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Anthropogenic impacts on water quality and macroinvertebrates distribution of Toho Lake, South-West Benin

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Abstract

The impact of the anthropogenic activities on the distribution of the macrobenthic organisms of Toho Lake was conducted. Ten physico-chemical parameters were measured and benthic organisms were collected from May to August 2016 at 8 stations with an Eckman grab. The auto-organizing map SOM was used to determine the similarity between stations according to the environmental variables. (species richness, relative abundance, Shannon-Weiner and Pielou' equitabiliy indices). Abundance-biomass Comparison (ABC) indices, Difference in Area by Percent" (DAP) and Shannon-Wiener Equitability Proportion (SEP) were used to reveal ecological stress in the lake In total, 23 species of macroinvertebrates gathering into18226 individuals divided into 4 classes (Insects, Gastropoda, Achaeta and Arachnids) were inventoried. The insects (20 species representing 91% of the specific richness and 99. 01% of the total individuals) had largely dominated this fauna with one species, *Enithares* sp.. Few water parameters (water transparency (40 - 90 cm), water temperature (26.50 - 30.3 °C), conductivity (213 - 350 mS/cm) and dissolved oxygen (1.75 - 6.06 mg/L)) varied significantly in time whereas depth (0.60 - 1.68 m)showed spatial variation. Three clusters, discriminated by SOM analysis revealed stresses on the organisms. The feeble values of Shannon and equitability indexes and the stress' index calculated have largely supported the impacts of anthropogenic activities on the distribution of species dominated by few taxa showed to be indicators of the ecological status of this ecosystem.

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Introduction

The continental aquatic ecosystems abound of macrobenthic organisms (Adandédjan*et al*., 2012). These organisms are a primary food source for many species of fish, amphibians and birds. Thus, they constitute an important link of the aquatic food web (Barbour *et al*., 1999; Tachet*et al*., 2006). They are composed of diverse zoological groups with varied sensitivities to different stresses such as pollution, habitat modification (Azrina*et al*., 2006; Moisan, 2010). Significant impacts due to human activities cause multiple changes in the biodiversity and assemblages of these organisms (Hellawell, 1986;Nedeau *et al*., 2003).

They are generally used as biological indicators to elucidate these changes of environmental characteristics and ecological strategies of species (Touzin, 2008).

In Benin, benthic macroinvertebrates are little known. The recent works carried out till here concern the Lake Nokoué (Gnohossou, 2006), the Porto-Novo Lagoon and Coastal Lagoon (Adandédjan *et al*., 2012), the Alibori River (AgblononHouélomè *et al*., 2016) and the Ouémé River (Zinsou *et al*., 2016). So, the analysis of macroinvertebrates structure of the aquatic ecosystems of Benin remains full. To fill this gap, our investigations focused on Lake Toho located in southwestern Benin where, apart from the study of Ahouansou Montcho (2003) on the fish fauna of the lake, no other studies were conducted (PADPPA, 2008). In this study, the author has already highlighted the excessive anthropogenic activities in the lake such as the overexploitation of halieutic resources, the environmental degradation, factors that contribute to the impoverishment of the biodiversity. As an exacerbated lake by the climate change, and the high level of anthropisation, its biodiversity would be destroyed (PADPPA, 2008). To provide better knowledge of its ecological status, the biodiversity of macrobenthic organisms in relation to physicochemical parameters of the lake and some stress indices have been determined.

Material and methods

Field of study

Lake Toho (Figure 1) extends, on average during the low water, from 6° 35' to 6° 40' N and from 1° 45' to 1° 50' E. It has a crescent shape oriented South-North. With an area of 9.6 km² during low water and 15 km² during floods, it is7 km long and 2.5 km wide at south and 0.5 km wide at north (AhouansouMontcho and Lalèyè, 2008). Its catchment area covers 374 km² and is located in the West Benin Wetlands Complex (site Ramsar 1017). Lake Toho has two important tributaries, the Diko and Akpatohoun Rivers, which only flow during the rainy seasons between May and mid-July. The third, the Kpacohadji Channel, plays both tributary and outlet roles by communicating the lake to the Sazué River.

Lake Toho is located in a subequatorial climate zone with a succession of four seasons, two rainy seasons alternated by two dry seasons. Its level variations are seasonal depending on the seasonal climate regime associated with the normal variations or changes in level.

