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Aquatic Insects distribution pattern focused on water quality in Aghien lagoon (Côte d'Ivoire; West Africa)

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Abstract
This study was carried to know the ecological status of Aghien lagoon water's using aquatic Insects. Insects and physicochemical variables were sampled monthly from June 2014 to MAY 2015 at eleven sampling site. Samplings were performed by the kick sampling technique and Van Veen Grab methods. A total of 7230 individuals from 68 taxa belonging to 08 orders and 46 families were identified. Diptera order was best represented with 11 families. The analysis of diversity index indicated that study site are low diversified although some physicochemical parameters presented some signs of disturbance unfavorable to insect's community proliferation. EP/C index and Chironomidae percentage showed a predominance of Chironomidae over others families of Ephemeroptera, Plecoptera, Trichoptera (EPT) groups that are pollen-sensitive organisms. These results suggest that waters of Aghien lagoon are moderately polluted and should be subject to biomonitoring.

Keywords: Aquatic Insects, diversity, water quality, Aghien lagoon, Côte d'Ivoire

1. Introduction
The water availability has always been the priority all development programs. Water bodies was crustial in biodiversity conservation, organism functioning and organic cycles [1, 2]. However, the efficient use of waters, especially for drinking water, requires knowing his status by monitoring and evaluating it's ecological integrity. Therefore, their monitoring must be done through the evaluation of reliable and adequate indicators such as biological indicators [3, 4]. Thus, new generations of surface water quality monitoring systems have consisted in the establishment of biotic indices from aquatic organisms such as macroinvertebrates which are organisms whose size at the end of larval development is greater than millimeter [5]. Several studies on macroinvertebrates have shown their importance in the food chain and in aquatic environments. This class of organisms includes aquatic insect larvae, some adult aquatic Insects, Crustaceans, Molluscs and Worms [6]. The main orders of aquatic insects included in the macroinvertebrates are Ephemera, Plecoptera, Trichoptera, Diptera, Coleoptera, Megaloptera, Hemiptera, Odonata and Lepidoptera [7]. These methods, using living organisms, have the advantage of being easy to implement. These methods respond to factors that affect water quality in addition to the effects of natural environmental features and anthropogenic influences. In Côte d'Ivoire, data on the use of macroinvertebrates for the development of biological index are few. However, their use routinely in several countries [8, 9] makes it possible to transpose and adapt proven experimental protocols to other contexts, particularly the Ivorian context. However, the ecological integrity status of Aghien lagoon water's has not yet been evaluated to detect the possible presence of health risks. It's macrofaunic diversity also remains very little known. This study main to study the diversity of aquatic insects and to estimate the water quality of the Aghien lagoon.

2. Material and Methods
2.1. Study site
The Aghien Lagoon is located in the South-eastern of Côte d'Ivoire between latitudes 5°22'N and 5°26'N and longitudes 3°49'W and 3°55'W (Figure 1). This lagoon is located to the north of the Ebrié Lagoon from which it is separated by the Potou Lagoon. The Aghien and Potou Lagoons communicate through a natural channel [10]. The Aghien Lagoon could reach 11 m deep [11]. This lagoon covers an area of 20 km² for a perimeter of 40.72 Km. It is supplied by two main tributaries, Djibi and Bété Rivers, and is almost exclusively continental all year long [12]. This gives to the hydrosystem a fluvial character [13]. Aghien Lagoon is subject to an equatorial climate characterized by four seasons [14].

