parallel to the Mae Sa Stream and is less affected by human activities. Therefore, understanding and explaining how stream biological communities are affected by a variety of environmental factors and different stressors is of primary importance in stream ecology. Thus, the aim of our study was to determine the distribution of freshwater algae and some water quality parameters in the Mae Ram Stream. In addition, this researchwill be the first report on the water properties and diversity of benthic diatoms and macroalgae in the Mae Ram Stream. The results of this study could also contribute to a better understanding of the distribution of freshwater algae in less explored areas

MATERIALS AND METHODS

Samples were collected in June and October 2019, from 9 sampling sites located in the Mae Ram Basin in Tambon Mae Ram, Mae Rim District, Chiang Mai Province. The details of the topography in each sampling site is presented in Table 1 and Fig. 1.

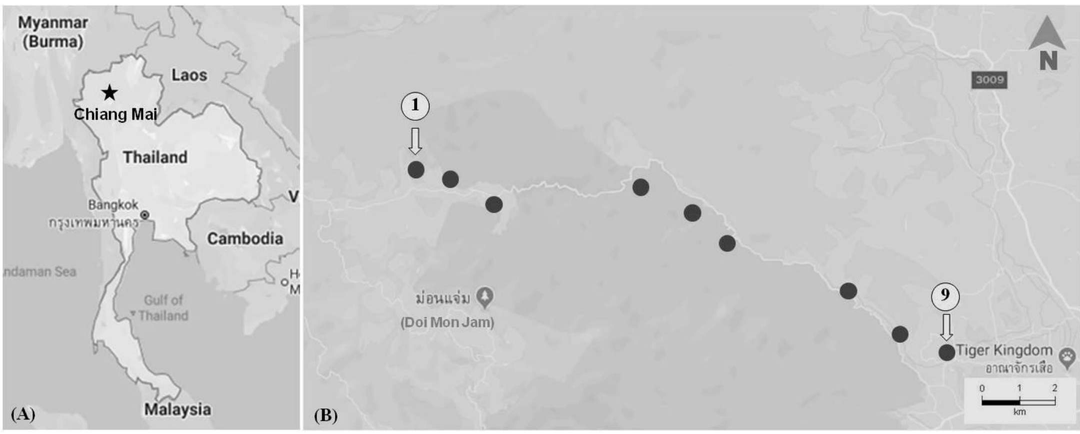

Fig.1 . *Map showing location of Chiang Mai Province and the 9 sampling sites in Mae Ram Basin.*

Table 1. *Sampling sites and their topography*

Sampling sites	GPS (Lat-Long)	Altitude (m)
1	18°57'40.7"N 98°48'30.2"E	883
2	18°57'28.2"N 98°48'57.4"E	866
3	18°57'26.3"N 98°49'17.5"E	838
4	18°57'31.9"N 98°51'2.5"E	551
5	18°57'22.4"N 98°51'42.3"E	484
6	18°57'06.8"N 98°52'03.3"E	467
7	18°56'26.9"N 98°53'22.1"E	354
8	18°55'56.3"N 98°54'00.9"E	346
9	18°55'45.8"N 98°54'41.9"E	335

Samples of freshwater algae including macroalgae and benthic diatoms were collected from difference microhabitats; stones or hard substrates such as bamboo stalks, aquatic plants and artificial substrates. The macroalgae samples were kept in a cool box (4-7 °C) and preserved with Glutaraldehyde 2%. Sampling coverage calculations were determined by using quadrates with a 1 m^2 and are shown according to the following scale: d = dominant (61-100%), f = frequent (41-60%), c = common (21-40%), r = rare (1-20%), to which were applied the method of Asmida et al. [8]. Benthic diatom samples were collected in 5 replicates at each sampling site, located throughout approximately a 10-meter stretch along the river. Specimens were brushed from the substrates with a toothbrush. A plastic sheet with a 10 cm^2 cutout was placed on the upper surface of the selected substrates. Benthic diatoms on the surface of the selected stones were brushed off and rinsed with distilled water until the cutout area was completely clear. Each sample was collected in a plastic bowl and transferred to a plastic container and then preserved with Lugol's solution. The benthic diatom samples were cleaned with concentrated acid according to the steps of the digestion method [9]. The samples were then mounted with Naphrax. Permanent slides were used in the counting and identifying processes. The relative abundance of each taxon was then indicated according to the following scale: d = dominant (50-20%), f = frequent (20-5%), c = common (5-1%), r = rare (>1%).

Freshwater algae were photographed using an Olympus Normaski microscope and were identified according to Krammer and Lange-Bertalot [10-13], Lange-Bertalot [14], Kumano [15], Taylor et al. [16], John et al. [17], Ahn [18] ,Peerapornpisal [19] and Wehr et al. [20]. In addition, the species diversity index (H’), evenness (E) and the species number of the benthic diatoms were determined and calculated following the Shannon Diversity Index [21].

Water samples were collected in 3 replicates from each site and kept in a cool box (4 °C). Measurements of some of the physico-chemical properties of the water were done at each sampling site such as the water temperature, velocity, pH, turbidity, total dissolved solids (TDS), conductivity and dissolved oxygen (DO). The values of BOD_5, ammonium nitrogen, nitrate nitrogen and soluble reactive phosphorus (SRP) were determined in the laboratory by the azide modification, the nesslerization, the cadmium reduction and the ascorbic acid methods, respectively [22]. The trophic status of the water quality was then evaluated from the main parameters such as conductivity, DO, BOD_5, ammonium-nitrogen, nitrate nitrogen and soluble reactive phosphorus according to Leelahakriengkrai and Peerapornpisal [24]

The differences in the physical and chemical water properties among sampling sites were tested by using the analysis of variance (ANOVA) and Least Significant Difference (LSD). To characterize the water quality in the Mae Ram stream, a cluster analysis was performed based on physical and chemical parameters by using PAST software.

