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Ecology of aquatic heteropters of two ponds with endemicity different from Buruli ulcer in the south of Cote d'ivoire (West Africa)

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Abstract
Heteroptera generally colonize most aquatic ecosystems and play an important vector role in the spread of Buruli ulcer. This study aims to determine the diversity and distribution of Heteroptera species in the two pools of Sokrogbo and Vieil Aklodj in southern Côte d'Ivoire. Heteropteran fauna is sampled monthly from January to December 2016 using a Troubleau net. Physico-chemical parameters of the water bodies visited are determined using standard protocols. The results show a total of 35 taxa, belonging to 9 families of heteropterans, at the two study sites. The number of taxa is respectively 32 and 25 at Sokrogbo and at Vieil Aklodj. Among the sampled taxa, *Micronecta scutellaris*, *Diplonychus nepoïdes*, *Diplonychus sp*., *Anisops sp*. and *Ranatra fusca* are the most abundant species. The indices Shannon Wiener, Equitability, Margalef and Evenness show that the Sokrogbo pond has a greater diversity than vieil Aklodj and that the differences are significant. The distribution of taxa in both pools depends on environmental variables such as conductivity and concentrations of nitrates, nitrites and phosphorus, which would be related to agricultural activities. The Sokrogbo fauna is therefore more diversified in aquatic Heteroptera than that of Vieil Aklodj, which could be due to environmental conditions and maintain the hyperendemicity of Sokrogbo to Buruli ulcer.

Keywords: Diversity, abundance, heteroptera, pond, sokrogbo, vieil aklodj

Introduction
The pools are small expanses of water, shallow. They are of natural or anthropogenic formation, being in impervious depressions, in rural, periurban, even urban context [1]. They play an important economic role through use in agricultural holdings, domestic consumption and the functions of livestock watering facilities. Ecologically, ponds are a diverse ecosystem and are very important habitats for many species of plants, crustaceans, fish, birds, and insects [2], [3]. Among the insects, the heteropterans would act as phoretic vectors of *Mycobacterum ulcerans*, a bacterium responsible for Buruli ulcer [4], [5]. Certain environments, mainly influenced by human activity, such as agriculture and rural areas, associated with the proximity of stagnant water are favorable to the presence of *M. ulcerans* in areas endemic for Buruli ulcer [6].
In Côte d'Ivoire, according to the National Buruli Ulcer Control Program (PNLUB), the health districts of Tiassalé and Dabou are respectively hyper endemic and meso-endemic for Buruli ulcer. Although the diversity and distribution of aquatic insects has been studied in several ecosystems [7, 8], few heteropteran studies have been conducted in temporary and permanent waters in Côte d'Ivoire. Our work aims to compare the dynamics and abundance of aquatic Heteroptera in two pools to assess species richness and diversity. This will allow us to better understand the role of aquatic Heteroptera in the transmission of Buruli ulcer in these environments.

Material and Methods
Field of study
The study was carried out in the health districts of Tiassalé and Dabou respectively, in the pools of the villages of Sokrobgo (SO) and Vieil Aklodj (VA). These two districts of southern Côte d'Ivoire benefit from a climate with a bimodal cycle marked by four seasons: two dry seasons and two rainy seasons. The average annual rainfall in the two departments is 1500 mm of rain, with average temperatures ranging from 26 to 27 °C.

The vegetation around the pond of Sokrogbo appears today largely degraded by the human activity. This pond is influenced by rice crops, vegetables, and the almost permanent presence of herds of oxen who come to drink. The vegetation around the pond of Vieil Aklodj, as in the Dabou Health District as a whole, consists mainly of many industrial plantations including rubber, oil palm, banana, among which are some formations forest and fallow land. This pond is therefore covered by a shady cover avoiding permanent exposure to sunlight.