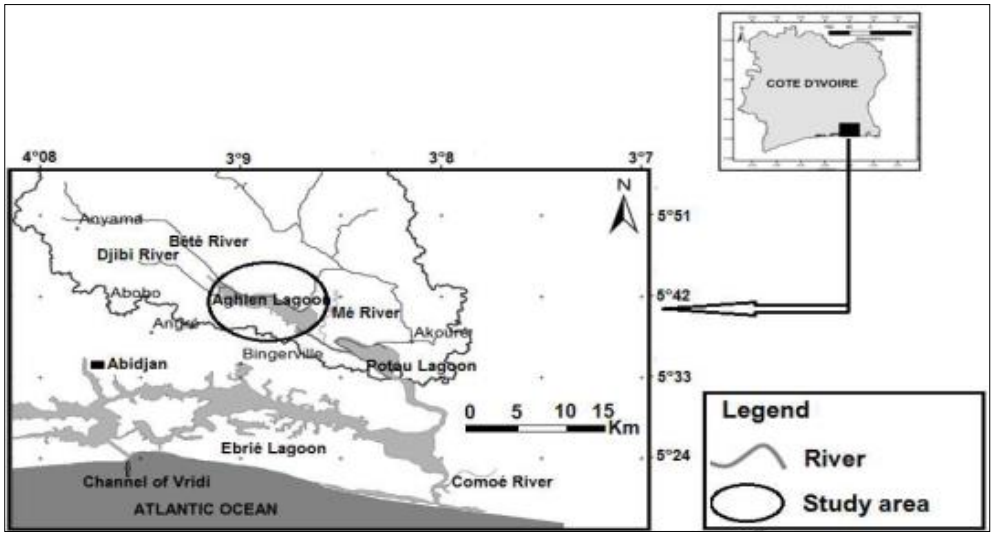

Fig 1: Location of the Aghien Lagoon in the South-Eastern of Côte d'Ivoire.

2.2 Sampling procedure

Sampling sites were selected to cover a fair degree of habitat heterogeneity in Aghien Lagoon. Studies stations are located along the main axis of the lagoon with two transects perpendicular to the longitudinal transect (Figure 2). The first transect is located opposite the of Akandjé city in order to determine if the water quality varies according to the distance to shore. The second transect is located in the western area of the lagoon. Macroinvertebrates sampling was carried out for twelve months at monthly intervals between June 2014 and May 2015. Benthic fauna were sampled in each of the eleven stations defined on Aghien lagoon following a longitudinal rampe with a kick net (250 microns mesh size) following SASS method (South African Scoring System) [15]. The samples were collected for two to three minutes by submerging the kick net and dragging it into the water column. The net has also been banged against the bottom substrate to dislodge and collect sediment organisms. The collect was also done using a Van Veen grab. At each site, three (03) sediment samples corresponding to a total area of 0.15 m^2 were taken at several depths. At the exit of water, the contents net were washed on a sieve of 0.5 mm. All samples were fixed in 70% alcohol. In the laboratory, all samples were sorted using a binocular microscope, counted and identified at the lowest taxonomic level by combining the appropriate key [16]. At each campaign, each sampling site was characterized by measuring water temperature (°C), turbidity (NTU), pH, conductivity (µS/cm), and dissolved oxygen (mg/l) with portable sensors. Water were taken from each sample site (station), stored in polyethylene bottles (500 ml) and kept at a temperature below 4°C to stop all the activities and metabolism of the organisms in the water. At the laboratory, these water samples were kept in a refrigerator for further determination of phosphorus, Phosphate, ammonium (NH_4^+; mg/l), nitrate (NO_3^-; mg/l) and nitrite (NO_2^- ; mg/l).

