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Impact of anthropogenic activities on water quality and Freshwater Shrimps diversity and distribution in five rivers in Douala, Cameroon

Tchakonté Siméon[1,2*], Ajeagah Gideon[1], Diomandé Dramane[2], Camara Adama Idrissa[2], Konan Koffi Mexmin[2], Ngassam Pierre[1]

[1]*Laboratory of Hydrobiology and Environment, Faculty of Science, University of Yaoundé I, PO BOX: 812 Yaoundé, Cameroon*

[2]*Laboratoire d'Environnement et de Biologie Aquatique, UFR-Sciences et Gestion de l'Environnement, Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire*

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Abstract

Shrimps are an important source of proteins for human beings and a considerable food webs component of invertebrate assemblages in tropical freshwater rivers. In order to determine shrimps diversity and to assess the impact of anthropogenic activities on their distribution, 12 sites were monitored; two of these located in a periurban forest area and the rest situated in urbanized and industrialized zones. Samplings were carried out monthly from September 2012 to September 2013, and shrimps were collected using a long-handled net (30x30 cm side, 400-µm mesh). Meanwhile, measurements of the environmental variables were taken. This study achieved for the first time in the Douala watershed permitted to put in evidence 7 freshwater shrimp species, *Caridina africana* (Kingsley, 1882), *Caridina nilotica* (Roux, 1833), *Macrobrachium thysi* (Powell, 1980), *Macrobrachium scabriculum* (Heller, 1862), *Macrobrachium equidens* (Dana, 1852), *Desmocaris trispinosa* (Aurivillius, 1898) and *Potamalpheops* sp (Powell, 1979) belonging to 4 families (Atyidae, Palaemonidae, Desmocarididae and Alpheidae). Among these species *M. thysi* a large-egged species which was said to be endemic to Ivory Coast, appear to be a first record for Central Africa. *C. africana* and *D. trispinosa* were the most abundant with respectively 50.41% and 36.07% of total abundance. All these species were present only at the two suburban sites, no specie being found in urban zone. Physicochemical analysis revealed the very poor health status of urban streams with highly polluted water, while periurban streams have very good water quality. Redundancy Analysis and Monte Carlo tests showed a spatial distribution of the shrimp community which is significantly influenced by conductivity, total dissolved solids, dissolved oxygen, turbidity, alkalinity, ammonium, nitrate, phosphate, Biochemical Oxygen Demand, canopy coverage and water depth. It is thus clear that, bad management of urban and industrial wastes contributes to damage the water quality and induce the extinction of freshwater shrimp species.

***Corresponding Author:** Tchakonté Siméon ✉ tchakontesimeoon@yahoo.frm

Introduction

Urban water management – and the impacts that rapid population growth, industrialization and climate change are having on it – is gaining increasing attention worldwide (Carden and Armitage, 2013). The pollution produced by the urban, industrial and agricultural activities exerts considerable pressures on aquatic ecosystems, which result in a deterioration of the water and habitats quality on which the aquatic organisms depend (Wang *et al.,* 2012; Morrissey *et al.,* 2013). Aquatic organisms integrate various types and degrees of environmental impacts which occur on a variety of spatial and temporal scales (Colas *et al.*, 2014). They permit to obtain a much more precise frame of the integrity of an ecosystem (Schuwirth and Reichert, 2012; Borics *et al.,* 2013). Meanwhile, in almost all the Cameroonian metropolis, various origins of wastewater and solid wastes are discharged directly in nature without any preliminary treatment (Tening *et al.,* 2013a). In Douala Township which is the most densely populated and industrialized area of Cameroon, the problem of pollution is more acute and complex. Indeed, in this city urbanization is anarchic with precarious sanitation systems, dwellings and industrial buildings are blended in the same place. This leads to severe promiscuities, and consequently to the omnipresence of pollution sources (Feumba *et al.,* 2011; Schuetze and Chelleri, 2013). It is then imperative, for any policy of conservation, durable and rational use of the ecosystems, to evaluate the health status of organisms present in the medium (Garcia-Roger *et al.,* 2011).

In Africa, very few works were devoted to the loss of biodiversity as response to the deterioration of the medium (Lévèque & Paugy, 1999; N'Zi *et al.,* 2008; Camara *et al.,* 2009). In Cameroon very few studies were led in this research axis, and a few related works are focused upon the relations existing between the environmental variables and fish fauna (Kamdem Toham and Teugels, 1998) or the dynamics of the benthic invertebrate communities (Foto *et al.,* 2011, 2012 and 2013). Regarding Cameroonian freshwaters shrimps, data on their systematic, biology and ecology are quasi-non-existent. However, shrimps may be present in the majority of Cameroonian rivers and may be good bioindicators (Foto *et al.,* 2011 and 2013). To our knowledge, no study has so far dealt with diversity and ecological requirements of shrimp in Cameroonian rivers.

This study undertaken for the first time in the rivers of the Douala Township, aims to inventory freshwater shrimp species and to evaluate the impact of the urban and industrial wastes on their diversity and distribution.

Materials and methods

Study area and sampling stations

Douala city is located at the bottom of the gulf of Guinea, along the estuary of the Wouri River. With an approximate surface of 38700 ha, this city extends between 3°58' - 4°07' of latitude Nord and between 9°34' - 9°49' of longitude East. It presents a plain spread out morphology with altitudes varying between 1.6 and 39 m (Olivry, 1986), under a wet tropical climate of Cameroonian type, characterized by two seasons that are: a long rainy season (March to November) and a short dry season (December to February) (Suchel, 1972). Rainfalls are abundant and regular with the annual average values varying between 2596 mm and 5328 mm. The air temperature is relatively high with a monthly average of approximately 28 °C (Suchel, 1972).

Samplings were carried out monthly, from September 2012 to September 2013 in 12 stations located in the three larger contiguous watershed basins (Tongo'a-Bassa, Nsapè and Mgoua), situated at the left bank of the Wouri River (Fig. 1).

In the watershed of Nsapè located in a priurban area particularly covered by vegetation of a secondary dense forest type, and sheltered of any urban and industrial activity, two stations (N_1 and N_2) were chose.

