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Distribution of Benthic Insect Fauna in a West African Lagoon: The Porto-Novo Lagoon in Bénin

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ABSTRACT

The distribution of aquatic insect fauna of Porto-Novo lagoon was studied through seasonally sampling from July 2007 to June 2008. A total of 52 taxa belonging to 7 orders and 29 families were recorded. The richest taxonomic diversity was observed for Heteroptera, Ephemeroptera and Odonates. Certain species such as *Diplonychus* sp. (Belostomidae), *Chironomus* sp., *Chironomus formosipennis* and *Polypedilum fuscipenne* (Chironomidae) and Libellulidae (*Libellula* sp.) were the most constant taxa observed during the sampling period. The distribution pattern observed thanks to the Kohonen map (SOM) is characterized by a rich assemblage and varied from upstream to downstream. The highest specific diversity (69.29%) was gotten during the low rainy season (October) and the lowest (29.8%), during the high dry season (February). This pattern resulted from the species reproductive process of most insects orders, in relation with a decrease of the rate of the salinity and an increased water temperature. But then, the low rate of species richness recorded during the dry season will be explained by the lacking of efficient recruiting and a strong predation during this period. Besides, hydrological factors and human activities could be also the important factors of controlling the distribution of this fauna. The invasion of the lagoon by the floating vegetation can be advanced as a factor of forçage of the temporal variations of the organisms.

Key words: Insects fauna, distribution, self-organizing map, lagoon, Porto-Novo

INTRODUCTION

The analysis of macrofauna community structure has been an important tool in environmental monitoring programs (Clarke and Warwick, 1994; Barbour *et al*., 1999). For the instance, community patterning is useful for revealing states of ecosystems in response to environmental disturbances. But the lack of information about the temporal variability of this fauna constitutes one of factors limiting the development of a consequent methodology for a good diagnose of the environment (Rosa and Bemvenuti, 2006). In West Africa, some information on these organisms exists but in Benin and in lagoons in particular, very little study has been done in this field. In the present survey, we chose to work on the insect fauna of Porto-Novo lagoon in the Southwest of Benin. This lagoon plays an important economical role for the riparian populations (intense fishing activities with the development of acadjas practice, exploitation of lagoon sand, transportation to join some lacustrine villages and traffics of gas and petrol for vehicles, development of the ecotourism with the building of smart hotels outskirts the lagoon, market close by, bridge, etc.). Anthropogenic activities linked to this lagoon mislead different types of pollutions (domestical, industrial and agricultural pollutions) that made it vulnerable and threatened the aquatic living resources present (Pearson and Rosenberg, 1978; Warvick *et al.*, 1987). Face to this situation, it is important to take measures in order to preserve biodiversity for the present and future generations. Characterizing the temporal and spatial variations of benthic assemblages becomes indispensable for knowing the structure of the communities on the one hand and the seasonal change of these assemblages, on the other hand (Ibarra *et al.*, 2005). Thus, in this study the temporal distribution pattern of insect fauna and its relationship with variability of water and sediment characteristics were studied.

MATERIALS AND METHODS

Study site: The Porto-Novo lagoon (6° 25 N and 2°38 E) is located approximately 30 km in the North-Eastern of Cotonou, precisely in the Southern of our political capital Porto-Novo. The lagoon is triangular in shape; covers an area of approximately 30 km^2 in the flood and 20 km^2 in the low waters. It is 6 km in length (W-E) and its width varies between 2 and 4 km. It is an ecosystem closed by the two first cities of Benin (Cotonou in the south and Porto-Novo in the North). At East, the lagoon is linked to the Lagos lagoon (Nigeria) after 100 km of its course; in the west, it is connected to Nokoué Lake by the Totchè channel. The water of the lagoon has two origins: oceanic through tidal action and continental through the input of permanent freshwater tributaries: (Ouémé, So, Blon, Avien) and run off. The climate is equatorial with four contrasting seasons. The lagoon receives a maximum water of 244,84 mm in June (big rainy season) followed by a secondary maximum of 143.92 mm in September (small rainy season) with a minimum of 44.09 mm in August (small dry season). Several anthropogenic activities occur in the lagoon. The fishing activities are concerned of 5500 people using various methods and techniques among which the acadja technique, specific to the lagoon. Another activity developed in this lagoon consists in the exploitation of lagoon's sand. This activity is practiced by all people living near the lagoon and constitutes a veritable one that occupies people. The eastern portion of the lagoon covers a soap factory. Also, this lagoon supports a dam on its all width. The remain length of lagoon is lined by vegetation of *Paspalum vaginatum*, *Typha australis*, *Eichinochloa pyramidalis*, *Phragmites australis* and *Cyperus* sp. The floating vegetation is dominate by *Eichornea crassipes*, *Ipomea aquatica*, *Pistia sratiotes*. In the channel of Totchè, we can meet a few mangroves trees and other planted trees like *Elaeis guineensis*, *Rhizophora racemosa* and *Acacia* sp.