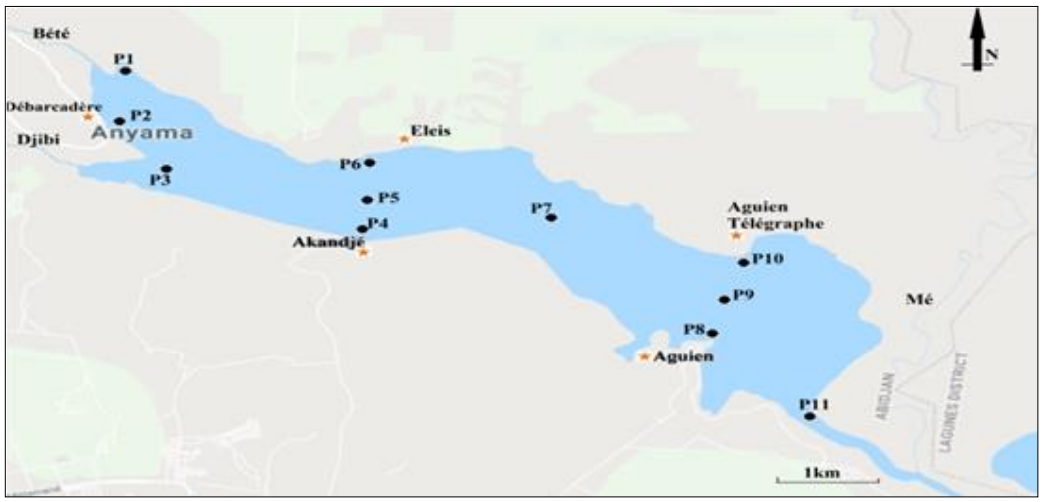

Fig 2: Map of Aghien lagoon with sampling sites P1 to P11 [17].

2.3 Data analysis

Biological indices such as Taxa richness (S); Abundance, Shannon index (H) and Equitability (J) have been used in the calculation of taxa richness and diversity [18]. In addition, EPT index, Chironomidae percentage and water pollution tolerance index were calculated to determine water biological quality.

- Taxa richness (S): is a measure of taxa richness;
- Shannon diversity index (H), H = -Σpi * log2pi. Where pi represents the relative abundance of taxa in the sample (pi = ni / N);
- Equitability J index (H'max = log 2 S). J = H '/ log2S. Where; H was the Shannon and weavers index S was the

number of taxa in samples;

- Occurrence percentage (F): F = Fi * 100 / Ft. where Fi = number of records containing taxa and Ft = total number of surveys conducted. Depending on the value of F, three groups are distinguished [19]: - constant taxa (F ≥ 50%); - accessory taxa (25% F <50%); - accidental taxa (F <25%);
- The EPT index is number of taxa belonging to the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT) in a station.
- The water pollution tolerance index (EPT/C) is the ratio between the aboundance of EPT and Chironomidae. When this ratio is close to 0, it indicates that the water is of poor quality and when it is greater than 10, the water is of good quality [20].
- The percentage of Chironomidae represents the ratio of Chironomidae abundance to the total abundance of organisms present in a site [21]. Thus, [22] proposes the following classification according to the relative abundance of Chironomidae: -% C> 75%: high polluted; 20% <% C ≤: 75%: moderately polluted, - 5% <% C <20% low polluted, -% C <5%: no polluted.

The Chi-2 test was carried out to understand if there is a significant difference (p = 0.05) in the distribution of macroinvertebrates according to the stations surveyed.

3. Results

3.1 Averages of physicochemical parameters at stations

Table 1 presents the different Averages of the physicochemical parameters. For all the abiotic descriptors considered, there are no significant differences between the variations in the different studied stations (Kruskal Wallis test p> 0.05).

Table 1: Averages of the physicochemical parameters in the different stations of the Aghien lagoon

Paramètres	Averages
Temperature (°C)	27,55 ± 0,29
Conductivity (µs/cm)	69,42 ± 0,75
Turbidity (UNT)	33,12 ± 3,03
pH	7,57 ± 0,21
Phosphorus (mg/l)	0,26 ± 0,5
Phosphate (mg/l)	0,09 ±0,03
Dissolved Oxygen (mg/l)	6,47 ± 0,30
Nitrate (mg/l)	1,11 ± 0,9
Nitrite (mg/l)	0,036 ± 0,010
Ammonium (mg/l)	0,19 ± 0,03
DCO (mg/l)	44,31 ± 7,43
DBO (mg/l)	17,49 ± 3,71
MES (mg/l)	14,23 ± 2,30

3.2 Taxonomic Composition and occurrence of aquatic insects

The taxonomic composition and occurrences of aquatic insects are presented in Table 2. A total of 68 taxa from 46 families and 8 orders were collected. Overall, there was a dominance of accidental taxa followed by accessory taxa. However, taxa such as *Centroptilum* sp, *Adenophlebia* sp., Orthocladiinae, *Zygonix* sp. appeared as accessory taxa in six of the seven riverbank stations. In addition, *Diplonychus* sp., *Micronecta* sp., *Mesovelia* sp. and *Microvelia* sp. appeared as accessory taxa in all seven stations. In addition, Chironomidae *Chironomus* sp. appeared as a constant taxon in ten of the eleven stations.