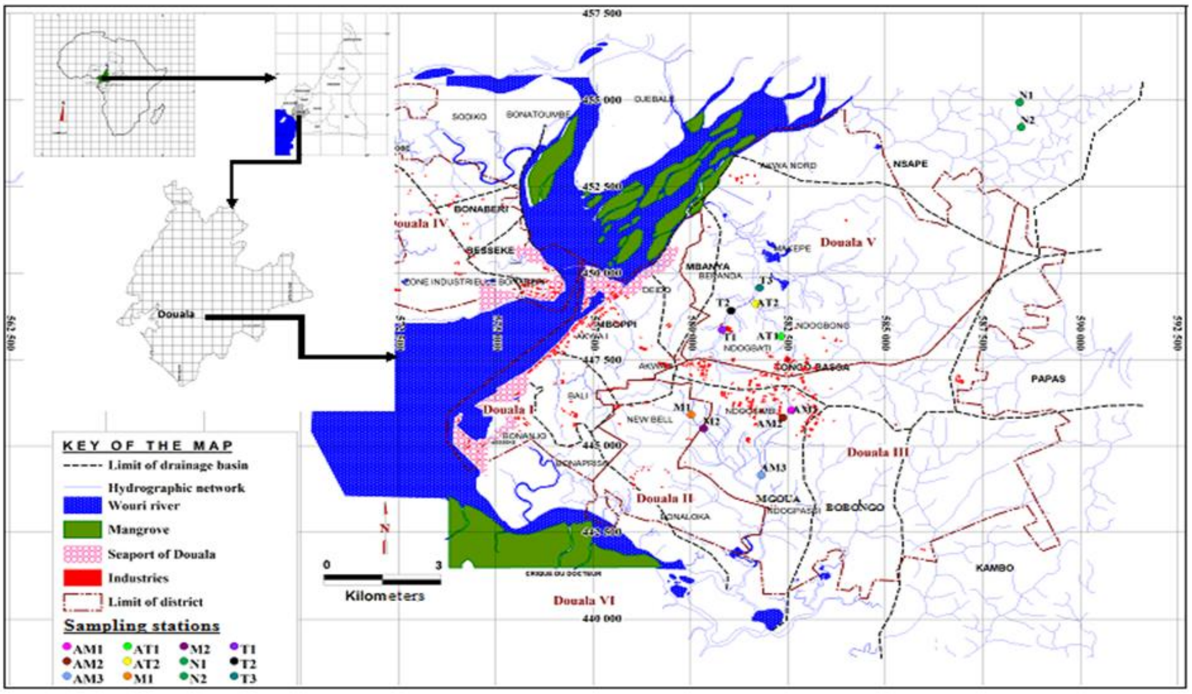

Fig. 1. Hydrographic map of the study areas showing sampling stations.

Contrariwise, the watershed basins of Tongo' a-Bassa and Mgoua are located in a full urban centre strongly industrialized and highly disturbed by human activities. In these river basins, several industries pour their effluents and other wastes directly in the environment without preliminary or adequate treatment. As far as, rivers constitute the principal dump and an excellence way to evacuate domestic and urban wastes in the wedged zones. Ten sampling stations were selected in this urban area: stations T_1, T_2, T_3, AT_1, and AT_2 (Tongo' a-Bassa river basin); stations M_1, M_2, AM_1, AM_2 and AM_3 (Mgoua river basin). The stations T_1 and T_2 are located respectively at 350 m upstream and 200 m downstream from the outlet of the effluent of an industry of chocolate factory and confectionery. Stations AT_1 and AT_2 are located respectively at 100 m and 3.5 km downstream from the outlet of a mixture of effluents coming from a brewery industry, a textile industry and an industry of manufacture of glasses. While station T_3 is located at 500 m downstream from the junction of the two preceding arms. The stations M_1 and M_2 are respectively localized at 350 m upstream and 250 m downstream from the outlet of the collection of effluents coming from the great Industrial Center of Bassa. This center shelters several industries exerting in various fields (Agro-alimentary, brewery, textile, chemical, automobile, petroleum…). Stations AM_1 and AM_2 are located respectively at 300 m upstream and 150 m downstream from the outlet of the effluent of a soap and cosmetic factory. Station AM_3 is situated at approximately 500 m upstream of the junction of this tributary with the main stream.

Measurement of environmental variables

At the level of each sampling station, 19 environmental variables were taken into account. Five physical parameters were determined to characterize the habitat. Mean depth and wetted width -in meter- were quantified on transects with equal distance interval across channel sections (Song *et al.,* 2009). Current velocity (m/s) was measured quarterly by timing the front of a neutral non-pollutant dye stuff (blue of methylene) over a known distance along the station. At each sampling site, canopy coverage (%) was estimated visually (Rios and Bailey, 2006). Additionally, types of substrate were characterized by measuring substrate particle size distribution based on methods described by Platts *et al.* (1983).

Measurements of physicochemical parameters of water at the different sampling stations were done according to APHA (1998) and Rodier *et al.,* (2009) standards. Thereby, water temperature (C), pH (CU) and Dissolved Oxygen (DO) rate (%) were measured *in situ* respectively using an alcohol thermometer, a HACH HQ11d pH-meter and a HACH HQ14d oxymeter. Likewise, salinity (‰), electric conductivity (EC) (µS/cm) and Total Dissolved Solids (TDS) (mg/L) were measured *in situ* using a HACH HQ 14d TDS-conductimeter. Turbidity (NTU) was measured in the laboratory with the help of a HI 93702 HANNA instruments. Suspended Solids (SS), ammonium, nitrates and Phosphates were also determined in the laboratory using HACH DR/2800 spectrophotometer. Alkalinity and oxydability were dosed by complexometry, whereas the Biochemical Oxygen Demand (BOD) was measured using a LIBHERR BOD analyzer.