Sampling stations

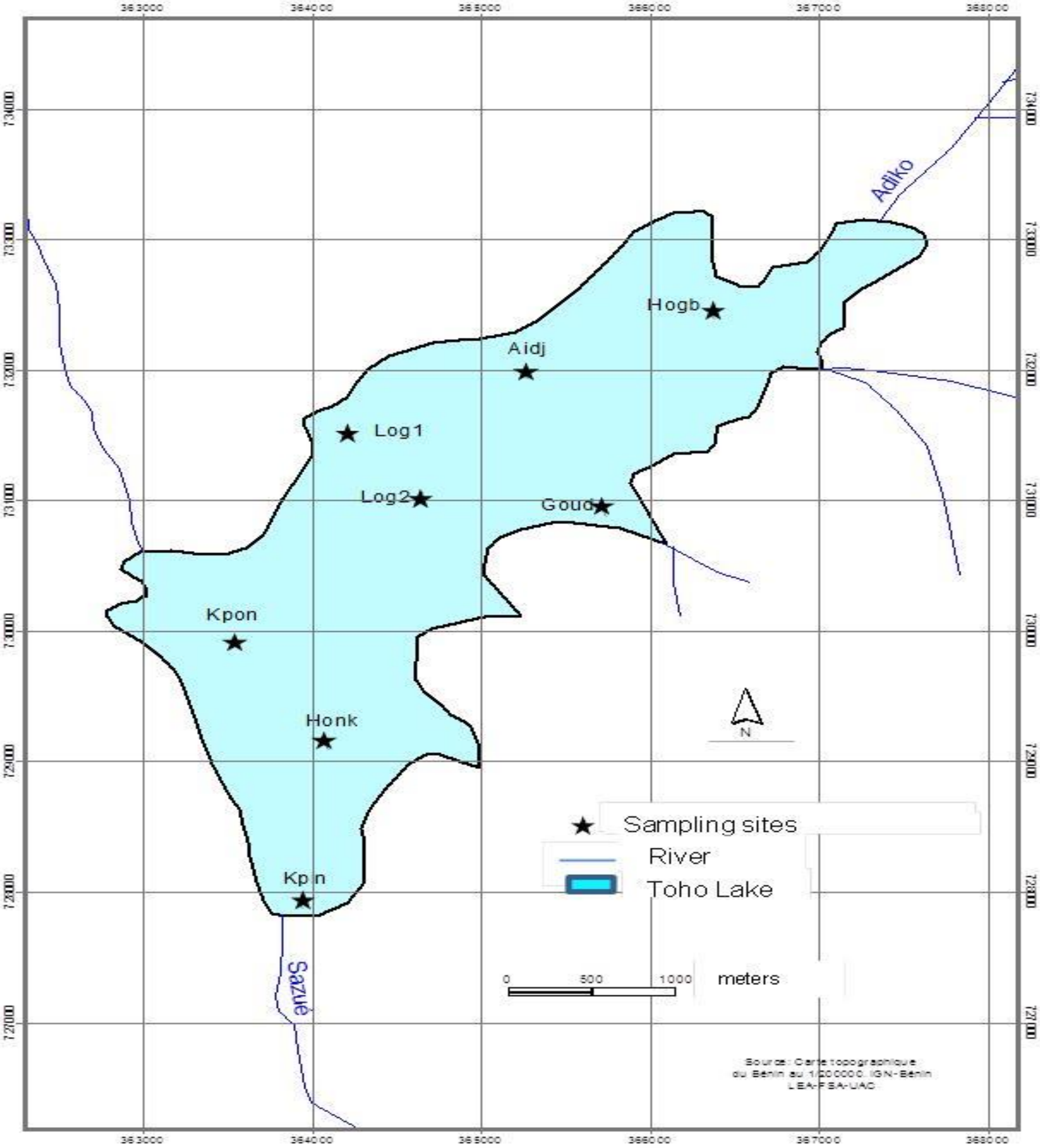
Prospecting and sampling were conducted from May to August 2016. Eight stations were selected based on criteria such as accessibility, habitat diversification and variability of human activities (Figure 1) and were sampled monthly. The different stations have the following characteristics: Logbo 1: facing to Logbo village, small market; Logbo 2: full water, sediment rich in detritus; Goudohoué: full water connected to temporary streams; Hogbonou: receiving runoff from the Tchihoué and Akpatohoun Rivers; Aïdjèdo: full water near floating cages of aquaculture; Kponou: receiving runoff from the Diko River, Honkpotanou: full water far away from villages; Kpinnou: intensive aquaculture in floating cages.

Sampling

Macroinverbates sampling

The Eckman grab (dimensions: 15 cm x 15 cm x 17 cm, sampled area: 0.0225 m²) was used for the sampling of benthic organisms.

At each station, 10 strokes were given. The resulting sample was sieved in a 1 mm mesh on the water of the lake before storing in a plastic bottle well labeled and containing 10% of formaldehyde solution.



Legend : HOGB = Hogbonou; AIDJ = Aïdjèdo, LOG1 = Logbo 1, LOG2 = Logbo 2, GOUD = Goudohoué, HONK = Honkpotanou, KPIN = Kpinnou, KPON = Kponou.

Fig. 1. Study area and sampling stations.

Once in the laboratory, the invertebrate specimens from each station were sorted out, carefully rinsed with cleaned water and preserved in 70% alcohol. They were counted and identified under binocular loupe (Nikon No. 4518360). During this operation, the invertebrates were separated according to their morphological appearance and grouped by class, order and family. The taxonomic determination was made up to the lowest taxonomic level possible using the appropriate identification keys.

Subsequently, the organisms were counted and weighed using an electronic scale with a range of 200 g and an accuracy of 0.001 g.

The weighing were consisted in passing the organisms to the oven set at 50°C for 5 to 10 min before weighting them. All specimens were weighed directly except for mollusks that the shells have been first removed after a 3-days stay in a mixture of trichloroacetic acid and formaldehyde to dissolve the shell (Costil, 1998).

Environmental variables sampling

Likewise, between 6.0 and 10.0 am, temperature, transparency, depth, dissolved oxygen, pH and conductivity of water were measured *in situ* at the same stations. A Secchi disk equipped with a graduated rope has used to measure water transparency and the depth. The pH, conductivity and dissolved oxygen measurements were performed with HANNA physico-chemical measuring devices. To assess the nutritional quality of the water, a water sampling was carried out at each station in 500 mL plastic bottles and stored in a cooler containing ice till to the laboratory for the dosage of nutrients (nitrites, nitrates, phosphates) using the spectrophotometer SHIMADZU UV-1205.

Data analysis and statistical treatments

Analysis of environmental variables

The mean and extreme values of the physical and chemical parameters of the lake were presented in a table 1. The Pearson correlation test was applied to test the normality of environmental variables and to orientate comparison tests (Anova for a normal distribution and Kruskal-Wallis test if not).