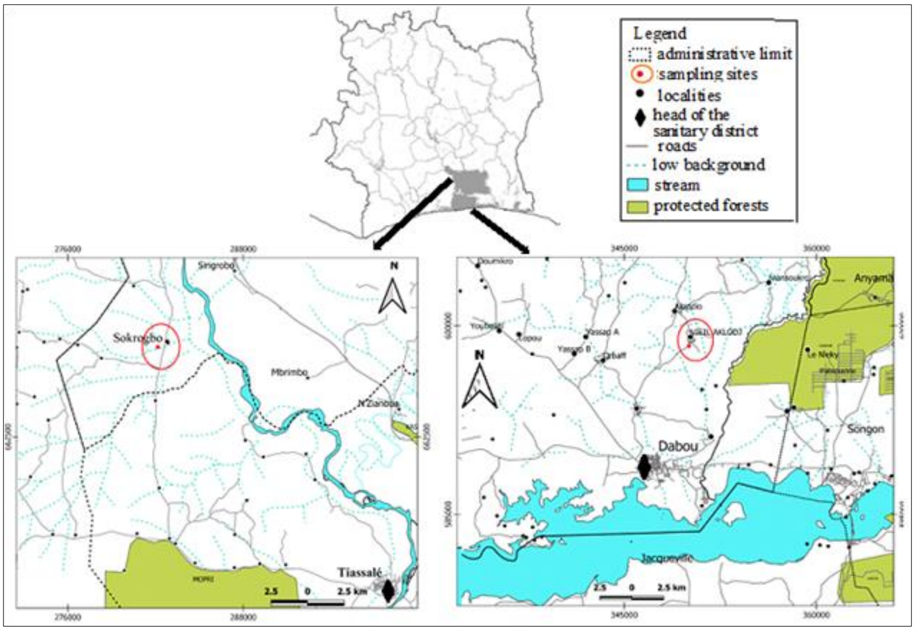

Figure 1: Location of Sokrogbo and Vieil Aklodj sampling sites in the Tiassalé and Dabou districts.

Measurement of physicochemical parameters

The physicochemical parameters of the water bodies visited were determined using standard protocols. Measurements were made in situ prior to insect sampling, using a Wagtech portable multi parameter probe for electrical conductivity, turbidity, temperature and pH of water, and a WTW oximeter. (OXY 340i) for the percentage of dissolved oxygen. Levels of manganese, phosphorus, nitrate, nitrite, iron were measured in the laboratory using a HACH molecular absorption spectrophotometer according to Murphy and Riley [9]. To do this, samples of water from the pond are brought from the sampling site in a cooler with cold accumulators.

Sampling of aquatic Heteroptera

The insects were collected monthly, from January to December 2016, using a Troubleau net. Three subsamples, at 10 shots per sub-sampling, were carried out in each pool. The contents of the net were dumped in a tray and then sieved using a strainer of 0.5 mm mesh vacuum. At the end of the collection, a first sorting was done in situ. All living creatures in each subsample were kept in pots with pond substrates to prevent drowning and death during transport to the laboratory.

Identification of collected insects

The identification and enumeration of the specimens were done at the laboratory of the Entomology and Herpetology Unit of the Institut Pasteur of Côte d'Ivoire. All specimens were identified under a binocular magnifying glass at 10 x magnification (0.7-4.5), to the species where possible, using assays [10, 11, 12, 13, 14].

Data analysis

■ The wealth index used was the Margalef (R) Index. This index indicates the number of species in a sample or the abundance of the species per unit area [15].

■ The degree of species composition or species diversity (H ') at each site was determined using the Shannon Wiener Index. This index indicates the degree of species composition per unit area [15].

■ Fairness can be used to assess the quality of stand organization [16, 17].

■ The homogeneity or pattern of species distribution relative to other species in a sampling unit was calculated using the equilibrium index, (E) [15].

Results

Abundance and diversity of aquatic Heteroptera

A total of 35 Heteroptera taxa belonging to 9 families were collected at the study sites (Table 1). The family Naucoridae with 8 taxa was the most diverse; this was followed by Nepidae and Belostomatidae with 5 taxa. In the Pleidae and Veleidae, only one taxon has been inventoried. Twenty-two taxa were found at both SO and VA. In contrast, ten and three taxa were sampled only at SO and VA, respectively. The taxonomic richness varied according to the study sites: 32 taxons collected at SO against 25 taxons at VA.

Sampling made it possible to collect 1621 individuals at SO and 920 at VA. The most common species found in both study sites were *Micronecta scutellaris* (48.3% SO, 32.72% VA) and *Diplonychus nepoides* (7.34 SO, 27.93 VA). Other species such as *Diplonychus sp* (4.87% at SO, 25% at VA), *Anisops sp* (7.34 to SO, 0.98 to VA) and *Ranatra fusca* (5.06 to SO, 3.15 to VA) have a variable abundance depending on the station. In general, scores for all ecological indices were higher at SO than at VA. This trend was first observed for the Margalef index, where the SO and VA specific richness were 4.063 and 3.517, respectively.