Sampling

Sampling of organisms: Aquatic insect were collected seasonally from July 2007 to June 2008. Soft bottoms were sampled in four occasions using box-corer Ekman type (0,030 m^2 of surface) at twelve stations (Fig. 1) located along the lagoon. At each station, 1 m^2 surface of the substratum was sampled until a depth of 20 cm in the sediment. In zones where the floating vegetation is dense, we used a sieve (mesh: 1-0.5 mm, diameter: 30 cm) equipped with a handle of wood designed in fact. Samples were roughly cleaned in the water of the lagoon with the sieve (1 to 500 μm of mesh). The retained material was preserved in globes and fixed in 10% formaldehyde. In the laboratory, samples were rinsed and animals were sorted and preserved in 70% alcohol before

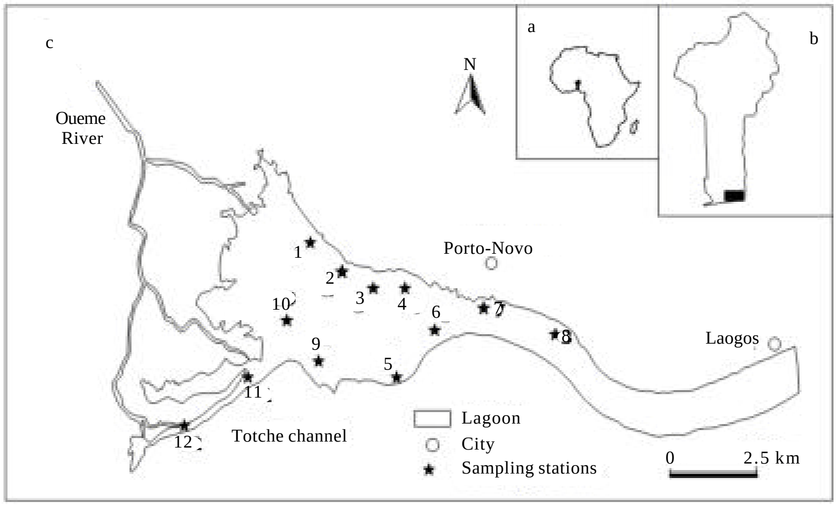

Fig. 1: Sample sites of Porto-Novo lagoon. The numbers represent the sample sites codes: 1: Djas; 2: Pn2; 3: Pn3; 4: Pn4; 5: Pn5; 6: Pont; 7: Douane; 8: Savonnerie; 9: Pnc; 10: PnPara; 11: Totchè 2 et 12: Totchè 1

operations of identification and counting. Invertebrates were then identified to the lowest possible taxonomic resolution. Several keys of identification were used such as Cafferty and Patrick (1981), Dejoux *et al.* (1981), Tachet *et al.* (2003), Christopher *et al.* (2008) and Zwlck (2004) and consulting specialists.

Environmental data: To each period of sampling, several environmental variables have been measured among which: the water temperature, the pH, the salinity and the dissolved oxygen concentration. The salinity was determined by a conductimeter-multiprocessor, the pH with a pH-meter and the dissolved oxygen concentration with the Winckler method. Sampling stations were fixed in advance with a GPS (Global Position System) that facilitated the accessibility of them at each sampling period. Additional samples of sediment were collected at each station to analyse grain size according to conventional techniques. Sand and fine fractions (clay + silt) were expressed as percentage of mud.

Data analysis

Specific composition analysis: We established the list of aquatic insects collected during the period per station. The similarity between different stations of sampling has been determined using the Jaccard similarity (Legendre and Legendre, 2001a, b; Gevrey *et al.*, 2004). Also, we applied the Mann-Whitney test (Edia *et al.*, 2007) to test for differences in species richness found in the stations.

Self-Organizing Map (SOM): To study the spatial and temporal variations of insect assemblages, we used the artificial non supervised neuron networks, the Self Organizing Maps (SOM) or maps of Kohonen (Kohonen, 1982; Brosse *et al.*, 2001). The advantage of this method is in the fact that it treats the extreme data (big abundance or extreme rarity), so often contained in the ecological data bases (Lek *et al.*, 1996; Kohonen, 2001; Giraudel and Lek, 2001) with ease. This technique proved its merits in the analysis of the distribution of ecological community patterns with the advantages to represent non linear relations (Ibarra *et al.*, 2005; Hopton and Mayer, 2006) instead of the classic methods of multivaried analyses (ACP, etc.). According to our analysis, the rare species can be also important to describe the structure of the ecosystem. Consequently, a lot of rare species can constitute an important source of food for other zoological groups of the ecosystem. The presence-absence matrix established for each station during the sampling period has been grouped into 48 samples of 52 columns (i.e., species). Each of the 48 samples of the data set constitutes a vector of 52 dimensions. Presence-absence matrix was preferred to species abundance because of the variability and the selectivity of methods used to collect organisms. The architecture of SOM consisted of two layers of neurons: the input layer that was composed of 52 neurons connected to each vector (line of the matrix), the output layer was composed of 30 neurons. We chose 30 neurons because the configuration gotten presented minimum values for both of quantization and topographic errors, which were used to appreciate the classification quality (Park *et al.*, 2003). The SOM algorithm calculates the connection intensities between input and output layers using an unsupervised competitive learning procedure (Kohonen, 1982) which classifies samples in each node according to their similarity in species composition. The connection intensity of the SOM corresponded to the probability of presence of a species in a group of samples and was indicated on the map by the dark cells: darker is a cell, more the probability of presence was higher (Lek *et al.*, 1996). At last, mean values of each environmental variable averages were calculated for each cell of the SOM map to understand relationships between the biological and environmental variables. These values assigned to the map were visualised using the same colour scale and then compared as well as with stations map and the biological attributes. The analysis was carried out using the SOM toolbox for Matlab.