Macrobenthic structure

The structure of macroinvertebrates communities was determined by taxonomic richness (S), relative abundance Nr and diversity. Diversity was measured by Shannon-Weiner index (H '= - Σ [Pi log2 (Pi)] (in bits) and Piélou's equitability (E = H' / log2 (S)).

The Self Organizing Maps (SOM) algorithm or Kohonen maps (Kohonen, 1982) were used to order stations based on environmental variables. This algorithm was run using the SOM Toolbox (version 2) for Matlab (Alhoniemi*et al.*, 2000).

To determine the presence of stress in the lake, three ecological stress indices were used such as the Abundance-Biomass Comparison Index (ABC), Difference in Area by Percent (DAP), and Shannon-Wiener Equitability Proportion (SEP) for the different clusters established by SOM. The index (ABC) is used to highlight the characteristics of assemblages that may come from stress on the ecosystem (Warwick 1986, Meire and Dereu, 1990). The ABC index is defined as the average of the difference between the cumulative proportions in terms of biomass and abundance:

$ABC = \frac{Ai - Bi}{N}$, with ABC = Abundance-Biomass

comparison index; Bi = biomass proportion of species i (ranked in decreasing order of proportion); Ai = proportion in abundance (number of individuals) of species i (ranked in decreasing order of proportion) and N = total number of species observed.

The index is positive in an unstressed environment, negative in a highly stressed environment and close to zero in an moderately stressed environment. The conceptual model proposed by Warwick (1986) uses curves known as "k-dominance" curves for biomass and abundance under three scenarios (Figure 2): no stress (a), moderate stress (b) and high stress (c).

The ABC index alone does not reveal generally the factors affecting natural populations such as droughts and floods. In this case, (DAP) ecological stress proposed by McManus and Pauly (1990) was used.

It represents a number that expresses the area formed by the intersection of the two curves and is calculated according to the expression:

$$DAP = \frac{Abundance\ area - Biomass\ area}{\mathrm{Ln}\,(S)}$$

And the biomass area or abundance area is calculated according to the expression:

$$Biomass\ area = \sum_{1}^{s-1} \left[C_i + (0,5 \times Y_i + 1)\right] \times \left[\ln(i+1) - \ln(i)\right]$$,

with S = total number of species; Ci = cumulated biomass (or abundance) up to the species of abundance of rank i; Yi = biomass (or abundance) of the species i. The DAP index is between -1 and +1, with high values indicating stress conditions.

The SEP index, introduced by McManus and Pauly (1990) was calculated to estimate the proportion of diversities in abundance and biomass. The high values of neperian logarithm of this index [(Ln (SEP)] refer to stress conditions (McManus and Pauly, 1990); its expressionis SEP= $\frac{H'(biomass)}{H'(abundance)}$, with SEP = Shannon-Equitability Proportion; and $H'_{Biomass}$ and $H'_{abundance}$ are the Shannon diversity indices determined respectively from biomass and abundance.

At the end,the Kruskal-Wallis test was used to globally compare the faunal richness and abundance between stations, months and clusters. STATISTICA software version 4.5 was used.

Results

Environmental variables

The mean and extreme values of the lake's physical and chemical parameters and also the variability level according to the months and stations were presented in Table 1.

Longitudinal variations of the parameters were not significant excepted for water depth (Anova, p = 0.013), nitrates concentrations (Kruskal- Wallis, p = 0.031) and phosphates concentrations (Kruskal-Wallis, p = 0.04). For months, parameters such as water transparency, water temperature, pH, conductivity and Dissolved oxygen showed significant variations (Table 1).

Table 1. Mean and extreme values of the physico-chemical water parameters of the Toho Lake.

	Mean values	Minimum			Maximum			Variations	
Variables		Values	Stations	Months	values	Stations	Months	Station	Month
Water transparency (cm)	49.56	40	HOGB	May	90	AIDJ	May	NS	*
Depth (m)	1.14	0.60	AIDJ	June	1.68	LOG1	August	*	NS
Water temperature (°C)	28.41	26.50	LOG2	May	30.3	KPON	June	NS	*
pH	6.87	5.21	LOG1	July	8.40	KPON KPIN	May	NS	***
Conductivity (µS/cm)	287.47	213	HOGB	July	350	GOUD	August	NS	***
DissolvedOxygen (mg/L)	4.15	1.75	HOGB	June	6.06	KPON	July	NS	**
Nitrates (mg/L)	7.87	0	HONK LOG1	All months August	72.70	HOGB	August	NS	NS
Nitrites (mg/L)	4.25	0	HONK GOUD AIDJ	All months	28	HOGB	August	NS	NS
Phosphates (mg/L)	0.20	0.02	LOG2	August	0.78	HOGB	July	NS	NS

Legend :Anova Test for all parameters and Kruskal-Wallis Test for Dissolved Oxygen. LOG 1, LOG2, HOGB, AIDJ, HONK, GOUD, KPON, are the codes of the stations

NS = none significatif ; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Abiotic typology

Figure 3 showed the distribution of study samples on the Kohonen map according to the hierarchical classification analysis.

The 8 cells of the Kohonen map were grouped into three clusters or zones (I, II and III). Thus, the cluster I was composed of samples from 3 stations (LOG 1, LOG 2 and KPON).