Table 2: Taxonomic composition and occurrences of aquatic insects in study stations Aghien lagoon: ***** = accidental taxa, ****** = accessory taxa, ******* = constant taxa, **-** = absent taxa.

Ordre	Famille	Taxon	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Coléoptères	Dytiscidae	*Bidesus* sp.	-	-	-	*	-	*	-	**	-	*	*
		Laccophilus sp.	-	-	-	*	-	-	-	*	-	*	*
	Elmidae	-	-	-	-	*	-	-	-	-	-	-	*
	Gyrinidae	*Orectogyus* sp.	*	-	-	-	-	-	-	-	-	*	-
	Haliplidae	*Haliplus* sp.	-	*	-	-	-	-	-	-	-	-	*
	Hydraenidae	-	**	*	-	**	-	-	-	**	-	*	*
	Hydrophilidae	*Coelostoma* sp	**	**	-	*	-	-	-	*	-	-	**
		Enochrus sp.	*	*	-	*	-	*	-	*	-	*	*
		Hydrobiinae	*	-	-	*	-	*	-	*	-	*	*
		Laccobius sp.	*	*	-	*	-	-	-	-	-	*	-
	Psephenidae	*Afroeubria* sp.	*	-	-	-	-	-	-	-	-	-	-
	Spercheidae	-	*	-	-	-	-	-	-	*	-	*	*
	Sphaeriusidae	*Microsporus* sp.	-	*	-	*	-	*	-	*	-	-	*
Ephéméroptères	Baetidae	*Centroptilum* sp.	**	**	-	**	-	**	-	**	-	**	*
		Cloeon sp.	-	*	-	-	-	-	-	-	-	-	*
	Heptageniidae	*Afronurus sp.*	-	-	-	-	-	-	-	-	-	*	-
	Leptophlebiidae	*Adenophlebia* sp.	**	**	-	***	-	**	-	**	-	**	***
		Adenophlebiodes sp.	-	*	-	-	-	-	-	-	-	*	-
		Choroterpes sp.	-	-	-	-	-	-	-	*	-	-	-
	Polymitarcyidae	*Ephoron* sp.	*	-	-	-	-	-	-	-	-	-	-
Trichoptères	Hydropsychidae	-	-	-	-	-	-	-	-	-	-	-	*
	Hydroptilidae	*Afritrichia* sp.	*	-	-	-	-	-	-	*	-	-	-
		Hydroptila sp.	*	-	-	*	-	-	-	*	-	*	*
	Leptoceridae	*Leptocerus* sp.	-	*	-	*	-	-	-	*	-	-	-
		Oecetis sp.	-	-	-	-	-	-	-	-	-	-	*
	Polycentropodidae	*Dipseudopsis* sp.	*	-	-	-	-	-	-	-	-	-	-
Plécoptères	Perlidae	*Neoperla spio*	*	-	-	-	-	-	-	*	-	*	**
Diptères	Blephariceridae	-	-	-	-	-	-	-	*	-	*	-	-