According to the Shannon Weiner index, a greater diversity of heteropterans was noted at SO with a value of 2.064, whereas VA obtained a score of 1.705.SO demonstrated that the fairness was greater than 0.254, followed by VA with 0.220. Significant differences were observed between the number of taxa (z = -2.12, P = 0.0333) and the number of individuals (z = -2.79, P = 0.0052) between the two sites of sampling.

Table 1: Taxonomic list and relative abundance of Heteroptera sampled in two ponds in Côte d'Ivoire

Famille	Taxons	Acronymes	SO	VA
Belostomatidae	*Diplonychus annulata**	Dipan	0,68	–
	Diplonychus nepoïdes	Dipne	7,34	27,93
	Diplonychus sp	Dipsp	4,87	25,00
	*Belostoma cordofana**	Belco	0,37	–
	*Lethocerus sp**	Letsp	0,43	–
Pleidae	*Plea pullula*	Plepu	4,26	0,76
Notonectidae	*Anisops sardea*	Anisa	4,75	0,22
	*Anisops stali**	Anist	1,67	–
	Anisops sp	Anisp	7,34	0,98
	Enithares sp	Enisp	0,37	0,11
Naucoridae	*Heleocoris breviceps*	Helbr	1,3	0,22
	Heleocoris sp	Helsp	1,48	0,11
	*Laccocoris sp**	Lacsp	0,8	–
	Macrocoris laticollis	Macla	0,49	0,33
	Macrocoris flavicollis	Macfl	0,06	0,11
	*Naucoris maculatus**	Nauma	0,12	–
	Naucoris sp	Nausp	0,49	0,22
	Neomacrocoris sp	Neosp	0,06	0,11
Nepidae	*Laccotrephes ater*	Lacat	0,68	2,50
	Laccotrephes brachialis	Lacbr	0,06	0,33
	Laccotrephes ruber	Lacru	0,06	0,65
	Laccotrephes sp	Lacps	0,12	0,87
	*Laccotrephes fabricii***	Lacfa	–	0,43
Ranatridae	*Ranatra fusca*	Ranfu	5,06	3,15
	*Ranatra sp**	Ransp	0,19	–
	Cercotmetus sp	Cersp	2,04	0,11
Corixidae	*Stenocorisea protrusa**	Stepr	0,43	–
	Micronecta scutellaris	Micsc	48,3	32,72
	Micronecta sp	Micsp	4,94	2,17
	*Sigara sp**	Sigsp	0,49	–
Veleidae	*Microvelia sp*	Micsp	0,12	0,33
Gerridae	*Eurymatra sp*	Eursp	0,37	0,11
	*Limnogonus chopardi**	Limch	0,25	–
	*Limnogonus sp***	Limsp	–	0,33
	*Rhogardotarsus hutchinsoni***	Rhohu	–	0,22

NB: * = Taxon sampled only at SO; ** = taxon sampled only at VA.

Environmental variables

The results of the descriptive analysis of the physico-chemical parameters measured in the pools of Sokrogbo and Vieil Aklodj are shown in Table 2. The dissolved oxygen and phosphorus levels are comparable between the two pools. All other measured parameters revealed a significant difference (p <0.005) between the two pools. There are also higher values of pH, temperature, turbidity, electrical conductivity of water, nitrate, nitrite and iron levels at Sokrogbo. However, this station has lower values of manganese compared to the values measured at Old Aklodj.

Table 2: Physico-chemical variables of the Sokrogbo (SO) and Vieil Aklodj (VA) pools (Côte d'Ivoire) measured between January and December 2016