It is characterized by high pH and nitrite concentration values. The cluster II composed of samples from 2 stations (HOGB and AÏDJ). They were discriminated by an enrichment in nutrients, nitrites, nitrates phosphates and a high transparency. Finally, the cluster III composed ofsamples from 3 stations (KPIN, GOUD and HONK). These stations are characterized by high values of the depth, water transparency, water temperature, conductivity and dissolved oxygen.

Table 2. List of macroinvertebrates collected in the Toho Lake during the study.

Class	Orders	Families	Species	Sampling stations codes							
				LOG1	LOG2	KPON	KPIN	GOUD	HONK	AIDJ	HOGB
Insects	Heteroptera /Hemiptera	Belostomidae	*Diplonychus*sp.				*	*			*
		Corixidae	*Micronecta*sp.						*		
			Micronectascutellaria						*		
			Unidentified 1					*			
		Nepidae	*Ranatra*sp.				*	*			
		Notonectidae	*Enithares*sp.	*			*	*	*		*
	Diptera	Chironomidae	*Polypedilumabissyniae*						*		
			*Chryptochrironomus*sp.						*		
			*Chironomus*sp.1	*							
			*Chironomus*sp .2	*							
			*Chironomus*sp.3						*		
			*Chironomus*sp. 4	*							
			Chironomusformosipennis						*		
			Ablabessmyiaappendiculeta						*		
			*Cryptochironomus*sp.						*		
			*Polypedilum*sp.					*			
		Ceratopogonidae	Unidentified 2					*			
	Odonata	Libellulidae	Unidentified 3	*				*	*		*
		Coenagriidae	*Coenagrion*sp.	*				*	*		
	Coleoptera	Elmidae	*Potamodyles*sp.						*		
Gastropoda	Mesogastropoda	Thiaridae	*Melanoïdes*spp.	*	*	*	*	*	*	*	*
Achaeta	Gnanthobdeliforms	Hirudidae	*Hirudos*sp.						*		
Arachnides	Arachnidea	Unidentified	Unidentified 4					*	*		
			Total per station	7	1	1	6	10	15	1	6
			Total Lac				23				

Legend : LOG1 = LOGBO 1 ; LOG2 = LOGBO 2 ; KPON = KPONOU : KPIN = KPINNOU : GOUD = GOUDOHOUE ; HONK = HONKPOTANOU ; AIDJ = AIDJEDO ; HOGB = HOGBONOU.

Benthic macrofauna

Taxonomic richness (S) and variations

A total of 18226 benthic macroinvertebrate individuals inventoried were represented 23 taxa (families, genera and species) (Table 2). These taxa were grouped into 12 families, 8 orders and 4 classes. The Insects, grouped into 5 orders, 9 families, 20 species, constituted the most important zoological group of the lake (75% of the total number of families and 86.95% of the species). Two families, Chironomidae (Insect Diptera) and Corixidae (Insect Heteroptera), have the highest S, with 10 and 3 species, respectively. The other families were each represented by only one species. The individuals of mollusks (Gastropoda) were grouped into 1 species (*Melanoïdes tuberculata*), thus in 1 order

(Mesogastropoda) and 1 family (Thiaridae). The individuals of Achaeta, the third zoological, were grouped into 1 species (*Hirudo*ssp.)of the genus *Hirudo*, familyHirudidae, orderGnanthobdeliforms. The Arachnids class was not identified.

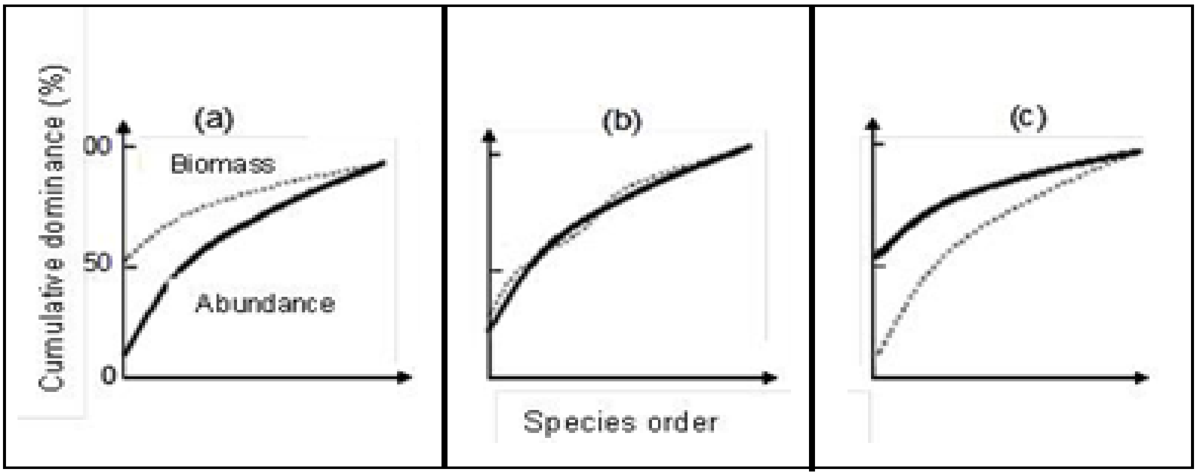


Fig. 2. K-Dominance schematic curves for the abundances and biomasses of the species under three hypothetical scenarios according to Warwick (1986). (a) = no stress; (b) = moderate stress and (c) = high stress.

Figure 4 illustrated the variations of S between stations,months and clusters during the study. The highest S(15 species) was obtained at HONK station whichvarying to 2 in May to 8 taxa in August (Figure 4 (a)) during the study.