Definition of SOM clusters: We defined relevant groups or clusters of samples that characterized insect fauna assemblages by performing a hierarchical classification analysis (Ward's linkage and method of Euclidean). To do so, we used a new matrix (30×52 output neurons×species) of the connection intensity values estimated by the SOM. The number of clusters was defined by applying the Bouldin-Davies Index (DBI), in which the minimum values indicated some low variance within groups and high variance between groups (Vesanto and Alhoniemi, 2000). Differences in species richness between clusters were tested applying the non-parametric test of Kruskal-Wallis, followed up by the Mann-Whitney test. We tested the season effect or the station effect by applying Anova test. For these different tests, we used the software STATISTICA.

RESULTS

Figure 2 showed the temporal trends of physical and chemical parameters measured during the period of the study. Water temperature followed the typical seasonal trend (Fig. 2a) reaching its highest and lowest values respectively in February-March and in October-November. Salinity (Fig. 2b) showed similar ranging between 13.3 psu (maximum value observed in February) and 0 psu (minimum value in September) with a yearly average of 2.39 psu. Water pH presented its highest variation between seasons but remained acidic during the dry seasons and basic during the rainy seasons (Fig. 2c). The dissolved oxygen concentration (Fig. 2d) had its lowest value during the small rainy season (September-October) and its highest value during the high dry season (February-March). The bottom of the lagoon was mainly sandy with small fractions of fine particles which rate varied between 0 and 13.1. Abiotic parameters were also studied using a

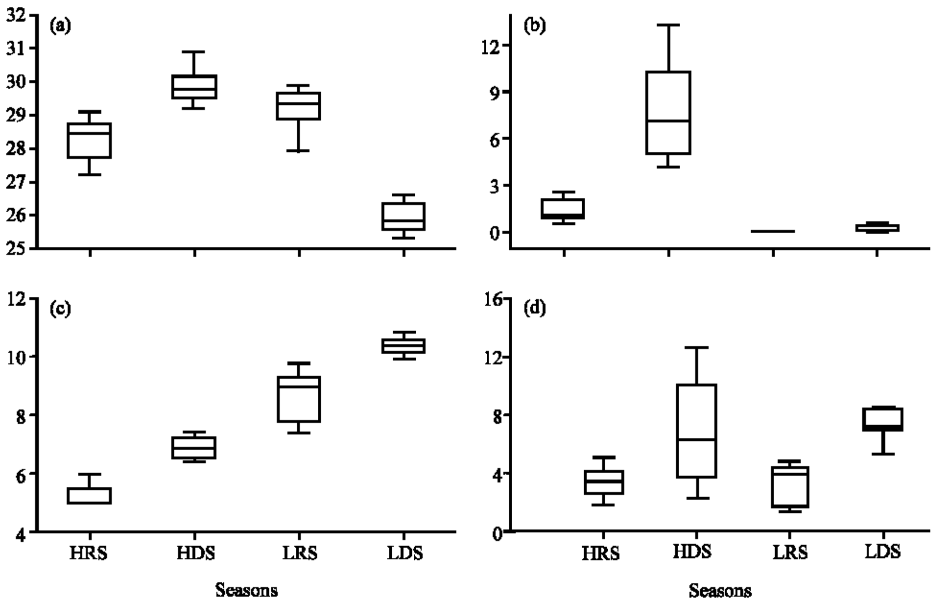

Fig. 2: Seasonal variability of: (a) water temperature (°C), (b) salinity (psu), (c) pH and (d) dissolved oxygen (mg L^{-1}). HRS, HDS, LRS, LDS represent respectively high rainy season, high dry season, low rainy season and low dry season

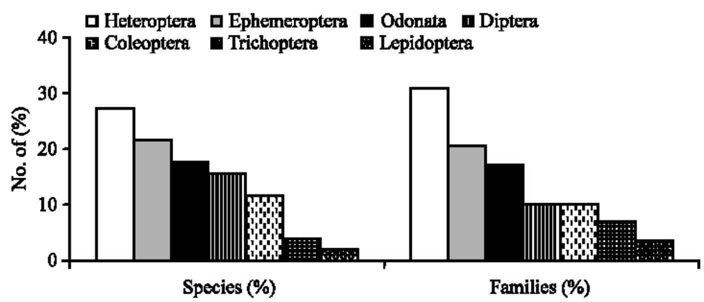

Fig. 3: Percentages of (a) number of species and (b) families of different orders of insects

Bravais-Pearson correlation analysis. The significance correlation between a given parameter between stations indicated a spatial evolution of this parameter interpreted as a gradient along the lagoon.