	Ceratopogonidae	*Atrichopogon* sp.	*	-	*	-	-	-	-	-	-	-	*
		Ceratopogon sp.	-	*	-	-	-	-	-	-	*	*	-
		Dasyhelea sp.	*	-	*	-	-	-	-	-	-	-	-
		Forcipomyia sp.	*	-	-	*	-	-	-	*	-	-	*
	Chaoboridae	-	*	-	-	-	-	-	*	-	-	-	-
	Chironomidae	*Chironomus* sp.	***	***	***	***	***	***	**	***	***	***	***
		Orthocladiinae	***	***	**	**	*	**	*	**	**	***	*
		Tanypodinae	*	*	*	-	*	*	*	*	*	**	**
	Culicidae	*Culex* sp.	-	-	*	-	*	-	-	-	-	*	*
	Empididae	-	**	*	-	*	-	-	-	*	-	-	*
	Muscidae	*Musca* sp.	-	-	-	-	-	-	-	-	-	*	-
	Psychodidae	-	*	-	*	**	*	-	*	-	**	**	**
	Simuliidae	*Simulium* sp.	-	-	-	-	-	-	-	-	-	*	-
	Stratiomyidae	-	-	-	-	-	-	-	-	*	-	-	-
	Syrphidae	*Eristalis* sp.	-	-	-	-	-	*	-	-	-	-	-
Lépidoptères	Crambidae	*Eoophila* sp.	-	*	-	-	-	-	-	-	-	-	-
	Pyralidae	-	*	-	-	*	-	*	-	-	-	*	-
Hémiptères	Belostomidae	*Diplonychus* sp.	**	**	-	-	-	*	-	**	-	**	**
	Corixidae	*Micronecta* sp.	**	**	-	*	-	-	-	**	-	**	**
	Gerridae	*Limmogonus* sp.	*	**	-	*	-	*	-	*	-	*	*
	Hydrometridae	*Hydrometra* sp.	*	*	-	-	-	*	-	*	-	-	*
	Leptopodidae	*Valleriola* sp.	-	-	-	-	-	-	-	-	-	*	*
	Mesoveliidae	*Mesovelia* sp.	**	**	-	**	-	*	-	**	-	**	***
	Naucoridae	*Laccocoris* sp.	**	*	-	-	-	-	-	*	-	-	*
		Macrocosis sp.	*	-	-	*	-	-	-	*	-	*	-
		Naucoris sp.	**	*	-	-	-	-	-	**	-	**	***
	Notonectidae	-	-	-	-	-	-	*	-	-	-	-	-
	Nepidae	*Ranatra* sp.	**	**	-	*	-	-	-	*	-	*	**
	Veliidae	*Microvelia* sp.	**	**	-	*	-	-	-	**	-	**	**
		Rhagovelia sp.	-	-	-	-	-	-	-	*	-	-	-
Odonates	aeshnidae	*Aeshna* sp.	-	-	-	-	-	-	-	-	-	-	*
	Coenagrionidae	*Coenagriocnemis* sp.	***	***	-	***	-	**	-	***	-	***	***
		Pseudagrion sp.	**	***	-	***	-	***	-	***	-	***	***
	Corduliidae	*Hemicordulia* sp.	-	-	-	-	-	-	-	*	-	-	-
	Isostictidae	-	-	-	-	-	-	*	-	-	-	-	-
	Libellulidae	*Crocothemis* sp	-	*	-	*	-	*	-	*	-	-	-
		Diplacodes sp	*	-	-	-	-	-	-	-	-	-	*
		Orthetrum sp.	-	*	-	*	-	-	-	-	-	-	-
		Pantala sp.	*	-	-	-	-	-	-	-	-	-	-
		Zygonix sp.	***	**	-	**	-	**	-	**	-	**	**

3.3 Structure and diversity of aquatic insects in stations

The summary of insect's Communities structural indicators in stations was presented in Table 3. A total of 68 taxa and 7230 Individuals insects were collected. The highest value of abundance (1588 individuals) was recorded in station P8 near the village of Aguien (Table 1). The station P10 near the mouth of the Bété River has the largest taxonomic richness (40 taxa) with 1000 individuals. The lowest abundance (27 individuals) was recorded in station P3located at the mouth of the Djibi River. Globally; Chironomidae represented more than third of Diptera abundance. The taxonomic richness and abundance of the riverbank stations (P1, P2, P4, P6, P8 and P10 P11) are higher than those of the open water stations (P3, P5, P7 and P9). The diversity analysis showed that the stations had relatively low Shannon index values ranging from 1.77 (station P8) to 2.44 bit (station P1). However, equitability values were relatively high in open water stations compared to riverbank stations.