RESULTS AND DISCUSSION

Freshwater algae diversity

A total of 111 specimens of benthic diatoms were identified in the Mae Ram Basin, and these were acknowledged as belonging to a common species found in rivers in Thailand such as the Ping River, the Tha Chin River, the Chi River, the Kwai River, the Chanthaburi River, the Tapee River, the Yom River, and the Wang River [25-27]. The most abundant species were *Eolimna minima* (31.0%), *Nitzschia* sp.1 (17.6%), *Achnanthes pusilla* (6.9%), *Gomphonema lagenula* (4.9%) and *Nitzschia palea* (4.3%). The dominant benthic diatoms and their degree of abundance are shown in Fig. 2 and Table 2. Eighty-eight and Eighty-three specimens of benthic diatoms were found in June and October, respectively.

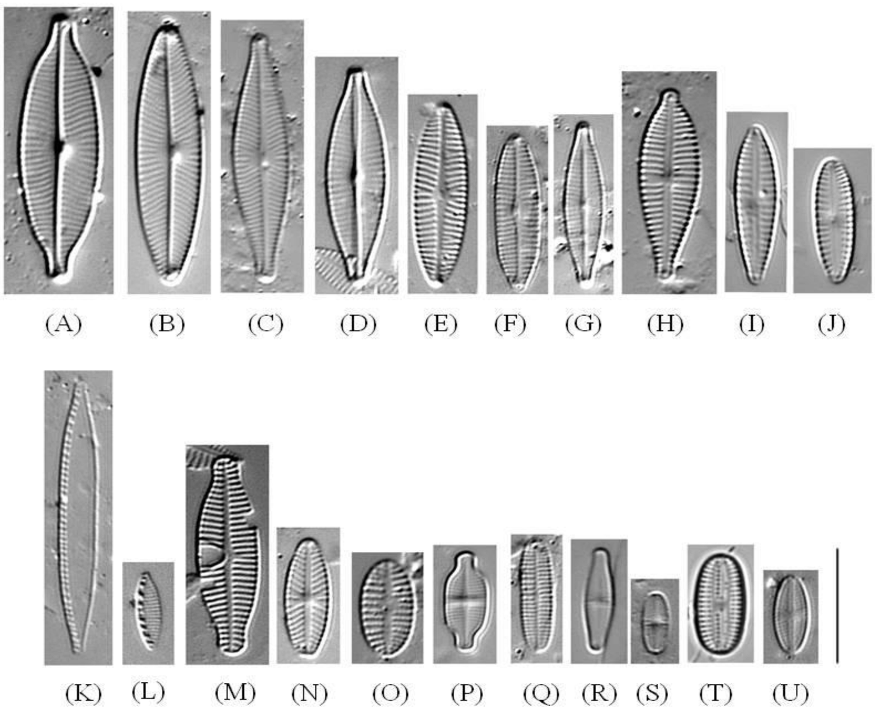

Fig. 2. *Light micrographs of dominant benthic diatoms in Mae Ram stream (A) Navicula rostellata, (B) Navicula symmetrica, (C) Navicula cryptocephala, (D) Navicula germainii, (E) Navicula cryptotenella, (F) Navicula erifuga, (G) Navicula sp.1, (H) Gomphonema lagenula, (I) Gomphonema parvulum, (J) Gomphonema minutum, (K) Nitzschia palea, (L) Nitzschia sp.1, (M) Planothidium rostratum, (N) Planothidium cf. distinctum, (O) Achnanthes oblongella, (P) Achnanthidium exiguum, (Q) Achnanthes pusilla, (R) Achnanthidium minutissimum, (S) Achnanthidium saprophilum, (T) Fallacia insociabilis, (U) Eolimna minima*

Table 2. *The relative abundance of dominant species and diversity index of benthic diatoms in Mae Ram Basin.*

	MR1		MR2		MR3		MR4		MR5		MR6		MR7		MR8		MR9	
Dominant species	J	O	J	O	J	O	J	O	J	O	J	O	J	O	J	O	J	O
Achnanthes oblongella	++	++	+++	+++	++	+++	-	-	-	-	-	+	+	++	++	+	+	-
A. pusilla	-	-	-	-	-	-	-	+++	+	++++	-	+	-	+	-	-	-	-
Achnanthidium exiguum	++	+	+++	++	+++	+	++	+	++	+	++	+	+++	+	++	+++	++	++
A. minutissimum	++	-	-	-	-	-	-	+	-	-	-	+	-	+++	-	+	-	+
A. saprophilum	+++	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eolimna minima	+	++++	+++	+++	++++	+++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	+++	+++
Fallacia insociabilis	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema lagenula	+++	+	+++	++	++	+	++	++	+++	-	++	+	++	+	+	-	++	+
G. minutum	-	-	-	-	-	-	-	-	+	-	-	-	+	+++	-	-	-	+
G. parvulum	+++	-	+++	-	+++	-	+	+	+	-	-	+	+	+	-	-	+	+
Navicula cryptocephala	++	-	++	-	++	-	-	-	+	-	++	+	+	++	++	++	++	+++
N. cryptotenella	+	+++	++	++	++	+++	++	+	+	-	++	++	+	+	++	++	++	++
N. erifuga	-	++	++	+	++	+++	-	-	+	-	-	+	-	++	+++	+++	+++	++
N. germainii	+	-	-	-	-	++	-	+	-	-	-	+	-	+	-	+	-	+++
N. rostellata	++	-	++	+	++	+	+	+	-	-	-	+	+	+	++	-	++	+
N. symmetrica	++	++	+++	+++	++	+++	+	-	+	-	-	++	-	+	++	+++	+++	+++
Navicula sp.1	+	+	++	+	+	+	+	-	-	++	+++	-	++	-	++	++	-	++
Nitzschia palea	-	+++	+++	+++	+++	+++	+++	+	+	+	+++	++	+	++	+++	+++	++++	++++
Nitzschia sp.1	+++	++	++	+++	++	++	+++	++++	++++	+++	+++	++++	+++	++++	+	++	++	++
Planothidium cf. *distinctum*	-	+	-	-	-	+	-	+	++	++	-	++	-	++	+	+	+++	+
P. rostratum	+	++	++	++	++	++	++	+	++	++	++	++	+++	+++	+++	++	++	+
Shannon Diversity Index	2.78	2.33	2.85	2.56	2.64	2.63	1.83	1.45	1.40	1.39	1.51	1.87	1.86	2.16	2.20	2.66	2.62	2.55
Evenness	0.40	0.25	0.48	0.39	0.39	0.46	0.22	0.16	0.18	0.22	0.32	0.15	0.20	0.29	0.38	0.51	0.57	0.46
Numbers of species	40	42	37	33	36	30	29	26	22	18	14	44	33	30	25	28	24	28