Also, GOUD station has gathered 10 taxawith the minimum (2) and the maximum (8) obtained respectively in May and July. At the same time, LOG 2, KPON and AIDJ presented only one species in all periods. As concerning the months, the maximum of invertebrate was collected in July and August that had 14 species. It is in May that the feeble richness was obtained (Figure 4-(b)).

As regarding clusters formed by SOM, the cluster III had the highest richness (19 species) whereas the clusters I and II gathered respectively 8 and 6 species. It is noticed that the species richness has significatively varied between stations and clusters.

Relative abundance Nr and variations

Two families of macroinvertebrates collected in the Toho Lake were dominant as there showed high Nr. The Notonectidae family was the most preponderant with 17742 individuals (97.73% of the total abundance) with a single species,*Enithares*sp. Followed the Thiaridae family, with 0.013% corresponding to 237 individuals of the unique species of this family encountered (*Melanoides* spp.) during the study. Other families such as the Belostomidae, the Corixidae, the Nepidae, the Chironomidae, the Ceratopogonidae, the Libellulidae, the Coenagrionidae, the Elmidae, and the Hirudidae had a relatively negligible Nr during the study.

Figure 5 illustrated the Nr variations between stations, months and clusters during the study. As regarding the abundance variations in stations, the highest Nr (17%) was obtained at PKIN station (46.55% of the total abundance) in July and August.

Although HONK has proved to be the richest station, it is one with relatively low abundance.

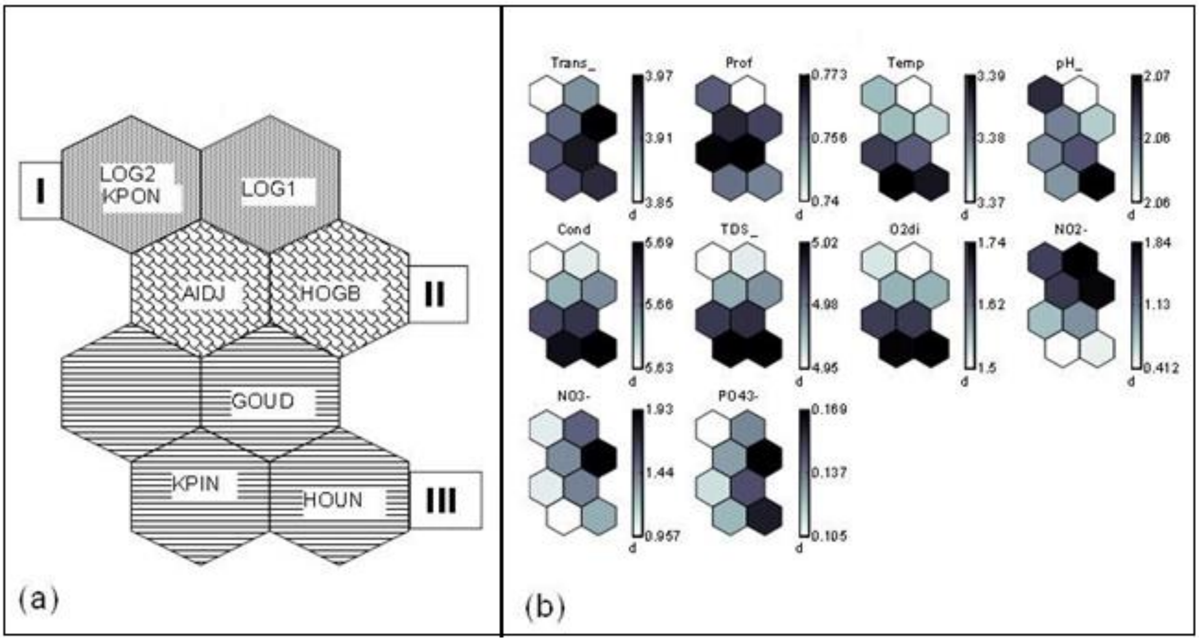
The lowest Nr was observed at the two stations, KPON and AIDJ in July(Figure 5 (a)). The two months July and August have shown the highest Nr (8) in benthos, the lowest abundance (Nr =1) was obtained in May (Figure 5 (b)). Among the clusters defined by SOM analysis, it is the cluster III that showed the important number of individuals collected; the cluster I, the lowest Nr (Figure 5 (c)). Only, the Nr between stations showed a significance variation.

Shannon index H' and Pielou's equitability E

The different values of the H' obtained from one station to another during the study oscillated between 0 bits (at LOG2, KPON and AÏDJ stations) and 0.98 bits (at LOG1 and HONK stations) (Figure 6-a). The variations of H' were significant between stations (Kruskal-Wallis test: $p < 0.05$). As for the Equitability, it noted similar space variations with the H' (Figure 6-c). This index varied significantly from 0.03 to 0.32, (Kruskal-Wallis test: $p < 0.05$) with the maximum and minimum values recorded at the same stations as the variation of the H'.

In time, H' varied in a decreasing manner over the study period (Figure 6-b). It felt from a maximum value of 1.2 bits obtained in May to 0.11 bits recorded in August. Similarly, Ehas decreased from a maximum value in May (0.55) to a minimum value (0.01) in August (Figure 6-d).

All these variations were also significant (Kruskal-Wallis test: $p < 0.05$). As concerning the clusters, H' has varied significatively to 1.22 in cluster I to 0.11 for cluster II and 0.20 for cluster III (Kruskal-Wallis test: $p < 0.05$). Also, the equitability values have evolved from 0.4 for cluster I to 0;04 for cluster II and 0.05 for cluster III; this variation was significative (Kruskal-Wallis test: $p < 0.05$).