Fifty-two taxa of aquatic insect (Table 1) belonging to 7 orders and 29 families were recorded. The Heteroptera (Fig. 3 a and b) presented the biggest diversity with 27.45% of the total taxa (31.03% of families), followed by the Ephemeroptera with 21.57% of the total specific richness (20.69% of families) and the Odonata (17.64% of the total species richness and 17.24% of families). The Diptera represented 15.68% of the total (10.34% of families) when Coleoptera gathered 10.34% of families and 11.76% of taxa. The Trichoptera and the Lepidoptera presented the lowest number (3.92 and 1.96%, respectively).

Four taxa belonging to 3 orders were most constant. There are: the Heteroptera that were the Belostomidae (*Diplonychus* sp.), the Ceratopogonidae; the Diptera as the Chironomidae (*Chironomus* sp., *Chironomus formosipennis, Polypedilum fuscipenne* and *Procladius* sp.) and the

Table 1: Insect species collected during the study period

			Stations											
Orders	Families	Taxa	to1	to7	pnc	pnp	pn5	pdj	pn4	pn3	pn2	pon	pnd	pns
Ephemeroptera	Oligoneuridae	*Elassoneuria* sp.	*									*		
		Baetis sp.					*	*			*	*		
		Pseudoclon sp.					*							
	Baetidae	*Centroptilum* sp.											*	
		Proclocon sp.	*											
		Cloon sp.												*
	Gomphidae	*Paragomphus hageni*					*				*			
	Leptophlebiidae	*Thraulus* sp.				*						*	*	
		Cacoterpes sp.							*					
	Caenidae	*Caenodes* sp.							*					
	Lestidae	*Lestes congener*	*											
Heteroptera	Belostomidae	*Diplonychus* sp.	*		*			*		*		*		*
		Hydrocyrius comlumbiac							*					
		Belostoma cordifana	*											
	Pleidae	*Plea pullula*					*		*					*
		Plea sp.				*	*	*	*					
		Plea leachi					*					*		
	Hydrometridae	*Hydrometra* sp.	*				*					*		
	Gerridae	*Limnogonus chopardi*					*		*			*		
	Veliidae	*Microvelia* sp.											*	
	Notonectidae	*Corixa punctata*									*			
	Corixidae	*Micronecta* sp.					*		*					
	Ranatridae													
	Ranatra nigra												*	
		Ranatra sp.					*						*	*
	Agriotypidae	*Agriotypus* sp.		*			*							
	Ceratopogonidae	*indéterm.*	*	*	*		*		*	*		*	*	
Odonata	Libellulidae	*Libellula* sp.	*				*							
		Palpopleura lucia lucia								*				
	Corduliidae	*Brachytemis* sp.										*		
		Phyllomacromia sp.							*			*		
	Macromiidae	*Oxygastia curtisii*										*		
	Coenagrionidae	*Coenagrion* sp.	*	*	*		*							
		Paragomphus hageni			*				*					
		Aeshna sp							*					
	Calopterygidae	*Phaon iridipennia*	*											
Diptera	Chaoboridae	*Chaoborus* sp.											*	
	Chironomidae	*Chironomus* sp.		*	*	*	*		*		*	*	*	*
		Procladius sp.		*			*		*			*		*
Diptera		*Polypedilum fuscipenne*	*					*				*	*	
		Ablabesmyia appendiculeta							*					
		Orthocladiinae			*									
	Simulidae	*Simulium damnosum*							*					
Coleoptera	Dytiscidae	*Hyphydrus* sp.						*						
		Meladema sp.							*					
		Hydrovatus sp.	*			*	*					*	*	
		Hydaticus sp.	*											
	Elmidae	Stenelmis sp.												
	Hydrophilidae	Amphiops sp.	*					*	*					*
	Scirtidae	Scyphon sp.											*	*
Trichoptera	Hydroptilidae	Protomacromea sp.		*			*							
	Leptoceridae	*Ceraclea* sp.					*						*	
Lepidopteres	Pyralydae	*Indéterm.*										*		*

*Presence of species. 1: pdj; 2: pn2; 3: pn3; 4: pn4; 5: pn5; 6: pon; 7: pnd; 8: pns; 9: Pnc; 10: pnp; 11: To7 et 12: To 1.

