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# Stream's water quality and description of some aquatic species of Coleoptera and Hemiptera (Insecta) in Littoral Region of Cameroon

Siméon Tchakonté[1*], Gideon A. Ajeagah[1], Nectaire Lié Nyamsi Tchatcho[1,3], Adama Idrissa Camara[2], Dramane Diomandé[2] & Pierre Ngassam[1]

[1]Laboratory of Hydrobiology and Environment, Faculty of Science, University of Yaoundé I, P.O. BOX 812 Yaoundé, Cameroon.
[2]Laboratory of Environment and Aquatic Biology, Nangui Abrogoua University, 02 P.O. BOX 801 Abidjan 02, Ivory Coast.
[3]Department of Aquatic Ecosystems Management, Institute of Fisheries and Aquatic Sciences at Yabassi, University of Douala, P.O. Box 7236 Douala, Cameroon.
*Corresponding author, e-mail: tchakontesimeoon@yahoo.fr

**ABSTRACT** Aquatic insects are the dominant taxon group in most freshwater ecosystems and are particularly suitable for large scale and comparative studies of freshwater community responses to human-induced perturbations. Understanding these responses is crucial for establishing conservation goals. In this study, we used three families of aquatic insects (Coleoptera Gyrinidae, Hemiptera Gerridae and Veliidae) as surrogates to measure the aquatic health of urban streams in the city of Douala, and we described eight characteristic species. Aquatic insects were sampled monthly over a 13-month period in two forested sites and ten urbanized sites. Meanwhile, measurements of the environmental variables were taken. Overall, 20 species were identified; the family Gerridae was the most diversified with 11 species, followed by Veliidae (5 species), and Gyrinidae (4 species). All these species were present only at the two forested sites; no species was found in the urbanized area all over the study period. Morphological description of the eight best indicator species (*Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp.1, *Orectogyrus* sp. 2, *Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1, *Eurymetra* sp. 2, *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp.) revealed not described characteristic features and potentially new species. This testified that in Cameroon, biodiversity of aquatic insects is yet entirely to be investigated, and that there is an urgent need in their taxonomic revision. Physicochemical analyses revealed the very poor health status of urban streams with highly polluted water, while suburban streams have unpolluted water. The results of redundancy analysis revealed that the presence of Gyrinidae, Gerridae and Veliidae species is undoubtedly favored by the high rate of dissolved oxygen, important canopy coverage and very low organic matter input. It is thus clear that polluted status of urban streams due to human activities is the primary cause of the extinction of aquatic insect species.

**KEY WORDS** Aquatic Coleoptera and Hemiptera; morphological features; sensitive species; water pollution.

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## INTRODUCTION

Climate change, loss of biodiversity and the growth of an increasingly urban world population are main challenges of this century (Müller et al., 2010). In developing countries, urban population and anarchic urban land use have dramatically increased over the past few decades. Such population growth and urban expansion are placing greater stresses on the natural environment (Cohen, 2003), leading to a strong variability on the physical and chemical features of lotic ecosystems by clearing riparian vegetation and opening canopy, increasing inputs of sediments, nutrients, organic matter and pollutants (i.e., heavy metals), altering flows and reducing habitat heterogeneity (Xu et al., 2013; Zhang et al., 2013). Such modifications result into drastic changes in the biological component and the ecological functioning of urban streams, with a deterioration of water quality and loss of sensitive aquatic biota (Tchakonté et al., 2014). There is therefore a growing need to better understand and predict how biotic communities respond to these disturbances.