Legend: Log1, LOG2, KPO; AIDJ; HOGB; GOUD, KPIN; HONK are the codes of the sampling stations. I, II and III are the clusters defined par the SOM analysis.

Fig. 3. SOM Map (a) and discriminant factors of each cluster (b).

Assessment of environmental stress

A total of 18194 individuals of 32.3443 g of benthos were used. The taxonomic richness and the number of individuals were respectively for cluster I: 8 taxa, 801 individuals for a biomass of 13.5305 g; cluster II: 8 species, 4561 individuals weighing 9.0054 g and finally cluster III: 22 species, 12862 individuals weighing 20.3422 g.

Figure 7 illustrated the trends of changes in the ecological stress ABC, the DAP and the SEP indexes values of the different clusters defined by the SOM.

In general, the abundance curves were located above those of the biomass, indicating high stress conditions at all stations. Also, the clusters showed negative values of the DAP index with its lowest value (- 0.22) for the cluster I formed by oxygenated stations, its high value (-0.09) was obtained with the cluster III enriched with nitrogen and phosphate nutrients. These DAP values confirmed the presence of pollution within clusters, which was greater in cluster III.

The log_e(SEP) values calculated for the different clusters of stations were negative for the cluster I and positive for the other two. Its values varied between -0.26 (in cluster I) and 2.10 (in cluster II).

This situation revealed that the organisms were strongly stressed in all parts of this lake but less important in the cluster I.

The benthos community of clusters II and III were more vulnerable. However, the benthos community issued from the cluster III were subjected to perturbations but less important than the cluster II.

Discussion

The richness, abundance and biodiversity indices obtained during the study tend to reveal the deterioration of the water quality of Toho Lake. Only, 23 taxa (genera and species) have been inventoried. This richness was feeble, compared with those found in the Nokoué Lake (76 taxa) (Gnohossou, 2006) and the Porto-Novo Lagoon (150 taxa) (Adandédjan *et al.*, 2012) in the southern Benin. This result could be explained by the short duration of the sampling that only covered two hydrological seasons, the great rainy season (mid-March to mid-July) and the short dry season (mid-July to mid-September). Also, the strong variations of the water level can contribute to the disappearance of the macroinvertebrates fauna. Their reconstitution will be accompanied by changes in composition and structure of the organisms' communities since their habitats have changed. The restoration of the fauna also needs time.

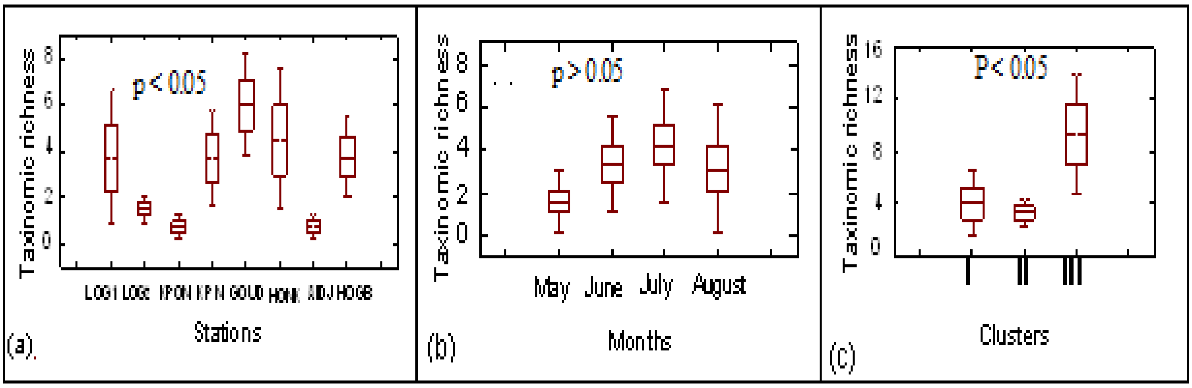
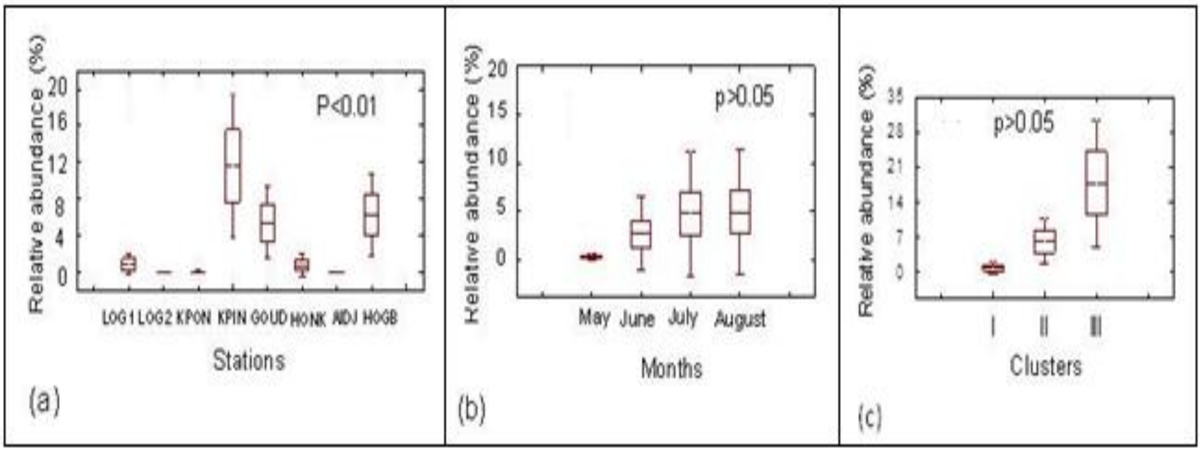


Fig. 4. The macrobenthic taxonomic richness variations between space (a), months (b) and clusters(c). p is the Kruskhal-Wallis value.