Table 3: Structural Indicators of aquatic insects in stations

Index	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Taxa richness_S	40	31	7	30	5	22	6	37	6	35	38
Total Abundance	1000	1018	27	871	86	316	30	1588	209	1399	686
EPT abundance	78	155	0	33	0	12	0	18	0	19	42
Chironomidae Abundance	420	504	13	577	72	161	26	1304	173	1142	319
Diptera Abundance	438	507	29	393	88	163	33	1310	212	1212	336
Other orders abundance	483	358	0	254	0	142	0	261	0	154	307
Shannon_H	2,44	2,12	1,65	1,38	1,31	1,86	1,3	1,17	1,22	1,25	2,19
Equitability_J	0,66	0,62	0,85	0,41	0,82	0,6	0,72	0,32	0,68	0,35	0,6

3.4 Correlation between water physicochemical parameters and Insects distribution

A canonical correspondence analysis was performed between water physicochemical parameters and the abundances of the 8 orders of Aquatic Insects (Figure 3). The representativity of all the axes was very significant (p-value = 0.0009). Axis I expressed 45.39% of the information, Axis II expressed 24.44%. The first two axes represented 69.83% of total

variability. The analysis of the graph showed that nitrate contents, conductivity and turbidity were most influence the variation of the Aquatic Insects orders abundances. Axis I revealed an association of nitrate with Diptera whereas it is negatively associated with abundances of Lepidoptera orders. However, on this axis I, turbidity, COD, and BOD are negatively correlated with the abundances of Hemiptera, Plecoptera, Trichoptera and Diptera. On axis II, there was an association between Conductivity and the abundances of Hemiptera, Coleoptera, Odanates, and Ephemeroptera.

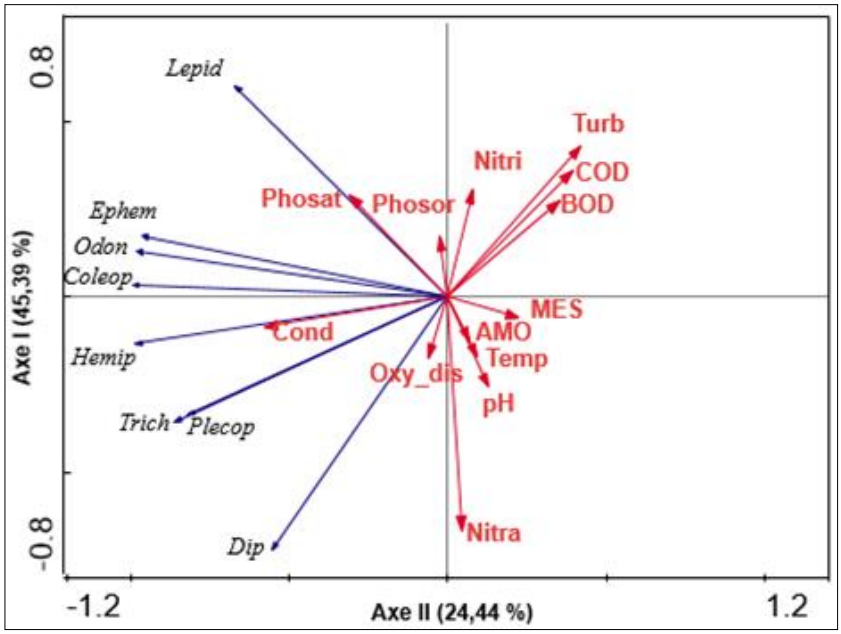

Fig 3: Canonical Correspondence Analysis (CCA) of aquatic insect orders and environmental variables. Temp: Temperature, Nitri: Nitrite, Nitra: Nitrate, AMO: Ammonium, Turb: turbidity, MES: Suspended susbstance, pH: Hydrogen potential, Cond: Conductivity, BOD: Biological oxygen demand, COD, Chemical oxygen demand, Phosat: Phosphate, Phosor: Phosphorus. Oxy_dis: Dissolved oxygen content. Coleop: Coleoptera, Hemip: Hemiptera, Trich: Trichoptera, Ephem: Ephemeroptera, Odon: Odonata, Plecop: Plecoptera, Lepid: Lepidoptera, Dip: Diptera.