	Vieil Aklodj					Sokrogbo					Test U Mann Whitney
	Min	Max	Med	Mean	SD	Min	Max	Med	Mean	SD	
T ° water (°C)*	21.00	28.00	24	24.93	0.18	24.00	29.00	27	26.94	0.11	0.0001
pH water*	4.60	7.10	6.10	5.96	0.06	6.30	6.80	6.60	6.62	0.01	0.01
Turbidity (NTU)*	2.33	13.40	5.63	6.57	0.27	11.40	1044.00	43.90	167.41	20.82	0.0001
Conductivity (µS/cm)*	19.70	243.00	33.40	71.38	5.97	80.40	1910.00	128.10	224.88	17.25	< 0.0001
O2 dissolved (mg/l)	1.09	4.64	1.84	1.93	0.06	1.14	4.23	2.06	2.07	0.06	0.743
Tx Maganese (µg/l)*	75.50	75.50	75.50	75.50	0.00	49.00	49.00	49	49.00	0.00	< 0.0001
Tx Phosphorus (mg/l)	0.04	2.35	0.77	0.87	0.06	0.07	2.57	0.69	0.70	0.05	0.078
Tx Nitrate (mg/l)*	0.30	6.50	1.21	1.53	0.13	1.15	8.12	2.94	2.95	0.13	< 0.0001
Tx Nitrite (mg/l)*	0.01	0.81	0.05	0.08	0.01	0.03	0.75	0.29	0.30	0.01	< 0.0001
Tx Iron (mg/l)*	0.34	0.95	0.60	0.61	0.02	0.93	6.46	3.35	3.35	0.13	< 0.0001

Correlation of environmental species-variables

The correlation between the population distribution of aquatic Heteroptera and the environmental variables of the two pools has been demonstrated by the canonical correspondence analysis (Fig 2). Only the I (λ1 = 0.200) and II (λ1 = 0.011) axes were considered in the data analysis. Axis I separates the species into two groups A and B. Group A is composed of A. stali, L. accocor, S. protr, L. chopa, L. ethocer, N. macul, Sigara, B. cordo, Anisops, Ranatra, Naucoris, Heleocor, Hsbrev, D annul, Enithare, Eurymatr, P. pullu, Cercotm. These species associated with the pond of Sokrogbo are negatively correlated with the variables electrical conductivity of the pond, iron, nitrite and nitrate rates on the axis I. The second group of species is composed of the taxa L. ater, M. flavi, L. ruber, Neomocra, D. nepoï, Micronec, M. latic, M. scute, L. brach, R. hutch, R. fusca, Laccotre, Microvel, L. fabri, Limnogon. These taxa associated with Vieil Akrodj's pond are positively correlated with these physicochemical variables on axis I.

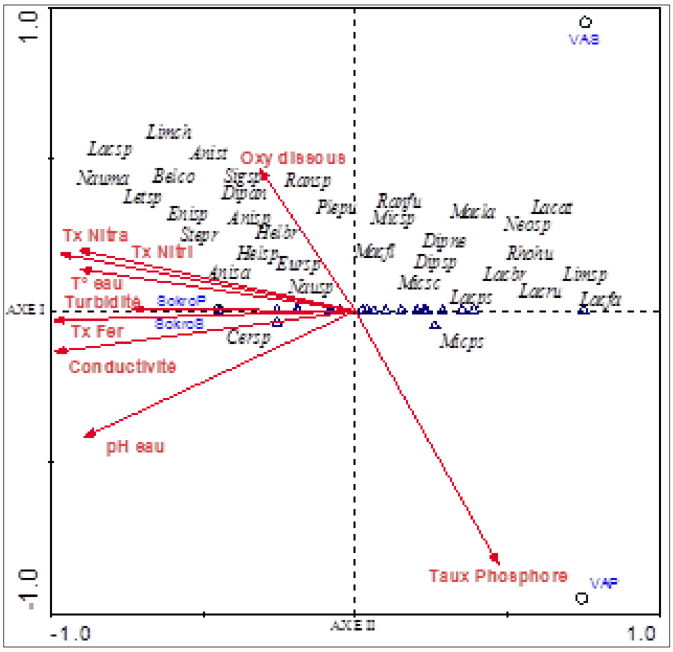

Fig 2: Canonical correspondence analysis showing the relationship between environmental variables and the Heteroptera abundance of the different study sites between January and December 2016.