Sampling and identification of freshwater shrimps

Shrimps were collected using a long-handled kick net (30 x 30 cm side, 400 µm mesh size). Samples were collected in a 100 m stretch for each station, following Protocols described by Stark *et al.* (2001). Materials collected in the sampling net were rinsed through a 400 µm sieve and all shrimp individuals were sorted and placed in plastics sampling bottles with 70° ethanol. In the laboratory, all the shrimps were handpicked using a fine dissection forceps and sorted into Petri dishes. All specimens caught were identified under a stereomicroscope using taxonomic keys (Monod 1980; Powell, 1980; Day *et al.,* 2001) and counted.

Data analyses

Shrimps richness, abundances and frequency of occurrence (FO) were used to classify species according to Dajoz (2000). Before performing the comparison test, the normality of data was checked using the Kolmogorov-Smirnov test. The Kruskal-wallis H-test follows by a test of multiple comparisons of rank were performed to compare physicochemical variables and shrimps abundances between sampling sites using PAST 3.0 software package. A significance level of $p < 0.05$ was considered. Hierarchical Ascending Classification (AHC) base on Euclidean distance and Ward's algorithm was performed to cluster sampling stations according to their physicochemical water quality status. Correlation between environmental variables and taxonomic richness of shrimps was determined by Spearman correlation test. In order to study relationships between environmental variables and the distribution and dynamic of the shrimp community, Canonical Redundancy Analysis (RDA) was performed based on the data matrix of shrimp abundances. RDA is a constrained ordination method, efficient in directly revealing relationships between the spatial structure of communities and environmental factors that might be responsible for that structure (Legndre *et al.*, 2011). Environmental variables and shrimp data were $\log10(x + 1)$ transformed prior to analysis. Monte Carlo permutations (499) were done so as to identify a subset of measured environmental variables, which exerted significant and independent influences on shrimp distribution at $p < 0.05$. RDA was performed using CANOCO for Windows 4.5 software (Ter Braak and Smilauer, 2002).

Results

Environmental variables

The mean and ranges values of environmental variables are shown in Table 1. Water temperature varied from 24 °C (N_1) to 36 °C (AT_1). The pH values varied between 4.7 (N_2) and 9.4 (AM_2). Dissolved oxygen was overall high in the catchment area of Nsapè (N_1 and N_2) with values ranging between 60% and 95.6%, while in stations situated in urban area, the values ranged from 0.9% (M_2) to 42.8% (AM_1). Electric conductivity ranged between 7 µS/cm (N_1) and 3690 µS/cm (AT_1). Similar variation trend was observed for TDS, with low (3.6 µS/cm) and high (1816 µS/cm) values registered at stations N_1 and AT_1 respectively. Salinity was nil in periurban sites, while the highest value (1.42 ‰) was recorded at station AT_1. Turbidity and suspended solids were globally very low in periurban stations with values ranging from 2 to 69 NTU and from 0 to 15 mg/L respectively. Whereas in urban zone, values of these parameters varied between 29 NTU (T_1) and 750 NTU (AT_1), and between 14 mg/L (T_1) and 409 mg/L (AT_1) respectively. Alkalinity varied between 0 mg/L (N_1) and 1050 mg/L (AT_1). The lowest values (0 mg/L) of nitrates, ammonium and phosphates were recorded in station N_1 and N_2, whereas the highest were registered at the stations T_1 (20.2 mg/L), M_1 (12 mg/L) and AT_1 (7.72 mg/L) respectively. As for oxydability and BOD, lowest values (1.2 and 5 mg/L respectively) were observed in station N_1, while the highest values (152 and 340 mg/L respectively) were obtained at station AT_1. Mean values of water's depth and wetted width fluctuated between 0.11 m (M_1) and 0.66 m (N_2); and between 1.9 m (AT_1) and 7 m (AM_3) respectively. The lowest mean value (0.22 m/s) of current velocity was recorded at the station AM_3, whiles the highest (0.89 m/s) was obtained in station AT_1. At the level of all the stations situated in urban area, canopy was absent; meanwhile it was estimated to 69% and 73% respectively at the level of stations N_1 and N_2. Four types of substrate were characterized for the whole study sites: Sandy (N_1 and N_2), Muddy sand (T_1, T_2, AT_1, M_1, AM_1 and AM_2), Sandy mud (AT_2) and Very sandy mud (T_3, M_2 and AM_3).

The Hierarchical Ascending Classification performed to cluster sampling stations according to their physicochemical water quality status, permitted to distinguish 3 groups of stations (Fig. 2). Group I is made up of stations N_1 and N_2 located in a periurban forest area, sheltered of any urban and industrial activity. Group II is constituted by only one station (AT_1) situated in a highly urbanized and industrialized zone, downstream from the outlet of many industrial effluents. The other nine sampling stations (T_1, T_2, T_3, AT_2, M_1, M_2, AM_1, AM_2 and AM_3) also located in the urban center, constitute the group III. The test of Kruskal-Wallis realized from the matrix of physicochemical variables, showed significant differences ($P<0.05$) between the groups I, II and III.

Composition and distribution of shrimp species

This study achieved for the first time in Douala watershed basins permitted to identify 7 freshwater shrimp species, *Caridina africana* (Kingsley, 1882), *Caridina nilotica* (Roux, 1833), *Macrobrachium thysi* (Powell, 1980), *Macrobrachium scabriculum* (Heller, 1862), *Macrobrachium equidens* (Dana, 1852), *Desmocaris trispinosa* (Aurivillius, 1898) and *Potamalpheops* sp (Powell, 1979) belonging to 4 families (Atyidae, Palaemonidae, Desmocarididae and Alpheidae respectively for the four genera). *Potamalpheops* sp, a very rare and small size shrimp was present only in station N_2. All these species were caught only at the two periurban stations (N_1 and N_2); no freshwater shrimp specie was found in any of the ten stations located in urban stream all over the study period (Table 2).