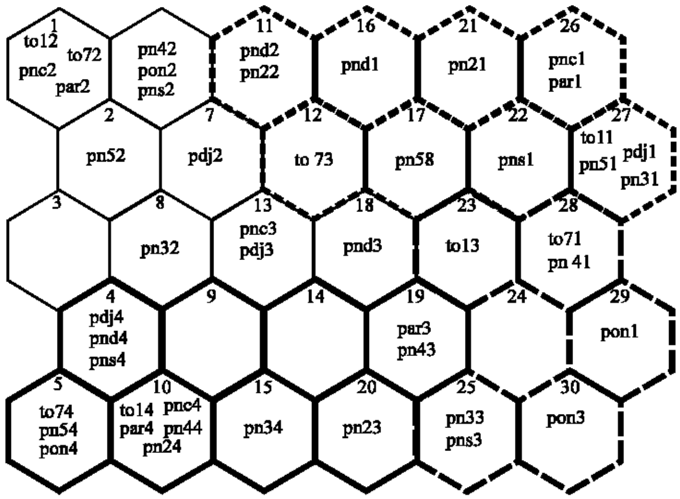

Fig. 4: Classification of samples using presence-absence data of insects during the study period

Odonata as the Libellulidae (*Libellula* sp.). In the same way, most of families were recorded only once. It is about the Dytiscidae (*Hyphydrus* sp., *Hydaticus matruelis*, *Meladema* sp.), the Chironomidae (*Ablabesmya* sp.), the Chaoboridae (*Chaoborus* sp.), the Orthocladiinae, the Baetidae (*Proclocon* sp. and Clocon sp.), the Leptophlebiidae (*Carcoterpes* sp.), the Oligoneuridae (*Elassoneuria* sp.), the Caenidae (*Caenodes* sp.), the Lestidae (*Lestes congener*), the Belostomidae (*Belostoma cordifana* and *Hydrocyrius columbiac*), the Veliidae (*Microvelia* sp.), the Notonectidae (*Corixa punctata*), the Ranatridae (*Ranatra nigra*), the Agriotypidae (*Agriotypus* sp.), the Calopteridae, Simulidae (*Simulium damnosum*) and in short the Corduliidae (*Brachytemis* sp.). Three stations situated in the centre of the lagoon (stations 5, 6, 4) and the station 12 have presented the highest species richness with respectively 35, 35, 31 and 29% of the taxa. In the seasonal way, the period of low rainy season (October-November) provided the highest species richness (69.23%) against 34.61% during the high rainy season (April-June). Also, the big and low dry seasons provided respectively 31.73 and 29.80% of the total diversity.

The Jaccard indexes calculated between stations were too low for certain of them, indicating no similarity between them. The strongest similarity was observed between stations 5 and 6, (Jaccard index > 50%; Mann-Whitney test, $p<0.05$).

The SOM classification on the basis of the presence-absence matrix gave a map composed of 30 output nodes; each node included samples with similar species (Fig. 4). The hierarchical classification analysis achieved on the matrix extracted of SOM presents 4 clusters of insects according to the minimum of Davis-Bouldin Index (DBI) (DBI = 0.8 for 4 clusters) (Fig. 5). The cluster I (Fig. 6) was constituted essentially of Diptera and Ephemeroptera species. The cluster II was mainly characterized by Beetles species and some accidental Diptera species collected during the small dry season. The cluster III was specifically composed of Odonata and Heteroptera species (Fig. 6) collected in dry seasons. In short, the cluster IV was essentially formed by samples of the high rainy season dominated by some Heteroptera and Ephemeroptera species. Diptera species were common to all clusters.

On the spatial way, the cluster II was formed of the samples located in the upstream (side Totchè channel) whereas the cluster III was constituted of the samples situated downstream (after the bridge). The clusters I and IV were constituted of samples of all stations and showed more seasonal pattern.

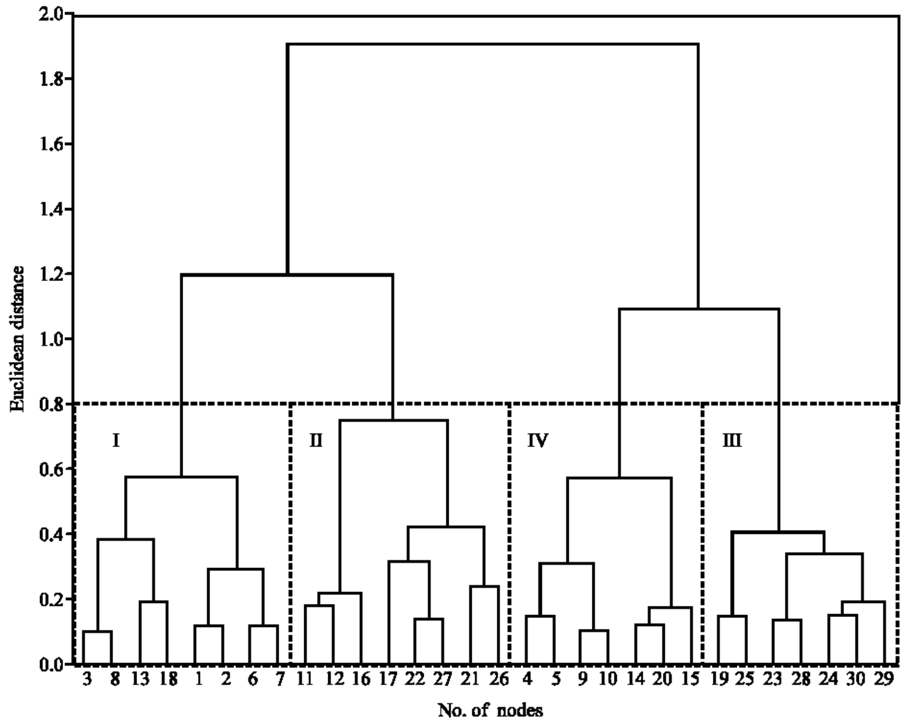

Fig. 5: Hierarchical clustering of the SOM cells with a Ward linkage method and a Euclidean distance; I, II, III and IV were the insect clusters defined