Discussion

The analysis of the environmental characteristics of the two sites visited indicates the existence of particular ecological characteristics for the two studied ponds. This indication is fundamental because variations in abiotic factors can explain the distribution of aquatic species with a dominant contribution of an environmental variable [18]. Comparative analysis of physico-chemical data revealed higher values of all water variables measured at Sokrogbo apart from manganese, which had rather high values at Vieil Aklodj. This result would be the consequence of the cumulative effect of climatic factors and anthropogenic actions. Indeed, the pond of Sokrogbo undergoes the effect of a climate of savannah by its situation in transition zone savannah-forest [19]. This vegetation offers a climate favorable to sunshine unlike the pond of Vieil Aklodj located entirely in forest area. This gives it a dense vegetation that affects the microclimate of the area. In addition, Doannio *et al*. [4] reported strong agricultural activity in Sokrogbo with a predominance of lowland rice cultivation. Turbidity, 20 times higher in Sokrogbo compared to Old Akrodj, is linked to this strong agricultural activity in the area. In agreement with Rossetti *et al*. [20], the organic loads in the water are probably a consequence of the leaching of the cultivated fields in the surroundings. In addition to water runoff from the watershed, intensive agro-pastoral activity has been observed around the pond at Sokrogbo, which is used for cattle watering. Intense numbers of animals and animal manure observed during the sampling periods may explain the high nitrogen compounds and electrical conductivity in the pond at Sokrogbo. This would be amplified by household activities, washing and bathing the local populations.

The taxonomic structure of the heteropterans obtained in the two study sites was characterized by 35 taxa and 9 families such as Belostomatidae, Pleidae, Notonectidae, Naucoridae, Nepidae, Ranatridae, Veleidae and Gerridae. These results indicate that aquatic insect fauna is more diverse than in previous studies. In fact, 13 taxa belonging to 8 families were collected in the same study areas [21], which should be related to the duration and frequency of sampling. Indeed, Doannio *et al* [4] conducted a sampling from May to August, while this study was conducted monthly over a year.

Differences were observed in species composition, abundance and diversity of Heteroptera fauna in both pools, SO and VA. The highest species richness (91.42% of all species) and highest abundance (63.80% of all species) were recorded at SO. Of 32 identified aquatic Heteroptera taxa, ten were recorded exclusively in this pond. The difference in taxonomic richness is confirmed by the greater value of Shannon's indices. One of the main parameters influencing the taxonomic richness and composition of insects is forest density. The VA pond is located at the highest altitude in a dense forest, which could explain the smallest number of species. The experiments of We *et al*. confirm it [22]; they found that altitude as a geographic parameter is the main factor correlated with the distribution of aquatic insects. In general, the number of species is higher in open habitats because one of the most important factors in the dispersal of flying aquatic insects is the polarotactic detecting of water masses [23], which has a positive influence on colonization [24].

Like taxonomic richness, the abundance of major taxa was higher at SO than VA. Among the taxons obtained, *Micronecta scutellaris* (Corixidae), *Diplonychus nepoides* (Belostomatidae), *Diplonychus sp* (Belostomatidae), *Anisops sp* (Notonectidae) and *Ranatra fusca* (Ranatridae) were the most abundant. The results of this study are consistent with the work of Doannio et al. [4] where *Micronecta sp* (Corixidae) accounted for more than 78% of the total abundance of SW aquatic insects. According to several authors [25], [26], [27], each family of heteroptera differs considerably in terms of morphology and ecological preferences. In rivers, they are found along the shallow water margins (Corixidae), on the water surface of the lentic brook (Gerridae and Veliidae) zones and the lotic stream areas (some Veliidae), and among aquatic vegetation (Belostomatidae, Notonectidae, Nepidae and Naucoridae). They can also be found under rocks in fast-flowing waters (some Naucoridae). Differences in diversity and abundance of taxa can also be explained by environmental variables. Among these variables, concentrations of nitrite, nitrate, iron and conductivity were identified as the highest factors influencing the distribution and development of Heteroptera. In fact, these high concentrations are linked to intense human activities, especially agricultural activities. The main consequences of these activities are the reduction of forests, the modification of biodiversity, the deterioration of soils and even desertification. Various studies have shown that insect assemblages are sensitive to human activities [28], [29], [30]. In addition, pesticide spraying in agricultural fields poses a threat to the biotic integrity of ponds. Sandin and Johnson [31] and Ravera [32] have estimated that the diversity and biotic indices of aquatic ecosystems could be influenced by pollution.

Conclusion

In this study, the number of taxa and heteropteran abundance was higher at Sokrogbo than Vieil Aklodj. The taxonomic richness and abundance of Sokrogbo Heteropteran species may justify the hyperendemic character of the Buruli ulcer zone. Indeed, previous studies have shown the presence of *Mycobacterium ulcerans* in the salivary glands of some aquatic Heteroptera that may be potential vectors of Buruli ulcer.

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