Macroinvertebrate communities in the lake are largely dominated by insects which are unevenly distributed in the lake. Chironomidae taxa were the most constant and Hemiptera taxa, the dominant group. Insects are more diversified and their life cycles very varied. So, these organisms could be the first colonizers of this ecosystem as it offers various habitats such as detritus, mud, etc. The study of the unequal short-term distributions of macroinvertebrates and their colonization on detritus has already been investigated and it has proved to be a strong link between abundance patterns and variations in the amount of detritus present in the environment (Mancinelli *et al.*, 2005). The recruitment of benthic organisms in the substrates depends mainly on the establishment of the first colonizers of these substrates which, in turn, depends on the conditions offered by these substrates and the biological cycles of the species (Guérin *et al.*, 1976).

The Diptera species, more diversified in the lake are mostly opportunistic and quickly take advantage of the disappearance of other species, occupying their ecological niches during unfavorable conditions.



Legend: LOG1, LOG2, KPON, KPIN, GOUD, HONK, AIDJ and HOGB are the codes of the sampling stations.

Fig. 5. Macrofauna relative abundance variations between stations (a), months (b) and clusters (c) during the study.

The Shannon and Equitability indexes calculated were feeble with significant variations in space and in time. The macrobenthic fauna of the lake was not diversified. A single taxon of the family Notonectidae (Hemiptera Insect) represented by the species *Enithares* sp., totaled 97% of the abundance. Corixidae Insects were the third group observed with 3 species. Also, one species of Mollusca Gastropoda was observed. These taxa seem to derive profit from the enormous mass of water that enters in the lake during the great rainy season, period that corresponds to this study. Usually, floods provoke nutrients enrichment and a high primary productivity, foods sources for grazers like the Thiaridae and Chironomidae species. Also, organic matters enrichment associated to microbial activity represents another feeding source for the detritivorous Chironomidae and the vulture Hemiptera and grazers (Adandédjan, 2013).

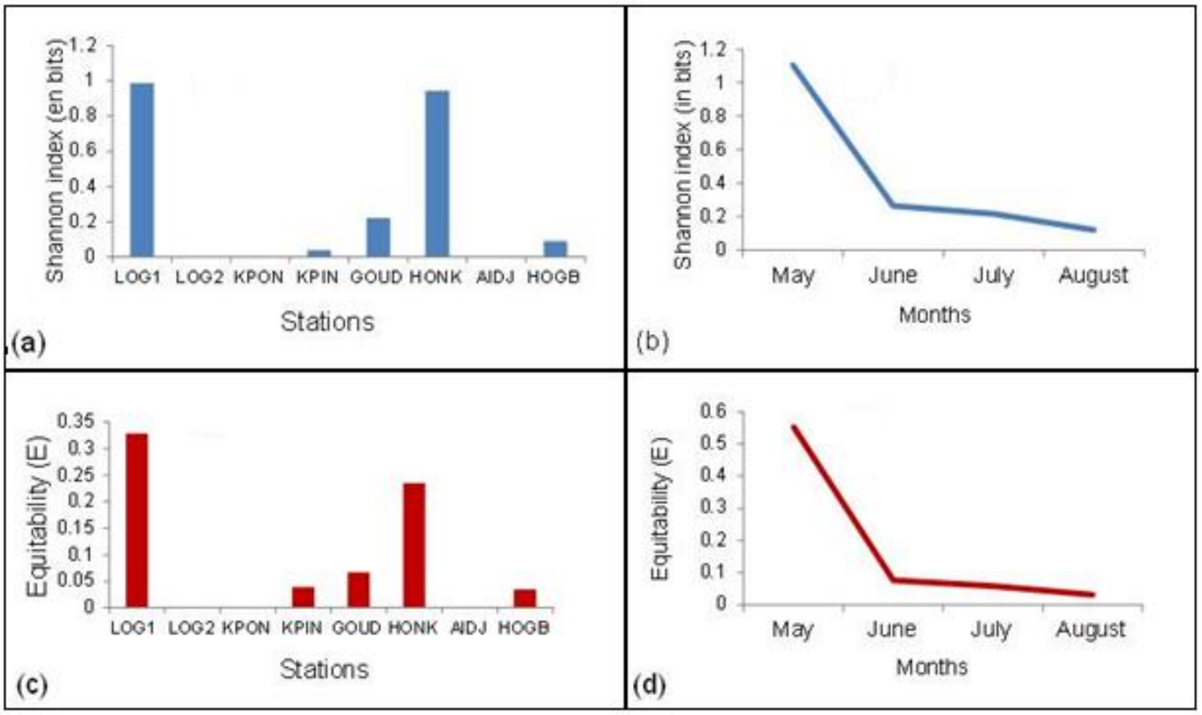
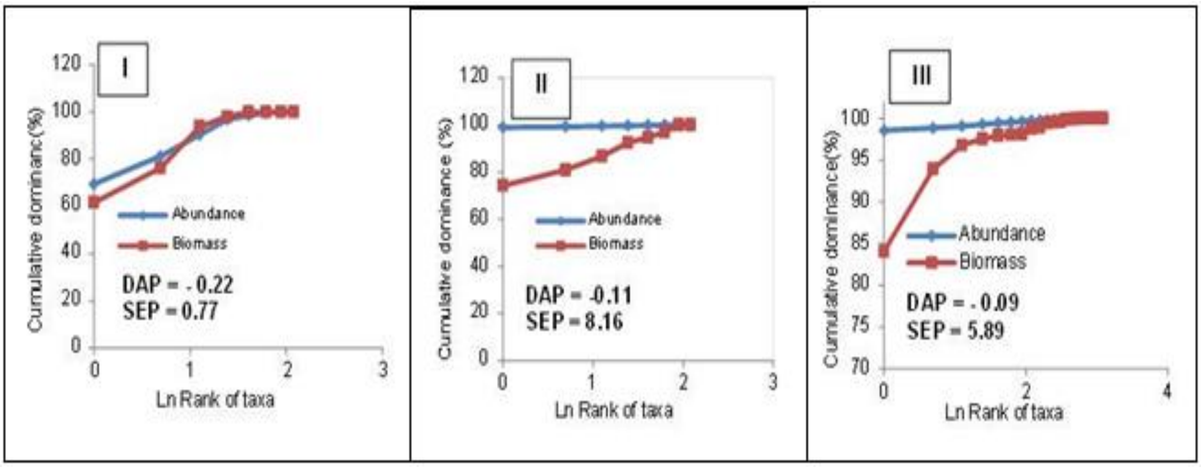