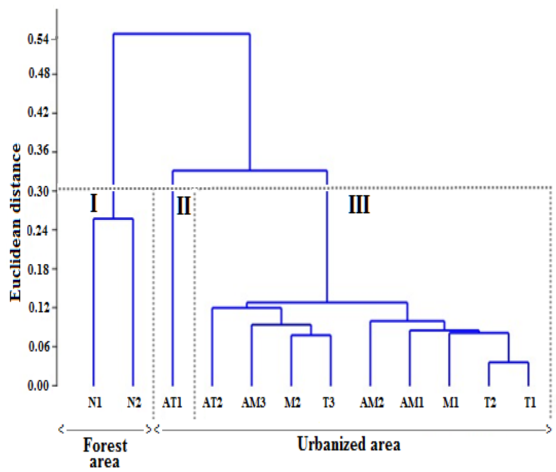

Fig. 2. Dendrogram highlighting the grouping of sampling stations on the basis of their physicochemical variables registered during the study period.

Among these 7 shrimp species identified in the periurban watershed basin during the study period, *C. africana* (FO=80.77%) and *D. trispinosa* (FO=61.54%) were very frequent. *C. nilotica* (FO=34.62%) and *M. thysi* (FO=26.92%) were accessory, while *M. equidens*, *M. scabriculum* and *Potamalpheops* sp were rare (FO<25%) (Fig. 3A). *C. africana* was the most abundant specie with *50.41%* of the total number of individual sampled. It was followed by *D. trispinosa* (36.07%), *C. nilotica* (6.56%), *M. scabriculum* (2.25%), *M. equidens* (2.25%), *M. thysi* (1.84%) and *Potamalpheops* sp (0.61%) (Fig. 3B).

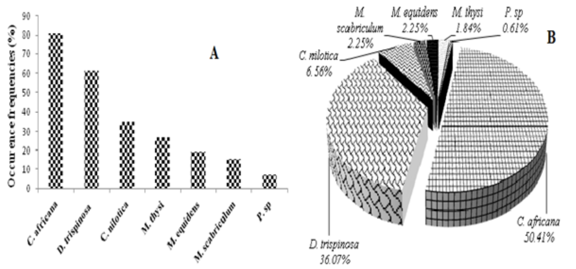

Fig. 3. Occurrence frequencies (A) and relative abundances (B) of shrimp species collected at the two periurban forest stations during the study period.

Relationships between environmental variables and shrimp's community

The analysis of the Spearman correlations (Table 3) indicated positive and very significant ($p<0.01$) correlations between the 7 species of shrimp and dissolved oxygen, canopy coverage and water depth. Contrariwise, it appeared that all the shrimp species were negatively and significantly influenced by high values of temperature, conductivity, TDS, salinity, turbidity, suspended solids, alkalinity, nitrates, ammonium, phosphates and BOD. Moreover, *C. nilotica*, *C. africana*, *D. trispinosa*, *M. scabriculum*, *M. equidens*, *M. thysi* were found to be negatively and very significantly influenced by pH and oxydability. Except suspended solids ($P=0.037$), *C. africana* ($P=0.028$) and *D. trispinosa* ($P=0.002$), the Mann-Whitney U-test showed no significant difference ($P>0.05$) between the two periurban forest stations (N1 and N2) regarding environmental variables and shrimps diversity and distribution.

Table 1. Mean and ranges values of environmental parameters evaluated at each sampling station during the study period.

Variables		Study stations											
		N_1	N_2	T_1	T_2	T_3	AT_1	AT_2	M_1	M_2	AM_1	AM_2	AM_3
Temperature (°C)	Mean	25.9	25.9	29.4	29.2	30.1	32.7	30.5	29.1	29.5	28.8	29.2	29.4
	Ranges	24-27	24-27	26-32	26-30.5	27-32.5	28.5-36	26.5-32	26.5-35	27-34	27-33	27.5-34	27-33.5
pH (UC)	Mean	6.14	6.19	7.01	6.98	6.72	7.93	6.71	6.92	6.79	6.75	8.16	7.01
	Ranges	4.8-7.1	4.7-7.8	6-7.8	6-7.8	5.7-8.2	5.7-9.4	5.8-8.4	6-8	5.9-8	5.9-7.9	5.8-9.4	5.6-8.9
Dissolved Oxygen (%)	Mean	75.4	80.3	14.6	17.7	2.9	4.7	5.5	6.3	5.7	21.3	10.5	5.6
	Ranges	63.3-90	60-95.6	3.3-35.1	3.5-39.6	1.1-6.9	2.2-10	2-11	1-28.5	0.9-23.1	5.3-42.8	1.6-20.9	1-26.3
Conductivity (µS/cm)	Mean	13.2	13.1	397.9	401.1	475.3	1559.2	624.2	403.1	677.5	291.3	478.9	443.7
	Ranges	7-34	8.8-17.9	135-539	130-533	139-610	426-3690	152-1106	201-696	288-2730	179-502	102-1765	211-895
TDS (mg/L)	Mean	6.8	7	204.8	206.3	240.9	804.8	319.5	206.7	343.6	148.5	243.9	227
	Ranges	3.6-16	4.2-9.5	81-263	77-260	83-314	208-1816	91-539	100-340	166-1365	85-243	61-857	116-437
Salinity (‰)	Mean	0.002	0.001	0.14	0.14	0.17	0.54	0.23	0.14	0.35	0.1	0.19	0.2
	Ranges	0-0.003	0-0.003	0.1-0.18	0.09-0.2	0.1-0.26	0.18-1.38	0.13-0.39	0.09-0.2	0.14-1.42	0-0.16	0-0.54	0.1-0.32
Turbidity (NTU)	Mean	14	26	102.2	116.3	131.6	259.7	173	125.1	119.9	94.2	122.6	106.9
	Ranges	2-40	2-69	29-440	58-318	65-322	108-750	63-384	82-220	58-320	65-120	58-400	60-260
Suspended Solids (mg/L)	Mean	4.2	7.7	62.9	54.9	100.5	163.5	99.2	77	71.6	47.9	72.7	86.9
	Ranges	0-10	1-15	14-379	15-334	36-327	63-409	43-266	28-133	43-140	21-98	25-189	33-308
Alkalinity (mg/L $CaCO_3$)	Mean	7.9	11.2	146.5	158	207.3	514.4	277.9	152.4	185.4	112.8	153.1	170.8
	Ranges	0-16	2-38	46-221	46-210	66-358	134-1010	56-464	68-200	62-468	62-176	88-388	74-314
Nitrates (mg/L NO_3^-)	Mean	0.1	0.2	2.8	1.5	3.7	7	4.4	2.2	3.2	1.9	3.2	3
	Ranges	0-0.6	0-0.5	0.9-20.2	0.6-2.8	1-9.4	1.6-18.9	0.7-11.3	0.7-8.5	0.8-6.1	0.7-4	0.9-4.9	1-5.2
Ammonium (mg/L NH_4^+)	Mean	0.1	0.1	4.5	4.6	4.4	4	3.1	5.2	4.2	3.1	2.5	3.3
	Ranges	0-0.2	0-0.2	1.3-9.2	1.4-9.6	2-10.4	1.4-9.6	1.6-5.1	1.5-12	1.7-8.7	1-9.7	1.2-7.6	1.4-5.9
Phosphates (mg/L PO_4^{3-})	Mean	0.1	0.1	1.2	1.1	1.3	2.2	1.4	1.5	1.2	0.9	0.9	1.4
	Ranges	0-0.4	0-0.7	0.6-1.8	0.5-1.9	0.4-2.5	0.8-7.7	0.6-3	0.8-4	0.4-2.4	0.1-1.8	0.3-1.8	0.6-2
Oxydability (mg/L)	Mean	9.1	13.6	23.1	25.2	40.7	79.4	38.4	26.9	33.3	26.4	32.2	42.6
	Ranges	1.2-20.2	1.4-24.9	11-59.3	9.7-54.7	19.2-98	18.4-152	18.2-79.6	6.5-63.6	12.8-62	4.9-53.7	16.6-61.2	27.5-76
BOD (mg/L)	Mean	13.1	16.2	96.9	156.2	158.5	218.1	176.2	89.6	105	94.6	121.2	139.6
	Ranges	5-25	5-35	30-185	90-240	80-285	110-340	110-255	45-160	75-175	55-145	90-165	95-205