++++ = dominant (50-20%), +++ = frequent (20-5%), ++ = common (5-1%), + = rare (>1%), - = absent. J = June 2019, O = October 2019.

A total of fourteen species of macroalgae were collected from the Mae Ram Basin. Seven species were classified into Division *Chlorophyta* (Green algae), namely *Cladophora* sp., *Hydrodictyon* sp., *Microspora* sp., *Oedogonium* sp., *Rhizoclonium* sp., *Spirogyra* sp.1 and *Spirogyra* sp.2. Two species were classified into Division *Cyanophyta* (Blue green algae), namely *Nostochopsis* sp. and *Oscillatoria* sp. Two species were classified into Division *Charophyta*, namely *Chara* sp. and *Nitella* sp. Three species were classified into Division *Rhodophyta*, namely *Audouinella* sp., *Compsopogon* sp.1 and *Compsopogon* sp.2. The identified macroalgae specimens are presented in Figure 3 and Table 3.

Table 3. *The distribution and relative abundance of macroalgae in Mae Ram Basin.*

	MR1		MR2		MR3		MR4		MR5		MR6		MR7		MR8		MR9	
	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc	Ju	Oc
Nostochopsis sp.	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Oscillatoria sp.	+	+	-	+	+	-	+	-	-	+++	-	++	-	-	-	-	-	-
Cladophora sp.	-	+++	-	-	-	+	-	++	-	++	-	+	-	-	-	-	-	-
Hydrodictyon sp.	+	-	++	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Microspora sp.	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Oedogonium sp.	+	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhizoclonium sp.	+	++	-	-	-	++	-	-	+	++	+	+	-	-	-	-	-	-
Spirogyra sp.1	+++	+++	+	-	-	++	-	-	-	-	-	++	-	-	-	-	-	-
Spirogyra sp.2	+++	+++	-	-	+	-	+	++	++	++	+	-	-	-	-	-	-	-
Chara sp.	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitella sp.	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Audouinella sp.	-	+	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-
Compsopogon sp.1	-	-	-	++	-	++	+	++	-	++	-	-	++	-	+++	-	+++	-
Compsopogon sp.2	-	-	-	-	-	-	-	-	-	-	-	+++	-	++	-	+++	-	+++
Number of species	6	8	2	4	3	5	4	4	3	5	2	5	1	1	1	1	1	1

++++ = dominant (61-100%), +++ = frequent (41-60%), ++ = common (21-40%), + = rare (1-20%), - = absent (Percentage coverage per 1 m^2)

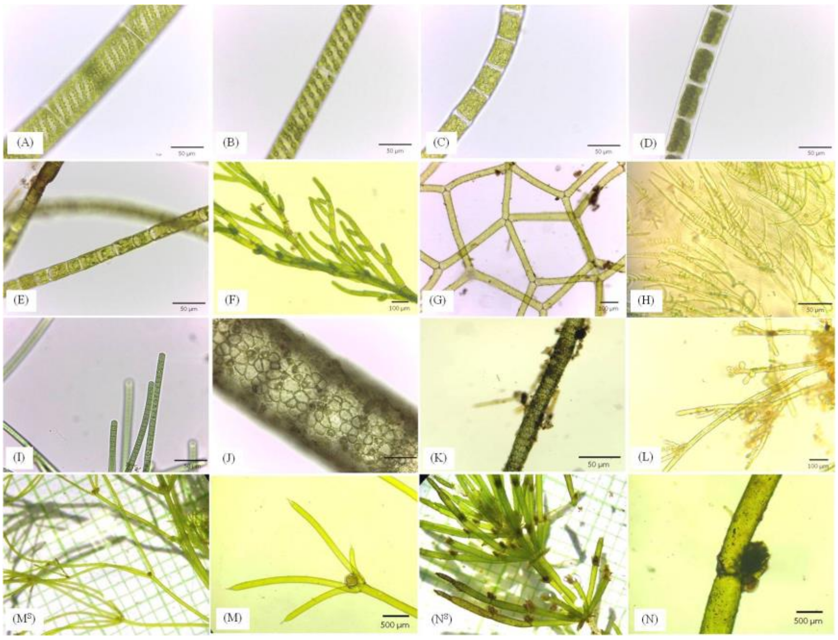

Fig. 3. *Light micrographs (X) and stereo micrographs (X^S) of macroalgae in Mae Ram stream.* **Chlorophyta:** (A) *Spirogyra* sp.1, (B) *Spirogyra* sp.2, (C) *Rhizoclonium* sp., (D) *Microspora* sp., (E) *Oedogonium* sp., (F) *Cladophora* sp., (G) *Hydrodictyon* sp.; **Cyanophyta:** (H) *Nostochopsis* sp., (I) *Oscillatoria* sp.; **Rhodophyta:** (J) *Compsopogon* sp.1, (K) *Compsopogon* sp.2, (L) *Audouinella* sp.; **Charophyta:** (M) *Nitella* sp., (N) *Chara* sp.