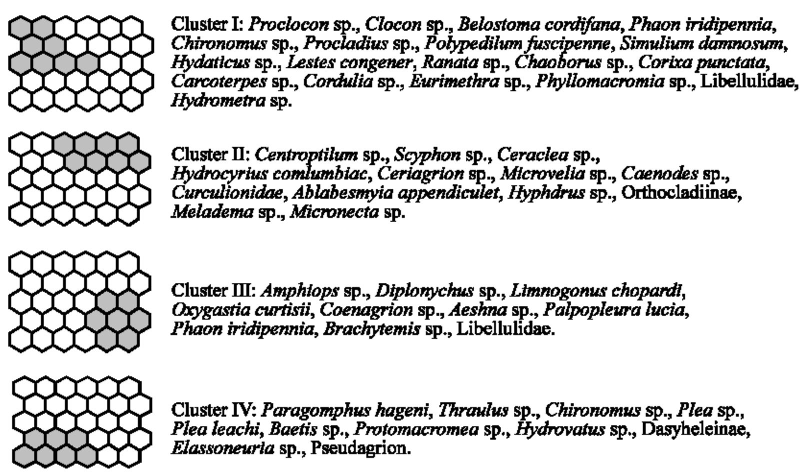

Fig. 6: Distribution patterns of insect taxa in each cluster defined by the hierarchical clustering applied on SOM map: dark color = high occurrence; light color = low occurrence (see absence)

The mean values of environmental parameters calculated by the SOM were shown in Fig. 7. Figure 7 showed a gradient distribution on the SOM map for salinity, dissolved oxygen and fine fractions except water temperature. The left superior part of the map (cluster I) was characterized by the highest values of salinity and dissolved oxygen concentration. As for the cluster II, it was characterized by the highest values of the water temperature. The group III situated in the right

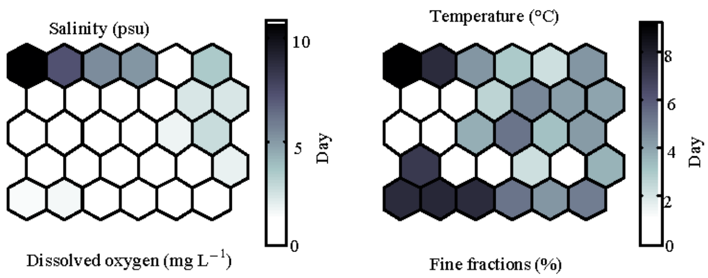

Fig. 7: Visualization of environmental variables on the SOM map according to insects taxa assemblages. (Dark/light represents high/low values)

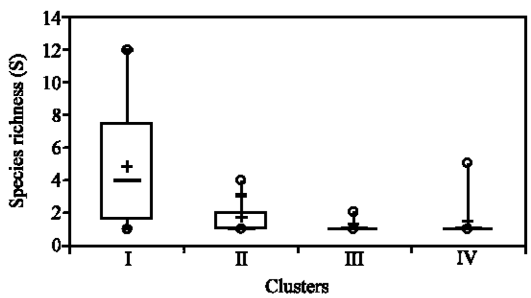

Fig. 8: Box-plots showing differences in taxonomic richness between the clusters defined by SOM. The box is corresponding to 50% of the values, the horizontal bars to the medium and vertical bars to the minimum/maximum values

bottom part of the map was defined rather by the highest percentage of fine particles. For cells situated in the left bottom part (cluster IV) of the map, it was the mean values of dissolved oxygen and fine fractions of sediment which discriminated it. Water temperature became determinant for all the clusters.

The Kruskal-Wallis test shows a highly significative difference ($p<0.05$) between clusters (Fig. 8).