Fig. 6. Shannon index H' (a and b) and Equitability E (c and d) variations during the study.

Their proliferation in the lake during the study is due to the availability of nutritive resources. Furthermore, there is a total absence of certain insect orders such as Ephemeroptera, Plecoptera and Trichoptera which presence is related to a good quality of the lake. These observations seem to constitute a serious alarm on the ecological state of Toho Lake. These results are widely sustained by the high concentrations of nutrients (nitrites, nitrates, phosphates) registered at HONK and LOG2. These stations would be the ones in direct contact with the zones of markets gardening, aquaculture in floating cages.



Legend: I, II and III are the number of the clusters.

Fig. 7. K-dominance curves of abundances and biomasses of benthic macroinvertebrates taxa of Toho Lake and stress evaluation in the clusters defined by SOM analysis.

Also, the low values of dissolved oxygen, water transparency, depth, and pH were registered at several stations sampled and indicated a poor quality of the lake water. In such environment, some species of benthos like Gastropoda and some insect larvae could never develop.

The same results were obtained in Fluxian Lake (China) subjected to intense human activities where Cui*et al.* (2008) has inventoredless than 40 species of molluscs and insects in their samples compared to the previous works. These results could be due to the numerous human activities developed in and around the lake. PADPPA had already cheiked in 2008, more than 2050 fishermen who exploit Toho Lake. Ahouansou Montcho since 2003, has counted 10 fish holes around the lake. Between 2003 and nowadays, with the increasing of the demography, people can imagine the intensity of all activities done in this lake without control. Also, in the rainy season, the washing drains the remains of pesticides used in the cotton culture into the lake. Equally, many riverside villages discharged daily the domestic wastes in this lake.

All these activities strongly influence aquatic fauna including benthic macroinvertebrates causing severe variations in their structure. According to Rosenberg and Rosenberg and Resh (1993), these invertebrates have different sensitivities to pollution. Some are polluo-sensitive, they disappear most rapidly from the environment; it is the case of Plecoptera and Ephemeroptera that were not found during the study. The same authors explained that when the pollutant load becomes excessive, several taxa disappear from the ecosystem while those that resist, the pollutant-tolerant, become more abundant.

Analysis of the ABC index values revealed that the lake's macrobenthic communities are under disturbances.

The comparison of the DAP and SEP indexes calculated for the clusters, makes possible to quantitatively determine the degree of stress within each cluster. In general, these observed values tend to reinforce the hypothesis of ecological imbalance of the lake and easily justify the poverty of the stations collected in benthic macrofauna. And the three clusters of stations, representative of the lake are subjected to various pollutions. Cluster I consists of the LOG 1, LOG 2 and KPON stations receiving nutrients from runoff (rich in nitrites and other pesticides) coming from the Tchihoué, Akpatohoun and Diko temporary rivers.

This residual pollution can cease with the withdrawal of water, that justifies the low stress suffered by organisms of this cluster, result confirmed by the Shannon and Equitability index values for this cluster that were high as compare to those obtained for the other clusters. Cluster II consists of AÏDJ and HOGB stations located in areas in contact with aquaculture and cotton zones.

These stations are under the yoke of increased organic pollution because they receive the runoff rich in pesticides used in cotton culture, hence the high values of DAP and Loge SEP with the proliferation of pollo-tolerant taxa and the increase of their densities. For the cluster III formed by the KPIN, HONK and GOUD stations, high taxinomic richness in polluo-tolerant taxa and abundance were registered.

If the HONK station is more diverse in macrofauna (Abundance, Indices H 'and E), it is that it offers not only more diverse habitats for fauna but also no human activities are settled; this station could be serve as the reference one for further study.

Conclusion

The anthropogenic activities impacts on the water quality, biodiversity and distribution of the lake's benthic macroinvertebrates were highlighted. Only opportunistic taxa were found at nutrient enriched stations proving that the lake is very disturbed, as shown the various indices calculated.

The results of this study are very important and constitute a database informing on how the use of bioindicators that are the benthic macro invertebrates can assist in the development and management of this ecosystem.

However, it would be better to extend the study to all hydrological seasons, to document the taxonomy of groups up to the specific level and to determine a reference station in this ecosystem from which it would be possible to predict the pollution level of others.

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