In this study, *Eolimna minima* was found to be in high abundance at all sampling sites. Accordingly, van Dam et al. [28] and Faustino et al. [29] reported that this species was commonly found at locations with mesotrophic to eutrophic conditions and could be indicative of the fact that they are a species that are capable of surviving in lenthic ecosystems. Thus, *Eolimna minima* was found to be present with a wide range of tolerance. However, *Nitzschia palea* was found to be present in high abundance at MR8 and MR9, which could be indicative of polluted conditions. The upstream sampling sites had oligotrophic to mesotrophic status represented by a high abundance of *Achnanthes oblongella*. According to Hirst et al. [30] and as per the Water Framework Directive [31], *Achnanthes oblongella* is a pollution sensitive species sensitive to metal pollution and highly enriched nutrients. Thus our finding suggests that the upstream site could be partially affected by metal contamination and nutrients. In the MR1 and MR2 in June, the water quality had a mesotrophic status, represented by a high abundance of *Gomphonema parvulum* but its absence or occurrence in low numbers in October. Salomoni et al. [32] reported that the *Gomphonema parvulum* species correlate strongly with a high level of nutrients. Therefore, the results indicated that the spatial-temporal variation and water quality were also important factors in explaining freshwater algae communities.

The macroalgae were presented in different taxonomic groups and were distributed throughout each of the sites. At the upstream sites, common species of Chlorophyta and Cyanophyta were found but a high abundance of *Compsopogon* spp. (Rhodophyta) was found at the downstream sites. Furthermore, Peerapornpisal et al. [6] reported that this genus was frequently found in sites of moderate to polluted water quality. Consequently, the distribution of benthic diatoms and macroalgae correlated with the water quality of each site. Notably, widespread species were found at upstream sites, while tolerant species were found at downstream sites. Moreover, only *Nitella* sp. and *Chara* sp. (Charophyta) were recorded at MR2 in October and were indicative of species that are commonly distributed in lentic bodies of water [33, 34]. In Thailand, few reports have been published on the species of algae that are present in running ecosystems, most of them were found in lentic ecosystems. Previous studies such as Silprasit et al. [35] found an abundance of *Nitella* sp. in paddy fields at Nakhon Nayok Province which are located in the central eastern part of Thailand and Sooksawat et al. [36] found *Chara aculeolata* in the Bueng Boraphet reservoir at Nakhon Sawan and *Nitella opaca* from freshwater ponds in Bangkok.

In this study, a comparison of freshwater algae in the Mae Ram and the Mae Sa Streams [5, 6] was done. There has been a report that *Nitzschia palea* and *Gomphonema parvulum* were found in high abundance in both streams, but *Eolimna minima* was only found in the Mae Ram Stream. Most macroalgae were reported as similar species, except for the group of freshwater red algae identified as *Batrachospermum* spp. that were found at the upstream sites of the Mae Sa Stream. These sites were associated with indications of good water quality, but this outcome was not presented in the conclusions of this investigation.

A comparison of benthic diatoms in the main rivers in Thailand such as the Ping River, the Yom River, the Wang River (Northern region), the Tha Chin River (Central region), the Chi River (Northeastern region), the Kwai River (Western region), the Chanthaburi River (Eastern region) and the Tapee River (Southern region) was done [25-27]. It was found that *Achnanthidium minutissimum, Gomphonema lagenula, Navicula rostellata* and *Nitzschia palea* are cosmopolitan freshwater pennate diatoms in Thailand. *Achnanthes oblongella* which were found in high abundance in oligo-mesotrophic status water quality in the Chanthaburi River and the Tapee River which supports our findings. A recent study [37] showed that *Eolimma minima* were present in the tributaries of the Ping River, which supports our findings that this species tends to be present in streams rather than rivers.

Shannon's diversity index and the evenness of benthic diatoms in the Mae Ram Stream are shown in Table 2. The diversity index of benthic diatoms ranged from 1.39-2.85 and the evenness ranged from 0.16-0.57. In MR2, where a total of 37 species were present, the highest diversity index of 2.85 (evenness 0.48) was recorded on June 2019 and MR5, where a total of 18 species were present, the lowest diversity index of 1.39 (evenness 0.22) was recorded on October 2019. The species richness of benthic diatoms ranged from 14-44 and macroalgae ranged from 1-8 with high numbers in the most upstream sites. Thus, the upstream site showed a higher value of diversity on the index and a higher number of species than other sites which could indicate a rich biodiversity as was observed in other the upstream areas.

Water quality

The physical and chemical factors and the trophic level for all 9 sites of the Mae Ram Stream are shown in Tables 4 and 5. The water quality of each site was found to be significantly different ($p<0.05$). The results of the cluster analysis of the water properties in the Mae Ram Stream were separated into 2 groups with 70% similarity (Fig. 4). Group 1 included the upstream sites (MR1 to MR6) for both sampling times, which revealed similarly low values of turbidity, TDS, conductivity, BOD and nutrients. Furthermore, Group 2 was comprised of samples collected from MR7 to MR9. The results revealed significant differences in the nutrient loading and water quality of each sampling site that were known to be due to the different activities occurring at the upstream and downstream locations.