DISCUSSION

The aquatic insects' fauna of the lagoon has showed a marked seasonal pattern strongly correlated with the seasonal variations of water parameters and the properties of sediments. In fact, this distribution of taxa that constituted the entomological communities of the lagoon was influenced on the one hand, by the availability of environmental resources essential for the reproduction and the growth (Di Castri and Younes, 1990) and on the other hand, by competitions. So, the high taxonomic richness gotten during the high rainy season (cluster I of the SOM map) is certainly linked to the low rates of water salinity, favourable conditions to the introduction and the reproduction of most orders of insects (Bemvenuti, 1987; Arab *et al*., 2004). The increasing number of taxa with the low value of salinity observed in the present work (less than 10 psu) has already been registered by Timms (1981) in 3 different salted lakes in Australia and by Gouvis *et al*. (2007) in Patos lagoon in Brazil. The same results have been also gotten in Ivory Coast by Edia *et al*. (2007) and Kouadio *et al*. (2008). During the recruitment period, species were submitted to a strong predation by fishes species (Huryn, 2009; Bemvenuti, 1987) among which, *Chrysischthys nigrodigitatus*, *Chrysischthys auratus*, *Monodactylus sebae*, *Pomadasys jubelini*, *Pellonula leonensis*, *Eleotris senegalensis* and some species of crustaceans as *Callinectes sapidus* that became very abundant in the lagoon and that fed insects larva. Also, this high taxonomic richness could be due to the aquatic plants proliferation that served as shelters to invertebrates against predators (Jonathan and Lee, 2006) and provided them as well as food and solids into which larva could cling to and even served of materials for nests construction (Jonathan and Lee, 2006). The predation and the high water temperatures and salinity rate during the dry seasons explained the low species richness obtained in the clusters III and IV. It resulted that either a high mortality rate, or that most orders of insects becoming adults have an aerial or terrestrial life. Also, in the lagoon intensive anthropic activities took place and concerned the fishing, the navigation and the extraction of the sand of the lagoon. In fact, thousand of tons of lagoon sand were extracted for the sale in industrial scale and this activity became more intense during the dry seasons. This extraction destroys habitats constituting real threats for the organisms' survival. The presence of acadjas, a fishing technique very developed in the lagoon contributed to the low rates of dissolved oxygen concentration, an eutrophisation that could be attributed not only to the organic pollution but also to the aquatic plant proliferation during the rainy seasons. Consequently, environmental stress reduced the community to a small number of species that can tolerate a wide range of conditions, reproduce rapidly when conditions were favourable and exhibited marked fluctuations in community structure.

Among dominant taxa, Heteroptera and Ephemeroptera were very abundant and diversified during the rain seasons whereas Beetles were more present during the dry seasons. The Chironomidae were more tolerant and are met in all seasons. The diversity increased to the upstream to the downstream. A lot of species recorded like Diptera and Coleoptera species were not characteristic of a single habitat. Such a pattern agreed better with the concept of a continuum of communities along an environmental gradient (Mills, 1969), biological continuum that characterizes the semi-closed ecosystems (Bazairi *et al*., 2003) as the Porto-Novo lagoon that doesn't communicate directly with the sea. Such ecosystems have been described by several authors as Atlantic coast, the estuary of Dormouse in France (Robineau, 1987). Also, lots of species identified have low richness (cluster IV). This aspect revealed that the lagoon was threatened by anthropic disturbances. The explanation of these observations is probably the big tolerance of benthic organisms to the physical chemical fluctuations of water that favoured the high occurrence of Diptera species so resistant to pollution. However, the use of networks neuron permitted to identify assemblages along this continuum in relation with gradients of water parameters despite the high number of accidental species.

In sum, this survey on the insects' fauna of the Porto-Novo lagoon was the first in the field and constituted a baseline for the further studies that can help achieve sustainable development and managed conservation. These first studies must mark the opening of new perspectives as for the assessment of the biological quality of aquatic ecosystems in our country. It would be interesting to explore several ecological microhabitats and consider some chemical (nitrates, phosphates, DBO), lithological and geomorphologic parameters to better characterize the different ecosystem typology. It will allow to acquire a better knowledge on the insects' tolerance to the water pollution, necessary in the monitoring of habitat integrity.

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REFERENCES

Arab, A., S. Lek, A. Lounaci and Y.S. Park, 2004. Spatial and temporal patterns of benthic invertebrate communities in an intermittent river (North Africa). Ann. Limnol. Int. J. Limnol., 40: 317-327.

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling, 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers Periphyton Benthic Macroinvertebrates and Fish. 2nd Edn., U.S. Environmental Protection Agency, Washington, DC.

Bazairi, H., A. Bayed, M. Glemarec and C. Hily, 2003. Spatial organization of macrozoobenthic communities in response to environnemental factors in a coastal lagoon of the NW African coast (Merja Zerga, Morocco). Oceanologica Acta, 26: 457-471.

Bemvenuti, C.E., 1987. Predation effects on a benthic community in estuarine soft sediments. Atlantica, 9: 5-32.

Brosse, S., S. Lek and C.R. Townsend, 2001. Abundance, diversity and structure of freshwater invertebrates and fish communities: an artificial neural network approach. N. Z. J. Mar. Freshwater Res., 35: 134-145.

Cafferty, M.C. and W. Patrick, 1981. Aquatic Entomology. The Fishermens and Ecologists Illustrated Guide to Insects and their Relatives. Jones and Bartlett Publishers, Boston.

Christopher, G.M., J. Klimaszewski and R.F. Lauff, 2008. The coastal rove beetles (Coleoptera, Staphylinidae) of Atlantic Canada a survey and new records. ZooKeys, 2: 115-150.

Clarke, K.R. and R.M. Warwick, 1994. Changes in marine communities: An approach to statistical analyses and interpretation. J. Zool., 166: 323-335.