3.5 Water quality evaluation

Table 4 summarizes the quality index data for the different sampling stations. The EPT index of the different stations fluctuated from 2 (station P6) to 7 (at stations P1, P8 and P11). Stations P3, P5, P7 and P9 located in open water had not recorded any individual belonging to the EPT complex. Pollution tolerance index for riverbank stations range from 0.01 (P8 station) to 0.31 (P2 station). Overall, the P3, P5, P7 and P9 stations located in the open water of Aghien lagoon have pollution tolerance index values equal to 0. From these two index of pollution tolerance and Chironomidae, the Sampling stations waters (P1, P2, P3, P4, P6 and P11) are moderately polluted, while P5, P7, P8, P9 and P10 have the characteristics of highly polluted water.

Table 4: Water quality index in the study stations. MP: moderately polluted, HP: high polluted.

Index	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
EPT/C	0,19	0,31	0	0,09	0	0,07	0	0,01	0	0,02	0,13
EPT Index	7	5	0	4	0	2	0	7	0	6	7
% Chironomidae	42	49,51	48,15	66,25	83,72	50,95	86,67	82,12	82,78	81,63	46,5
Quality class	MP	MP	MP	MP	HP	MP	HP	HP	HP	HP	MP

3. Discussion

The spatial variation of the different abiotic descriptors of the Aghien lagoon reveals that the parameters considered do not vary significantly from one station to another. This non-significant variability of the abiotic parameters between the prospected sites could be explained by a permanent exchange of the water of the various stations considered under the impulse of the waves, current on the surface of the lagoon, which could cause important circulations of water masses [23]. Moreover, this result shows that the physicochemical parameters of the water were at times beyond the thresholds required for good quality water [24]. These fluctuations could be explained by several phenomena including exposure to solar radiation, the extent of photosynthetic activity of algae and aquatic plants, the presence of dissolved solids, the impacts of human activities in the watershed of lagoon (agriculture, waste dumping ...) [25].

The results obtained during this study showed that entomological composition of lagoon waters is similar to those described in many African waters. They corroborated several studies that have shown the predominance of the class of insects in aquatic environments [26, 27, 28]. However, each station had a low diversity imputed to environmental conditions. Similarly, very low values of equitability index were observed in some stations would reflect unbalanced insect's population organization. Other stations showed a balanced stand in terms of taxon (E> 0.6). This result is linked to habitat stability and biotic interactions [29].

Plecoptera, Ephemeroptera and Trichoptera are considered indicator organisms that tend to disappear when water becomes polluted. Consequently, the presence of Perlidae of the order Plecoptera, of four respective families of the orders

of Ephemeroptera and Trichoptera in some stations could reflect the average quality of these waters [27]. This situation was confirmed by the low values of the EPT index in the different stations. However, the results of the EPT/C index confirmed that Aghien lagoon waters were fair quality [20]. This was confirmed by the relative abundance of Chironomidae, which is an indicator of water pollution of heavy metals [22]. The values of this index indicated an average polluted water overall. Physicochemical factors conditioned life in the aquatic environment. Among these parameters, the most important are the temperature and the dissolved oxygen level [20]. Indeed, the temperature of the water influenced the quantity of oxygen and available energy for the biological productivity and the chemical processes in the lakes necessary for aquatic life. This assertion confirmed the results of the canonical correspondence analysis, which showed that that nitrate contents, conductivity and turbidity were most influence the variation of the Aquatic Insects orders abundances. Second, this would be justified by the impact of anthropogenic releases on the distribution of these organisms [8].

4. Conclusion

This study was carried to characterize the entomological fauna of Aghien lagoon waters and to appreciate the ecological quality. The different physicochemical parameters considered did not varied significantly in stations. All the insects collected in the Aghien lagoon are quite diversified with 68 taxa from 46 families. The waters of the studied stations are moderately polluted and seem to show signs of disturbance reflected by the physicochemical parameters. The waters of the Aghien Lagoon are full of taxa such as *Diplonycus* sp. *Micronecta* sp. which are vectors and/or potential parasitic hosts of *Microbacterium ulcerans*, causative agent of Burili ulcer. Thus, this lagoon should be subject to bio-surveillance.

5. Acknowledgement

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