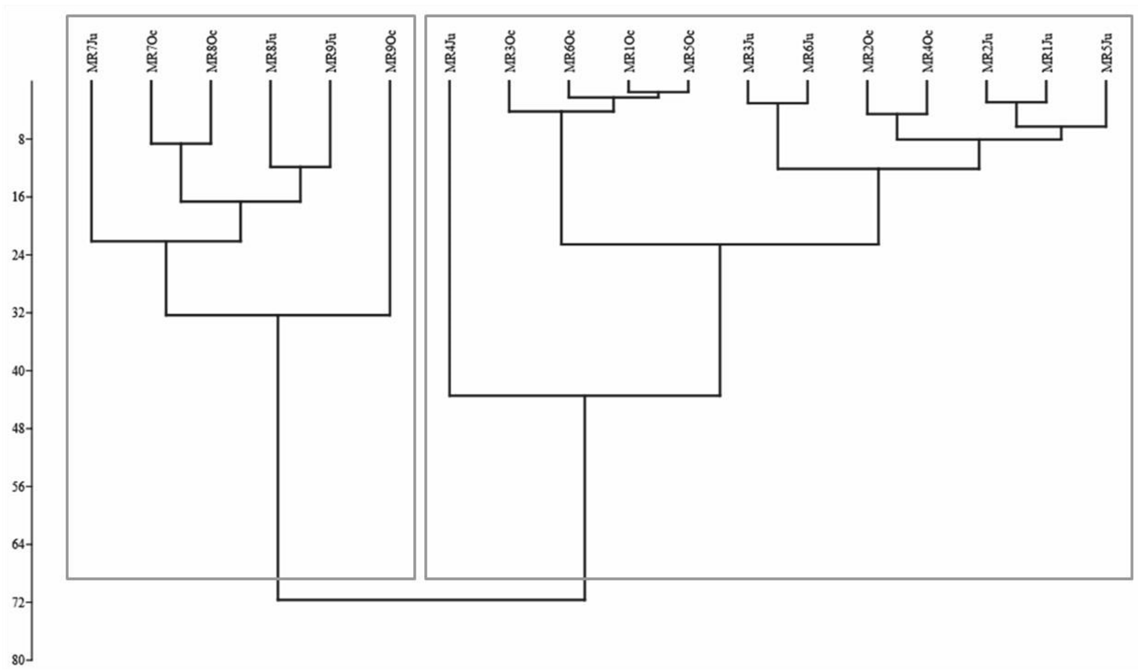

Fig. 4. *Cluster analysis of water properties grouping all sampling sites in Mae Ram Basin.*

Table 4. *Results of the physical and chemical factors of Mae Ram Basin (n=3).*

Sampling sites	Water Temperature (°C)	Velocity (m/s)	Turbidity (NTU)	pH	TDS (mg/l)
MR1Ju	23.3 ± 1.2^{ab}	0.28 ± 0.11^{ab}	11.56 ± 1.54^{bc}	8.02 ± 0.07^{i}	110.90 ± 0.88^{cd}
MR2Ju	24.0 ± 0.0^{b}	0.40 ± 0.21^{ab}	15.78 ± 2.46^{cd}	7.60 ± 0.04^{de}	108.56 ± 1.24^{c}
MR3Ju	24.7 ± 0.6^{bc}	0.28 ± 0.07^{a}	29.67 ± 1.15^{e}	7.79 ± 0.05^{f}	115.83 ± 0.89^{e}
MR4Ju	25.0 ± 0.0^{bc}	0.34 ± 0.08^{ab}	60.78 ± 2.91^{g}	7.97 ± 0.05^{i}	91.93 ± 1.05^{a}
MR5Ju	25.0 ± 0.0^{bc}	0.38 ± 0.14^{ab}	11.44 ± 1.84^{bc}	7.97 ± 0.02^{i}	112.41 ± 2.26^{d}
MR6Ju	26.0 ± 0.0^{cd}	0.34 ± 0.05^{ab}	13.89 ± 2.46^{bc}	8.29 ± 0.03^{j}	117.64 ± 1.30^{efg}
MR7Ju	28.7 ± 0.6^{fg}	0.79 ± 0.20^{b}	32.33 ± 1.00^{e}	7.83 ± 0.01^{fg}	143.56 ± 0.19^{hi}
MR8Ju	30.0 ± 1.0^{g}	0.32 ± 0.08^{ab}	41.89 ± 3.10^{f}	7.93 ± 0.02^{gh}	155.11 ± 0.19^{j}
MR9Ju	29.0 ± 1.7^{fg}	0.44 ± 0.13^{ab}	182.33 ± 6.36^{h}	7.90 ± 0.01^{fgh}	160.89 ± 2.22^{k}
MR1Oc	22.0 ± 0.0^{a}	0.24 ± 0.20^{ab}	3.50 ± 0.60^{a}	7.58 ± 0.03^{cde}	119.36 ± 1.67^{fg}
MR2Oc	23.6 ± 0.2^{b}	0.37 ± 0.20^{ab}	2.80 ± 0.58^{a}	7.01 ± 0.08^{a}	103.17 ± 1.14^{b}
MR3Oc	24.2 ± 0.1^{b}	0.48 ± 0.13^{ab}	2.98 ± 0.47^{a}	7.35 ± 0.05^{b}	116.74 ± 0.35^{ef}
MR4Oc	24.5 ± 0.3^{bc}	0.37 ± 0.13^{ab}	21.45 ± 1.87^{d}	7.82 ± 0.06^{fg}	105.17 ± 1.17^{b}
MR5Oc	26.8 ± 0.2^{de}	0.45 ± 0.19^{ab}	8.10 ± 3.00^{ab}	7.30 ± 0.04^{b}	120.21 ± 0.67^{g}
MR6Oc	27.6 ± 0.3^{ef}	0.31 ± 0.04^{ab}	2.90 ± 0.84^{a}	7.97 ± 0.03^{i}	118.22 ± 1.22^{efg}
MR7Oc	28.8 ± 0.1^{fg}	0.35 ± 0.09^{ab}	17.29 ± 2.55^{cd}	7.66 ± 0.05^{e}	141.32 ± 0.49^{h}
MR8Oc	28.4 ± 0.1^{f}	0.57 ± 0.16^{ab}	12.10 ± 3.16^{bc}	7.47 ± 0.03^{c}	145.93 ± 1.06^{i}
MR9Oc	28.0 ± 0.1^{ef}	0.40 ± 0.04^{ab}	34.48 ± 4.67^{e}	7.51 ± 0.04^{cd}	162.01 ± 0.38^{k}