Table 2. Abundances and distribution of shrimp species in different study stations; in the same row, abundances of shrimp species followed by different letters are significantly different (Kruskal-Wallis test; $p < 0.05$). (-): absence.

Taxa			Stations		
Families	Genera	Species	N_1	N_2	All other stations
Atyidae	*Caridina*	*C. africana*	60^a	186^b	-
		C. nilotica	8^a	24^a	-
Palaemonidae	*Macrobrachium*	*M. scabriculum*	4^a	7^a	-
		M. equidens	3^a	8^a	-
		M. thysi	2^a	7^a	-
Desmocarididae	*Desmocaris*	*D. trispinosa*	24^a	152^b	-
Alpheidae	*Potamalpheops*	*P.* sp	-	3	-

Table 3. Summary of Spearman correlation between shrimp abundances and environmental variables.

	C. nilotica	*C. africana*	*D. trispinosa*	*M. scabriculum*	*M. equidens*	*M. thysi*	*P. sp*
Temperature (°C)	-0.322**	-0.531**	-0.451**	-0.211**	-0.269**	-0.252**	-0.171*
pH (UC)	-0.235**	-0.371**	-0.201*	-0.053ns	-0.077ns	-0.193*	-0.092ns
Dissolved Oxygen (%)	0.347**	0.573**	0.502**	0.218**	0.257**	0.320**	0.162*
Conductivity (µS/cm)	-0.356**	-0.566**	-0.468**	-0.233**	-0.259**	-0.279**	-0.187*
TDS (mg/L)	-0.356**	-0.566**	-0.469**	-0.233**	-0.254**	-0.282**	-0.189*
Salinity (‰)	-0.337**	-0.557**	-0.476**	-0.217**	-0.259**	-0.298**	-0.170*
Turbidity (NTU)	-0.356**	-0.560**	-0.489**	-0.221**	-0.254**	-0.281**	-0.139ns
Suspended Solids (mg/L)	-0.364**	-0.576**	-0.462**	-0.224**	-0.251**	-0.267**	-0.162*
Alkalinity (mg/L $CaCO_3$)	-0.363**	-0.577**	-0.477**	-0.216**	-0.269**	-0.301**	-0.171*
Nitrates (mg/L NO_3^-)	-0.356**	-0.565**	-0.475**	-0.246**	-0.253**	-0.273**	-0.161*
Ammonium (mg/L NH_4^+)	-0.371**	-0.578**	-0.468**	-0.222**	-0.261**	-0.289**	-0.169*
Phosphates (mg/L PO_4^{3-})	-0.360**	-0.564**	-0.457**	-0.242**	-0.263**	-0.253**	-0.159*
Oxydability (mg/L)	-0.342**	-0.505**	-0.375**	-0.209**	-0.209**	-0.251**	-0.157ns
BOD (mg/L)	-0.371**	-0.584**	-0.473**	-0.226**	-0.252**	-0.304**	-0.158*
Water width (m)	0.037ns	-0.036ns	0.070ns	-0.022ns	0.006ns	0.086ns	0.08 ns
Water depth (m)	0.301**	0.414**	0.424**	0.166*	0.207**	0.281**	0.183*
Current velocity (m/s)	0.060ns	0.111ns	0.078ns	0.04 ns	0.047ns	0.039ns	0.017ns
Canopy coverage (%)	0.569**	0.881**	0.782**	0.362**	0.414**	0.475**	0.279**

* or **: correlation is significant at the level p≤0.05 or 0.01 respectively

ns: non-significant correlation

The results of redundancy analysis revealed that the relationships between the seven shrimp species and their habitat conditions follow mainly the first two axes (Fig. 4), which accounted for 99.3% of the total variance. These two axes well highlight the spatial distribution of the shrimp assemblage in Douala watershed basins in response to the environmental conditions. The first axis opposed periurban stations in positive coordinates to urban stations in negative coordinates. All the seven freshwater shrimp species were found to be negatively affected by high values of temperature, conductivity, TDS, salinity, turbidity, suspended solids, alkalinity, nitrates, ammonium, phosphates, pH and BOD. Furthermore, the presence and abundance of *C. nilotica*, *C. africana*, *M. scabriculum*, and *M. equidens*, appear to be highly and positively influence by good oxygenation of water and high percentage of canopy coverage; whilst in the other hand, *D. trispinosa, M. thysi* and *Potamalpheops* sp seemed to quite appreciate deep water.