As an important functional group in stream ecosystems that sustains the stability and complexity of aquatic communities, insects have frequently been used to indicate changes in the composition of stream communities that respond to anthropogenic disturbances since they are sensitive indicators of long-term environmental changes in water and habitat quality (Rosenberg & Resh, 1993; Song et al., 2009; Zhang et al., 2013). Within the insects, Ephemeroptera, Plecoptera and Trichoptera are well known as good bioindicators in stream ecosystems (Rosenberg & Resh, 1993; Foto Menbohan et al., 2013; Nyamsi Tchatcho et al., 2014), whereas the use of aquatic Coleoptera and Hemiptera in biomonitoring studies is rare. Despite their limited use in stream biomonitoring, some aquatic Coleoptera and Hemiptera taxa have been shown as being sensitive to increase in sediment and organic pollution (e.g., Hauer & Resh, 1996; Zettel & Tran, 2004). Furthermore, most Hemipteran's species are endemic to particular islands or continental regions and often have extremely limited distributions, issuing them a bioindicator identity.

In the city of Douala which is the most densely populated and industrialized area of Cameroon, urbanization is anarchical with precarious sanitation systems in shanty quarters; household disposals, municipal and industrial wastewater and solid wastes are discharged directly in the environment without preliminary or adequate treatment (Tening et al., 2013; Tchakonté et al., 2014).To our knowledge, no study has so far dealt with diversity, morphological description and ecological requirement conditions of aquatic insect of the families Gyrinidae, Gerridae and Veliidae in Douala rivers. Indeed, these Coleoptera and Hemiptera accomplish their entire live cycle in aquatic milieu (except pupal stage of Gyrinidae); they are therefore in permanent contact with the aquatic environment and might reflect even the most subtle changes occurring in the medium.

This study aimed thus to inventory and to describe characteristic species of Gyrinidae, Gerridae and Veliidae in urban and forest streams of Douala city, in order to provide further information on the systematic of these families and to offer hypotheses as to how the species are distributed.

## MATERIAL 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. This city extends between 3°58'- 4°07' of latitude North and between 9°34' - 9°49' of longitude East, and presents a flat topography with altitudes varying between 1.6 and 39 m (Olivry, 1986). The climate of this region was classified by Suchel (1972) as a wet tropical type, characterized by a short dry season (December to February) and a long rainy season (March to November). 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 watersheds (Nsapè, Tongo'a-Bassa and Mgoua) situated at the left bank of the Wouri River (Fig. 1).

The watershed of Nsapè is located in a peri-urban area situated at about 30 km away from the urban centre. This watershed is particularly covered by vegetation of a secondary dense forest type, composed of high trees, shrubs and tall grasses (undergrowth) which alternate with some cleared spaces used for traditional farming purposes. This forested area is uninhabited and sheltered of any urban/industrial activity. Two stations identified as $N_1$ and $N_2$ were selected in this forested area. Inversely, Tongo'a-Bassa and Mgoua basins are located in industrialized areas and are highly polluted by human activities. Five sampling stations ($T_1$, $T_2$,