Notes: Values expressing the Mean±SD followed by similar letters in a column do not differ significantly at $p<0.05$

Table 5. *Results of the chemical factors and trophic level of Mae Ram Basin (n=3).*

Sampling sites	Conductivity ($\mu s/cm^{-1}$)	DO (mg/l)	BOD_5 (mg/l)	NO_3 (mg/l)	NH_4^+ (mg/l)	SRP (mg/l)	Trophic level
MR1Ju	157.56 ± 1.20^{bc}	5.15 ± 0.43^{abc}	1.93 ± 0.90^{abcd}	0.94 ± 0.19^{e}	0.13 ± 0.02^{ab}	0.41 ± 0.11^{abcd}	mesotrophic
MR2Ju	155.98 ± 0.33^{b}	4.88 ± 0.33^{a}	2.33 ± 0.42^{bcd}	0.71 ± 0.05^{bcde}	0.09 ± 0.01^{a}	0.33 ± 0.08^{ab}	mesotrophic
MR3Ju	165.82 ± 1.21^{de}	4.99 ± 0.14^{ab}	1.60 ± 0.40^{abc}	0.52 ± 0.17^{abcd}	0.15 ± 0.02^{ab}	0.44 ± 0.10^{abcd}	mesotrophic
MR4Ju	131.33 ± 1.33^{a}	5.50 ± 0.12^{c}	1.60 ± 1.00^{abc}	1.29 ± 0.24^{f}	0.31 ± 0.05^{bcd}	$0.47+0.06^{abcd}$	mesotrophic
MR5Ju	162.17 ± 0.88^{cd}	5.31 ± 0.08^{bc}	3.47 ± 1.33^{d}	0.76 ± 0.19^{cde}	0.21 ± 0.04^{ab}	0.96 ± 0.05^{e}	mesotrophic
MR6Ju	168.01 ± 0.83^{e}	5.51 ± 0.09^{c}	2.13 ± 0.58^{bcd}	0.32 ± 0.13^{ab}	0.50 ± 0.11^{e}	0.93 ± 0.04^{e}	mesotrophic
MR7Ju	204.24 ± 2.76^{g}	5.26 ± 0.07^{abc}	2.13 ± 0.76^{bcd}	0.29 ± 0.05^{a}	0.28 ± 0.05^{abc}	0.59 ± 0.07^{cd}	mesotrophic
MR8Ju	222.11 ± 1.64^{i}	4.94 ± 0.02^{ab}	3.27 ± 0.12^{cd}	0.33 ± 0.03^{ab}	0.30 ± 0.14^{bc}	0.82 ± 0.10^{e}	mesotrophic
MR9Ju	232.44 ± 2.71^{j}	5.04 ± 0.05^{ab}	3.47 ± 1.01^{d}	0.45 ± 0.02^{abc}	0.61 ± 0.08^{e}	0.90 ± 0.05^{e}	mesotrophic
MR1Oc	183.63 ± 2.56^{f}	7.84 ± 0.07^{gh}	0.73 ± 0.12^{ab}	0.80 ± 0.20^{cde}	0.49 ± 0.04^{de}	0.56 ± 0.16^{bcd}	Oligo- mesotrophic
MR2Oc	158.72 ± 1.76^{bc}	7.08 ± 0.07^{de}	0.80 ± 0.40^{ab}	0.57 ± 0.15^{abcde}	0.30 ± 0.12^{bc}	0.35 ± 0.07^{abc}	Oligo- mesotrophic
MR3Oc	179.60 ± 0.54^{f}	7.64 ± 0.07^{fgh}	1.67 ± 0.12^{abc}	0.83 ± 0.06^{cde}	0.45 ± 0.09^{cde}	0.60 ± 0.03^{d}	mesotrophic
MR4Oc	161.79 ± 1.80^{cd}	8.02 ± 0.09^{h}	3.13 ± 0.12^{cd}	0.77 ± 0.15^{cde}	0.15 ± 0.02^{ab}	0.55 ± 0.08^{bcd}	mesotrophic
MR5Oc	182.55 ± 3.85^{f}	7.63 ± 0.06^{fgh}	0.27 ± 0.12^{a}	0.63 ± 0.15^{abcde}	0.46 ± 0.03^{cde}	0.36 ± 0.08^{abcd}	Oligo- mesotrophic
MR6Oc	181.87 ± 1.88^{f}	7.54 ± 0.07^{fg}	0.93 ± 0.12^{ab}	0.63 ± 0.15^{abcde}	0.28 ± 0.10^{abc}	0.27 ± 0.07^{a}	Oligo- mesotrophic
MR7Oc	217.41 ± 0.76^{h}	7.27 ± 0.05^{ef}	1.07 ± 0.12^{ab}	0.60 ± 0.10^{abcde}	0.24 ± 0.02^{ab}	0.60 ± 0.12^{d}	Oligo- mesotrophic
MR8Oc	224.54 ± 1.67^{i}	6.77 ± 0.12^{d}	2.47 ± 0.12^{bcd}	0.87 ± 0.15^{de}	0.22 ± 0.02^{ab}	0.58 ± 0.10^{bcd}	mesotrophic
MR9Oc	249.35 ± 1.96^{k}	6.96 ± 0.16^{de}	2.87 ± 0.70^{cd}	0.30 ± 0.00^{a}	0.22 ± 0.02^{ab}	0.95 ± 0.06^{e}	mesotrophic