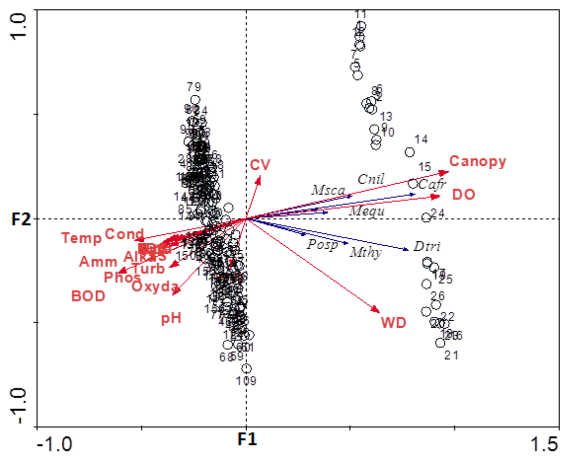

Fig. 4. Redundancy Analysis triplot showing gathering of shrimp species (Cafr-*Caridina africana,* Cnil-*Caridina nilotica,* Dtri-*Desmocaris trispinosa,* Mequ-*Macrobrachium equidens,* Msca-*Macrobrachium scabriculum,* Mthy-*Macrobrachium thysi,* Posp-*Potamalpheops* sp) in response to environmental variables (Alk-Alkalinity, Amm-Ammonium, BOD-Biochemical Oxygen Demand, Cond-Conductivity, DO-Dissolved Oxygen, nitra-Nitrates, oxyda-Oxydability, pH-pH, phos-Phosphates, Sali-Salinity, SS-Suspended solid, TDS-Total Dissolved Solids, Temp-Temperature, Turb-Turbidity, WD-Water depth, WW-Water width). 1, 2, 3,…,26: samples collected in periurban stations during the study period; 27, 28, 29,…,156: samples collected in urban stations during the study period.

Discussion

This assessment study revealed a great significance difference between periurban and urban water quality and ecology. The relative low temperature values observed in stations N_1 and N_2 could reflect the character of forest streams little exposed to the solar rays thanks to the important canopy coverage (Qui, 2013). In line with Akindele and Adeniyi (2013), the high percentage of oxygen saturation (>75 %) in these suburban stations is an index of very good water quality. Indeed, in forest zone high photosynthetic activities of river basin, natural ventilation and the presence of rapid flow rate and curved flow of water which lead to disturbance and recirculation of water, favor its reoxygenation at the water/air interface. Furthermore, the low acidity of water, the low mean values of conductivity, TDS, salinity, turbidity, suspended solids, alkalinity, diverse ions (NO_3^-, NH_4^+, PO_4^{3-}), oxydability and BOD recorded throughout the study period in the suburban stations could indicate on one hand, low mineralization of water, and on the other hand, a low organic matter loads, thus indicating good water quality of the Nsapè watershed basin. These results are in accordance with those obtained by Foto *et al.* (2013) in a suburban forest stream of the Yaoundé city. Similar observations were documented by Wang *et al.* (2012) in the tributaries of Qiangtang River (China).

Contrariwise, high temperature values registered in stations located in urban and industrial zone can be attributed to anthropogenic activities. In fact, according to Porse (2013) anarchic land used, overpopulation, domestic and industrial activities are factors that interfered to increase air temperature. Also, hypoxic condition of water, very high values of conductivity, TDS, salinity, turbidity, suspended solids, alkalinity, diverse ions (NO_3^-, NH_4^+, PO_4^{3-}), oxydability and BOD obtained at these stations, testified the highly polluted state of these urban streams due to stormwater, domestic and industrial wastes. These results corroborate those of Tening *et al.* (2013a) conducted in Douala-Edea mangrove ecosystem, and Tening *et al.* (2013b) in Douala metropolis. Similar results were published by Kaonga *et al.* (2013) in Malawi and Dhillon *et al.* (2013) in India. Moreover as specified by clustering classification (Figure 2), station AT_1 appears to be the most polluted point, followed by a set a stations (T_3, M_2, AM_3 and AT_2) situated downstream of the outlet of industrial effluents. This clearly highlights the contribution of industrial wastes in water quality damaging. Similar observations were documented in India by Jain (2012) and Bhat *et al.* (2013) and in China by Wang *et al.* (2012) and Hanting and Lili (2013).