Dejoux, C.J., M. Elouard, P. Forge and J.L. Maslin, 1981. Catalogue iconographique des insects aquatiques de Cote d'Ivoire [Iconographical Catalogue of aquatic insects of Ivory Coast]. Report ORSTOM, Bouake, Ivory Coast.

Di Castri, F. and T. Younes, 1990. Fonction de la biodiversité biologique au sein de l'ecosysteme. Acta Oecologica, 11: 429-444.

Edia, O.E., S. Brosse, A. Ouattara, G. Gourene, P. Winterton and S. Lek-Ang, 2007. Insect assemblages patterns in four West-African Coastal Rivers. J. Biol. Sci., 7: 1130-1138.

Gevrey, M., J.L Giraudel, L. Ector, S. Lek, F.R. Rimet and Y.S. Park, 2004. Water quality assessment using diatom assemblages and advanced modelling techniques. Freshwater Biol., 49: 208-220.

Giraudel, J.L. and S. Lek, 2001. A comparison of Self-Organizing Map and some conventional statistical methods for ecological community ordination. Ecol. Modelling, 146: 329-339.

Gouvis, N., T. Kevrekidis and A. Koukouras, 2007. Temporal changes of a macrobenthic assemblage in Evros Delta (North Aegean Sea). Internationale Revue Gesamten Hydrobiologie Hydrographie, 82: 67-80.

Hopton, M.E. and A.L. Mayer, 2006. Using self-organizing maps to explore patterns in species richness and protection. Biodiversity Conserv., 15: 4477-4494.

Huryn, A.D., 2009. Aquatic Insects-Ecology, Feeding and Life History. Elsevier, USA., pp: 132-143.

Ibarra, A.A., Y.S. Park, S. Brosse, Y. Reyjol, P. Lim and S. Lek, 2005. Nested patterns of spatial diversity related for fish assemblages in a west European river. Ecol. Freswater Fish, 14: 233-242.

Jonathan, H.P. and F.A. Lee, 2006. Aquatic invertebrate responses to fish presence and vegetation complexity in Western Boreal wetlands, with implications for Waterbird productivity. Wetlands, 26: 1-12.

Kohonen, T., 1982. Self-Organizing formation of topologically correct feature maps. Biol. Cybernetcics, 43: 59-69.

Kohonen, T., 2001. Self-Organizing Maps. 3rd Edn., Springer-Verlag, Berlin, Germany.

Kouadio, K.N., D. Diomande, A. Ouattara, Y.J.M. Kone and G. Gourene, 2008. Taxonomic diversity and structure of benthic macroinvertebrates in Aby lagoon (Ivory Coast, West Africa). Pak. J. Biol. Sci., 11: 2224-2230.

Legendre, P. and L. Legendre, 2001a. Book Revew. 2nd Edn., Elsevier Science BV, Amsterdam.

Legendre, P. and L. Legendre, 2001b. Numerical ecology. J. Classification, 18: 285-288.

Lek, S., M. Delacoste, P. Baran, I. Dimopoulos, J. Lauga and S. Aulagnier, 1996. Application of neural networks to modelling nonlinear relationships in ecology. Ecol. Modelling, 90: 39-52.

Mills, E.L., 1969. The community concept in marine zoology with comments on continuum and instability in some marine communities: A review. J. Fish. Res. Board, 26: 1415-1428.

Park, Y.S., R. Cerephino, A. Compin and S. Lek, 2003. Application of artificial neural networks for patterning and predicting aquatic insect species richness in running waters. Ecol. Modelling, 160: 265-280.

Pearson, T.H. and R. Rosenberg, 1978. Macrobenthic succession in relation to organic enrichment and pollution of marine environment. Oceanogr. Mar. Biol. Ann. Rev., 16: 229-311.

Robineau, B., 1987. Caracterisation des peuplements macrozoobenthiques de l'estuaire de la Loire Characterization of the Loire estuary macrozoobenthic assemblages. Vie Milieu, 37: 67-76.

Rosa, L.C. and C.E. Bemvenuti, 2006. Temporal variability of the estuarine macrofauna of the Patos Lagoon, Brazil. Revista Biología Marina Oceanografía, 41: 1-9.

Tachet, H., P. Richoux, M. Bourneau and P. Usseglio-Polatera, 2003. Invertebres d'eau douce: Systemetique, biologie, ecologie. http://www.nhbs.com/invertebrates_deau_douce_systematique_biologie_ecologie_tefno_112427.html.

Timms, B.V., 1981. Animals communities in three Victorian lakes of differing salinity. Hydrobiologia, 81: 181-193.

Vesanto, J. and E. Alhoniemi, 2000. Clustering of the self-organizing map. IEEE Trans. Neural Networks, 11: 586-600.

Warvick, R., M. Pearson and T.H. Ruswahyuni, 1987. Detection of pollution effects on marine macrobenthos: Further evaluation of the species abundance/biomass method. Mar. Biol., 95: 193-200.

Zwlck, P., 2004. Key to the West Palaearctic genera of stoneflies (Plecoptera) in the larval stage. Limnologica Ecol. Manage. Inland Waters, 34: 315-348.