Notes: Values expressing the Mean±SD followed by similar letters in a column do not differ significantly at $p<0.05$

In the upstream areas, the majority of human activities are agricultural such as onion, garlic and flower farms while in the downstream areas, there are many potential environmental impacts from human activities such as community areas, agricultural and livestock activities along the stream. For this reason, downstream sites are more contaminated than upstream sites. This pattern of upstream and downstream differences in water quality in relation to high human levels of disturbance within the stream was similar to the findings of a number of other previously published reports from other countries [38-39]. However, the trophic status in each sampling site of the Mae Ram stream is shown in Table 5 and was classified as mesotrophic, except at MR1, MR2, MR5, MR6 and MR7 in October, which was classified as oligo-mesotrophic. This finding clearly indicated that the nutrient level in October was lower than June. In a comparison of water quality between the Mae Ram Stream and the Mae Sa Stream, the Mae Ram Stream showed lower levels of BOD5, TDS, conductivity, SRP, ammonium nitrogen and nitrate nitrogen than the Mae Sa Stream. This outcome was attributed to the fact that the area of the Mae Ram Stream was less affected by human activities.

CONCLUSION

In this research, the diversity of freshwater algae was shown by the presence of common species indigenous to Thailand. *Eolimna minima* and *Nitzschia* sp. 1 were present as the first and second most dominant species at each sampling site. This outcome was indicative of a wide tolerance of all species. However, *Nitzschia palea* and *Compsopogon* spp. were found to be present in high abundance at the downstream sites, which indicated a change of water quality at those downstream sites. Moreover, *Nitella* sp. and *Chara* sp. were only found at the upstream sites. These are believed to be rarely present in the lotic ecosystems of Thailand. Some physical and chemical factors such as TDS, conductivity, BOD_5, and orthophosphate increased from upstream to downstream, whereas there were no great differences for the trophic level of water quality in June and October. In this study, we collected samples from a total of nine sampling sites that were located in both the upstream and downstream areas; however, the samples were collected in either June (the dry season) or October (the rainy season). Thus, in future research studies, we are preparing to collect samples during all seasons in order to determine a fully accurate relationship between freshwater algae and water quality.

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REFERENCES

[1] Nguanchoo, V., Srisanga, P., Swangpol, S., Prathanturarug, S., Jenjittikul, T. (2014): Food plants in Hmong cuisine in Northern Thailand. Thai Journal of Botany 6(2): 131-145.

[2] Siri, S., Ponpituk, Y., Safoowong, M., Marod, D., Duengkae, P. (2019): The natural forest gaps maintenance diversity of understory birds in Mae SaKog Ma Biosphere Reserve, northern Thailand. Biodiversitas 20(1): 181-189.

[3] Wongsawad, C., Rojanapaibul, A., Mhad-arehin, N., Pachanawan, A., Marayong, T., Suwattanacoupt, S., Rojtinnakorn, J., Wongsawad, P., Kumchoo, K., Nichapu, A. (2000): Metacercaria from freshwater fishes of Mae Sa stream, Chiang Mai, Thailand. The Southeast Asian Journal of Tropical Medicine and Public Health 31: 54-57.

[4] Wongsawad, C., Rojtinnakorn, J., Wongsawad, P., Rojanapaibul, A., Marayong, T., Suwattanacoupt, S., Sirikanchana, P., Sey, O., Jadhav, B.V (2004): Helminths ofvertebrates in Mae Sa Stream, Chiang Mai, Thailand. The Southeast Asian Journal of Tropical Medicine and Public Health 35: 140-146.

[5] Peerapornpisal, Y., Pekthong, T., Waiyaka, P., Promkutkaew, S. (2000): Diversity of phytoplankton and benthic algae in Mae Sa stream, Doi Suthep-Pui National Park, Chiang Mai. The Journal of the Siam Society 48: 193-211.

[6] Peerapornpisal, Y., Nualcharoen, M., Suphan, S., Kunpradid, T., Inthasotti, T., Mungmai, R., Dhitisudh, L., Sukchotiratanaa, M., Kumano, S. (2006): Diversity and habitat characteristics of freshwater red algae (Rhodophytes) in some water resources of Thailand. ScienceAsia 32: 63-70.

[7] Bellinger, E.G., Sigee, D.C. (2015): Freshwater Algae: Identification, Enumeration and Use as Bioindicators. John Wiley & Sons, Oxford.

[8] Asmida, I., Siti, K.M.H., Norashirene, M.J., Dzulsuhaimi, D., Ahmad, I. (2015): Utilising quadrat method for biodiversity study of seaweeds in Blue Lagoon, Port Dickson, Malaysia. Proceeding of International Symposium on Fundamental and Applied Sciences, Osaka, 5-7 March 2015.

[9] Taylor, J.C., Harding, W.R. Archibald, C.G.M. (2007): A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission, Pretoria.

[10] Krammer, K., Lange–Bertalot, H. (1986): Bacillariophyceae.1. Teil: Naviculaceae. In: Ettl H, Gerloff J, Heynig H, Mollenhauer D (eds.), Süsswasserflora von Mitteleuropa. Band 2/1. Gustav Fisher Verlag, Stuttgart.

[11] Krammer, K., Lange–Bertalot, H. (1988): Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae and Surirellaceae. In: Ettl H, Gerloff J, Heynig H, Mollenhauer D (eds.), Süsswasserflora von Mitteleuropa. Band 2/2. Gustav Fisher Verlag, Stuttgart.

[12] Krammer, K., Lange–Bertalot, H. (1991a): Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae and Eunotiaceae. In: Ettl H, Gerloff J, Heynig H, Mollenhauer D (eds.), Süsswasserflora von Mitteleuropa.Band 2/3. Gustav Fisher Verlag, Stuttgart.