This study achieved in Douala watershed basins permitted to identify 7 freshwater shrimp species. This taxonomic richness is greater than that recorded by Foto *et al.* (2013) in a suburban forest stream of the Yaoundé city where just 2 species were identified. This difference is probably due to the geographical situation of these regions. In fact, Douala Township is closer to the sea compared to Yaoundé and it is known that many crustacean species have their larval stages in brackish or marine water (N'zi *et al.*, 2008). Our specie richness is greater than that obtained by Camara *et al.* (2009) in Banco River (3 species) and slightly lower than that recorded by N'zi *et al.*, (2008) in Boubo river where 9 species were identified in 19 sampling sites. All the 7 species were present only in the two suburban forest stations which have very good water quality and are less subjected to anthropogenic activities. The absence of shrimps in urban stations can be explained by the very poor water quality of Douala urban streams due to uncontrolled discharge of domestic, urban and industrial wastes and sewages in the rivers. Spearman correlation and redundancy analysis which showed negative influence of polluted water on shrimp distribution confirm this hypothesis. This observation corroborated the results of N'zi *et al.* (2008) which showed the decrease of shrimp species richness downstream of the outlet of the effluents of a palm oil industry in the river Boubo. Our results are also in accordance with those of Foto *et al.* (2011 and 2013) which showed that in Yaoundé, shrimps were absent in urban streams of the Mfoundi river basin and present in suburban streams of the same ecological region. Several studies have shown that species richness, abundance and distribution of benthic macroinvertebrate's assemblages are generally extremely influence by physicochemical water quality (Nicola *et al.,* 2010; Wang *et al.*, 2012; Morrissey *et al.,* 2013; Colas *et al.*, 2014). Among shrimp species caught, *C. africana* was the most frequent and abundant. This specie is positively influenced by well oxygenated water and high canopy coverage. This observation confirms that of Foto *et al.* (2013) who also found positive correlation between Atyidae and dissolved oxygen concentration. Similarly, N'zi *et al.* (2008) documented that the distribution of this specie was influenced by canopy coverage. It was follow by *D. trispinosa* which also requires good water quality. This result is opposite to that of Camara *et al.* (2009) which showed that *D. trispinosa* seems to tolerate unfavorable conditions such as low dissolved oxygen and significant organic matter input. In the midst of Palaemonidae, *M. thysi* a large-egged species which was first said to be endemic to Ivory Coast (Powell, 1980; Camara *et al.,* 2009), appear to be a first record for Cameroon. This testified that in Cameroun, biodiversity of shrimps is yet entirely to be investigated. Although *Macrobrachium* was the most represented genus with 3 species (*M. thysi, M. equidens* and *M. scabriculum*), these latter were not frequent, nor abundant. This might be due to the rivers' sizes. Indeed, Nsapè is a small head watershed river with just 8.8 km length and 2.5 m mean width. *Potamalpheops* sp, a very rare and small size shrimp was present only in station N_2 with very low occurrence and abundance. The rarity of this Alpheid shrimp even in brackish water has already been documented (Anker, 2001).

Conclusion

This study highlight that species richness and distribution of freshwater shrimps in Douala watershed basin are highly and negatively influence by polluted waters which cause their extinction. Thus, these freshwater shrimps are sensitive to anthropogenic disturbance and can be used in bioassessment program. However, because of this important shrimp richness and the restricted worldwide distribution of *M. thysi,* it's urgent to protect and restore these hydrosystems. Therefore, there is the need for an elaborate characterization of wastewaters and water bodies, and evaluation of treatment facilities of municipal and industrial waste to assess the status and control of water pollution. Also, industrial managers should take responsible actions in managing their waste facilities; residents along the rivers should embrace the culture of using the appropriate means of waste disposal rather than discharging their waste into streams.

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References

Akindele EO, Adeniyi IF. 2013. A study of the physicochemical water quality, hydrology and zooplankton fauna of Opa Reservoir catchment area, Ile-Ife, Nigeria. African Journal of Environmental Science and Technology **7(5)**, 192-213.

Anker A. 2001. Taxonomie et évolution des Alpheidae (Crustacea, Decapoda). Thèse de Doctorat, Muséum National d'Histoire Naturelle, Paris. 2 vols : 547 + 331 pp.

American Public Health Association (APHA). 1998. Standard method for examination of water and wastewater, American Public Health Association, 20th edition, Washington, DC, 1150 p.

Bhat SA, Meraj G, Yaseen S, Bhat AR, Pandit AK. 2013. Assessing the impact of anthropogenic activities on spatio-temporal variation of water quality in Anchar lake, Kashmir Himalayas. International Journal of Environmental Sciences **3 (5),** 1625-1640.

Borics G, Varbiro G, Padisak J. 2013. Disturbance and stress: different meanings in ecological dynamics? Hydrobiologia **711,** 1–7.

Camara IA, Konan MK, Diomandé D, Edia EO, Gourène G. 2009. Ecology and diversity of freshwater shrimps in Banco National Park, Côte d'Ivoire (Banco River Basin). Knowledge and Management of Aquatic Ecosystems **393 (05),** 1-10.

Carden K, Armitage NP. 2013. Assessing urban water sustainability in South Africa; not just performance measurement. Water **39(3),** 345-350.

Colas F, Vigneron A, Felten V, Devin S. 2014. The contribution of a niche-based approach to ecological risk assessment: Using macroinvertebrate species under multiple stressors. Environmental Pollution **185,** 24-34.

Dajoz R. 2000. Précis d'Écologie, 7^{e} édition, Dunod, Paris, 615 p.

Day JA, Stewart BA, de Moor IJ, Louw AE. 2001. Guides to the Freshwater Invertebrates of Southern Africa, Volume 4: Crustacea III. Water Research Commission Report, No. TT 141/101, Pretoria-South Africa, 151p.

Dhillon MK, George MP, Mishra S. 2013. Water quality of River Yamuna – Delhi stretch. International Journal of Environmental Sciences **3 (5),** 1416-1423.

Feumba R, Ngounou Ngatcha B, Tabue Youmbi JG, Ekodeck GE. 2011. Relationship between climate and groundwater recharge in the Besseke watershed (Douala-Cameroun). Journal of Water Resource and Protection **3,** 607-619.

Foto Menbohan S, Koji E, Ajeagah G, Bilong Bilong CF, Njiné T. 2012. Impact of dam construction on the diversity of benthic macroinvertebrates community in a periurban stream in Cameroon. International Journal of Biosciences **2(11),** 137-145.

Foto Menbohan S, Tchakonté S, AJeagah G, Zébazé Togouet SH, Bilong Bilong CF, Njine T. 2013. Water quality assessment using benthic macroinvertebrates in a periurban stream (cameroon). International Journal of Biotechnology **2(5),** 91-104.

Foto Menbohan S, Zébazé Togouet SH, Nyamsi Tchatcho NL, AJeagah G, Njine T. 2011. Evolution Spatiale de la Diversité des Peuplements de Macroinvertébrés Benthiques dans un cours d'eau Anthropisé en Milieu Tropical (Cameroun). European Journal of Scientific Research **55(2),** 291-300.

Garcia-Roger EM, Sanchez-Montoya MDM, Gomez R, Suarez ML, Vidal-Abarca R, Latron J, Rieradevall M, Prat N. 2011. Do seasonal changes in habitat features influence aquatic macroinvertebrate assemblages in perennial versus temporary Mediterranean streams? Aquatic Sciences **73,** 567–579.

Gooré Bi G. 1998. Contribution à l'étude des crevettes d'eau douce de Côte d'Ivoire : systématique, biologie et analyse socio-économique de la pêche de Macrobrachium vollenhovenii (Herklots 1857) et de M. macrobrachion (Herklots 1851) (Crustacea Decapoda, Palaemonidae) du bassin de la Bia, Thèse de Doctorat 3e cycle, 145 p.

Hanting Z, Lili W. 2013. River water quality assessment based on CWQII in Hua country, China. International Journal of Environmental Sciences **3 (5),** 1478-1484.

Jain S. 2012. Assessment of water quality at the three Stations of Chambal River. International Journal of Environmental Sciences **3 (2),** 881-884.

Kamdem Toham A, Teugels GG. 1998. Diversity patterns of fish assemblages in the Lower Ntem River Basin (Cameroon), with notes on potential effect of deforestation. Archiv für Hydrobiologie **141,** 421-446.

Kaonga CC, Kambala C, Mwendera C, Mkandawire T. 2013. Water quality assessment in Bangwe Township, Blantyre City, Malawi. African Journal of Environmental Science and Technology **7(5),** 259-266.

Legendre P, Oksanen J, Ter Braak CJF. 2011. Testing the significance of canonical axes in Redundancy Analysis. Methods in Ecology and Evolution **2,** 269–277.

Lévèque C, Paugy D. 1999. Impact des activités humaines: In: Les poissons des eaux continentales africaines: diversité, écologie, utilisation par l'homme (Lévêque C. & Paugy D., eds.), 365-383.

Monod T. 1980. Décapode. In: Durand J.R. and Levêque C. (eds.), Flore et faune aquatiques de l'Afrique sahélo-soudanienne, Vol. I, 44, Paris, ORSTOM, 369–389.

Morrissey CA, Boldt A, Mapstone A, Newton J, Ormerod SJ. 2013. Stable isotopes as indicators of wastewater effects on the macroinvertebrates of urban rivers. Hydrobiologia **700,** 231–244.

N'Zi KG, Gooré Bi G, Kouamélan EP, Koné T, N'Douba V, Ollevier F. 2008. Influence des facteurs environnementaux sur la répartition spatiale des crevettes dans un petit bassin ouest africain – rivière Boubo – Côte d'Ivoire. Tropicultura **26(1),** 17–23.

Nicola GG, Almodo´var A, Elvira B. 2010. Effects of environmental factors and predation on benthic communities in headwater streams. Aquatic Sciences, **72,** 419–429.

Olivry JC. 1986. Fleuve et rivières du Cameroun. Collection Monographie Hydrologie, MESRE/ORSTOM, 781p.

Platts WS, Megahan WF, Minshall GW. 1983. Methods for evaluating stream, riparian and biotic conditions. General Technical Report 138, US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Porse EC. 2013. Stormwater Governance and Future Cities. Water **5,** 29-52.

Powell CB. 1980. The genus Macrobrachium in West Africa, I: Macrobrachium thysi, a new large-egged species from the Côte d'Ivoire (Crustacea Decapoda Palaemonidae). Revue de Zoologie Africaine **94,** 317–326.

Qiu Z. 2013. Comparative Assessment of Stormwater and Nonpoint Source Pollution Best Management Practices in Suburban Watershed Management. Water **5,** 280-291.

Rios SL, Bailey RC. 2006. Relationships between riparian vegetation and stream benthic communities at three spatial scales. Hydrobiologia **553,** 153–160.

Rodier J, Legube B, Marlet N, Brunet R. 2009. L'analyse de l'eau. 9e édition, DUNOD, Paris, 1579p.

Schuetze T, Chelleri L. 2013. Integrating Decentralized Rainwater Management in Urban Planning and Design: Flood Resilient and Sustainable Water Management Using the Example of Coastal Cities in The Netherlands. Water **5,** 593-616.

Schuwirth N, Reichert P. 2012. Prévoir la présence des organismes dans les rivières. Eawag News **72,** 14-17.

Song MY, Leprieur F, Thomas A, Lek-Ang S, Chon TS, Lek S. 2009. Impact of agricultural land use on aquatic insect assemblages in the Garonne river catchment (SW France). Aquatic Ecology **43,** 999–1009.

Stark JD, Boothroyd KG, Harding JS, Maxted JR, Scarsbrook MR. 2001. Protocols for Sampling Macroinvertebrates in Wadeable Streams. New Zealand Macroinvertebrates working group, report no. 1, 57 p.

Suchel JB. 1972. Le climat du Cameroun**.** Thèse de Doctorat 3eme cycle, Université de Bordeaux III, 186 p.

Tening AS, Chuyong GB, Asongwe GA, Fonge BA, Lifongo LL, Mvondo-Ze AD, Bih Che V, Suh CE. 2013a. Contribution of some water bodies and the role of soils in the physicochemical enrichment of the Douala-Edea mangrove ecosystem. African Journal of Environmental Science and Technology **7(5),** 336-349.

Tening AS, Chuyong GB, Asongwe GA, Fonge BA, Lifongo LL, Tandia BK. 2013b. Nitrate and ammonium levels of some water bodies and their interaction with some selected properties of soils in Douala metropolis, Cameroon. *African Journal of* Environmental Science and Technology **7(7),** 648-656.

Ter Braak CJF, Smilauer P. 2002. CANOCO reference manual and Canodraw for Windows user's guide: software for canonical community ordination (version 4.5), Microcomputer Power, Tthaca,New York, USA. 500p.

Tonkin D, Death RG, Collier KJ. 2013. Do productivity and disturbance interact to modulate macroinvertebrate diversity in streams? Hydrobiologia **701,** 159–172.

Wang B, Liu D, Liu S, Zhang Y, Lu D, Wang L. 2012. Impacts of urbanization on stream habitats and macroinvertebrate communities in the tributaries of Qiangtang River, China. Hydrobiologia **680,** 39–51.