[13] Krammer, K., Lange–Bertalot, H. (1991b): Bacillariophyceae 4Teil: Achnanthaceae. In: Ettl H, Gerloff J, Heynig H, Mollenhauer D (eds.), Süsswasserflora von Mitteleuropa. Band 2/4. Gustav Fisher Verlag, Stuttgart.

[14] Guiry, M.D., Guiry, G.M. (2020): AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org

[15] Kumano, S. (2002): Freshwater Red Algae of the World. Biopress Limited, Bristol.

[16] Taylor, J.C., Harding, W.R., Archibald, C.G.M. (2007): An Illustrated Guide to Some Common Diatom Species from South Africa. Water Research Commission, Pretoria.

[17] John, D.M., Whitton, B.A., Brook, A.J. (2002): The Freshwater Algal Flora of the British Isles: an Identification Guide to Freshwater and Terrestrial Algae. Cambridge University Press, Cambridge.

[18] Ahn, Y. (2012): Algal Flora of Korea: Chrysophyta: Bacillariophyceae: Pennales: Raphidineae: Achnanthaceae. National Institute of Biological Resources, Incheon.

[19] Peerapornpisal, Y. (2013): Freshwater algae in Thailand. Chiang Mai University, Chiang Mai.

[20] Wehr, J.D., Sheath, R.G., Kociolek, J.P. (2015): Freshwater Algae of North America, 2nd eds. Elsevier Inc, San Diego.

[21] Odum, E.P., Barrett, G.W. (2004): Fundamental of Ecology, 5nd eds., W.B. Saunders, Philadelphia.
[22] Eaton, A.D., Clesceri, L.S., Rice, E.W., Greenberg, A.E., Franson, M.A.H. (2005): Standard Methods for the Examination of Water and Wastewater, 21st eds, American Public Health Association (APHA), Washington DC.
[23] Hammer, Ø., Harper, D.A.T., Ryan, P.D. (2001): PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 1-9.
[24] Leelahakriengkrai, P., Peerapornpisal, Y. (2011): Water quality and trophic status in main rivers of Thailand. Chiang Mai Journal of Science 38(2): 280-294.
[25] Leelahakriengkrai, P., Peerapornpisal, Y. (2011): Diversity of benthic diatoms in six main rivers of Thailand. International Journal of Agriculture and Biology 13: 309–316.
[26] Yana, E., Peerapornpisal, Y., Mayama, S. (2013): Diversity of benthic diatoms and correlation with water quality of Yom River, Thailand. International Journal of Applied Environmental Sciences 8(15): 1935-1948.
[27] Nakkaew, S., Pekkoh, J., Peerapornpisal, Y. (2015): Diversity of benthic diatoms and relationship with some aspect of water properties in the Wang River, Thailand. International Journal of Applied Environmental Sciences 10(1):265-280.
[28] Van Dam, H., Mertens, A., Sinkledam, J. (1994): A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1):117-133.
[29] Faustino, S.B., Fontana, L., Bartozek, E.C.R., Bicudo, C.E.M., Bicudo, D.C. (2016): Composition and distribution of diatom assemblages from core and surface sediments of a water supply reservoir in Southeastern Brazil. Biota Neotropica 16 (2): e20150129.
[30] Hirst, H., Juttner, I., Ormerod, S.J. (2002): Comparing the responses of diatoms and macroinvertebrates to metals in upland streams of Wales and Cornwall. Freshwater Biology 47: 1752–1765.
[31] Water Framework Directive (2014): Phytobenthos-Diatoms for Assessing River and Lake Ecological Quality (River DARLEQ2). Water Framework Directive-United Kingdom Advisory Group, Stirling.
[32] Salomoni, S.E., Rocha, O., Torgan, L.C. (2017): Seasonal and spatial variation of the epilithic diatoms: case study of an organic pollution gradient in a subtropical region of southern Brazil. Acta Limnologica Brasiliensia 29: 1-11.
[33] Bueno, N.C., Prado, J.F., Meurer, T., Bicudo, C.E.M. (2011): New records of Chara (Chlorophyta, Characeae) for subtropical Southern Brazil. Systematic Botany 36:523-541.
[34] Meurer, T., Bueno, N.C. (2012): The genera *Chara* and *Nitella* (Chlorophyta, Characeae) in the subtropical Itaipu Reservoir, Brazil. Brazilian Journal of Botany 35(2): 219-232.
[35] Silprasit, K., Ngamniyom, A., Kerksakul, P., Thumajitsakul, S. (2016): Using morphology and genomic template stability (GTS) to track herbicide effect on some submersed aquatic plants. Applied Environmental Research 38(1): 75-85.
[36] Sooksawat, N., Meetam, M., Kruatrachue, M., Pokethitiyook, P., Inthorn, D. (2016): Equilibrium and kinetic studies on biosorption potential of charophyte biomass to remove heavy metals from synthetic metal solution and municipal wastewater. Bioremediation Journal 20(3): 240-251.
[37] Kunpradid, T., Peerapornpisal, Y., Leelahakriengkrai, P. (2016): Biodiversity of benthic diatoms and aquatic insects at Mae tuen stream passing Omkoi District Chiang Mai Province, Thailand. Ecology, Environment and Conservation 22 (4):1601-1608.
[38] Adiyiah, J., Aboagye-Larbi, H., Acheampong, M.A. (2013): Comparative assessment of the upstream and downstream water qualities of River Tano in Ghana. Environmental Engineering Science 2:283–292.
[39] Altuna, M., Martí, E., Sabater, F., Díez, J.R., Riera, J.L., Izco, F., Elosegi, A. (2019): Incorporating in-stream nutrient uptake into river management: Gipuzkoa Rivers (Basque Country, North Spain) as a case study. Sustainability 11: 1-17.