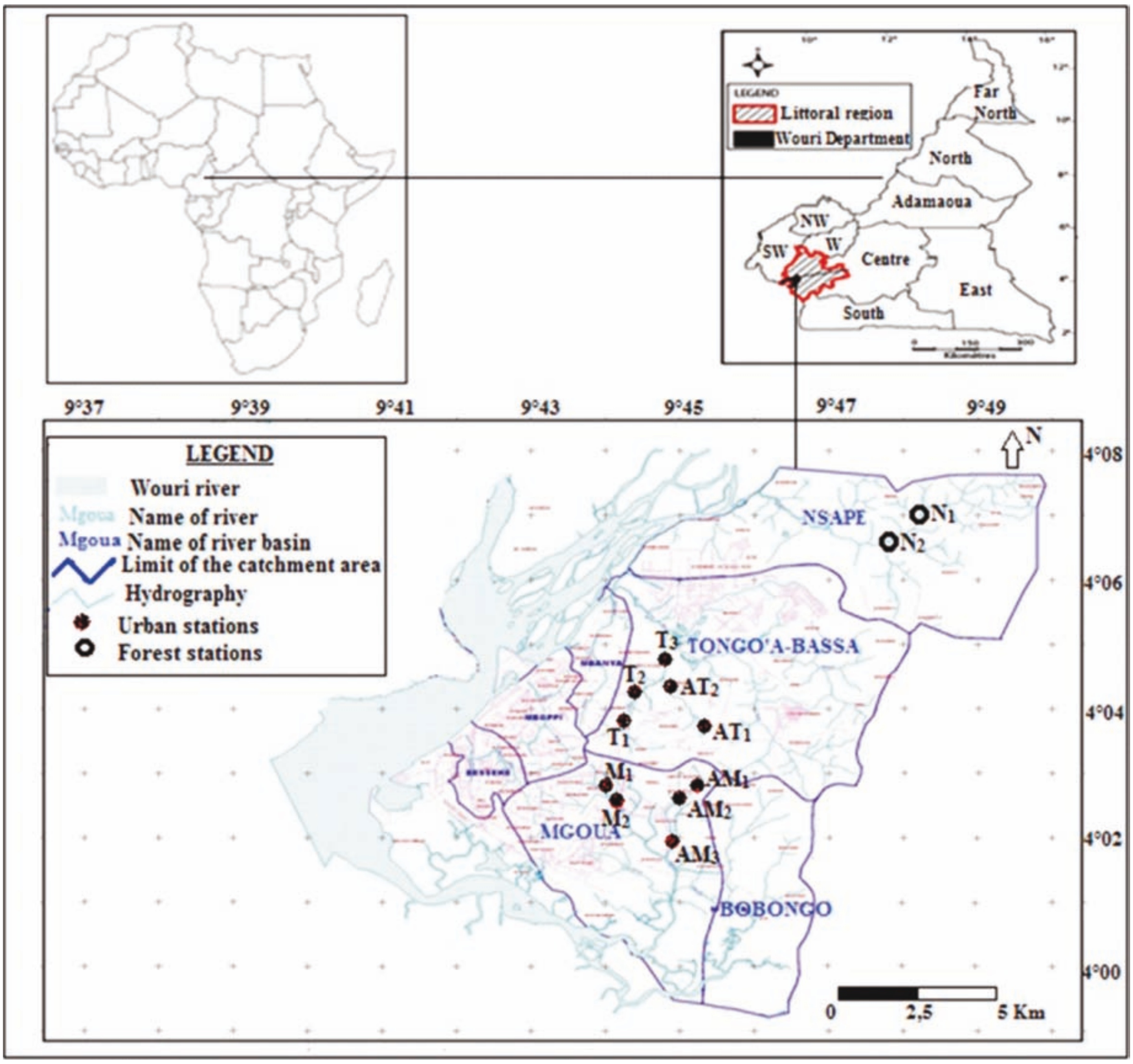



Figure 1. Hydrographic map of the study sites showing sampling stations.

$T_3$, $AT_1$, and $AT_2$) were selected in the Tongo' a-Bassa catchment. The stations $T_1$ and $T_2$ are localized 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 effluents coming from a brewery industry, a textile industry and an industry of manufacture of glasses. While station $T_3$ is situated at 500 m downstream from the junction of the two preceding arms. The five other stations ($M_1$, $M_2$, $AM_1$, $AM_2$ and $AM_3$) were chosen in Mgoua river basin. The stations $M_1$ and $M_2$ are respectively localized at 350 m upstream and 250 m downstream from the outlet of effluents coming from the great Industrial Centre of Bassa. 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, while station $AM_3$ is situated at approximately 2.4 km downstream of this effluent.

### *Measurement of environmental variables*

At each sampling station, 15 environmental variables were taken into account. Three physical parameters were determined to characterize the habitat. The mean water depth (WD) was measured on transects with equal distance interval across the river sections (Song et al., 2009). Current velocity (CV) was measured by timing the front of a neutral non-pollutant dye (blue of methylene) over a calibrated distance. At each sampling station, canopy coverage (%) was estimated visually (Rios & Bailey, 2006).

The measurements of physicochemical parameters of water at each sampling station were done following APHA (2009) and Rodier et al. (2009) standard methods. Water temperature, pH, and dissolved oxygen (DO) were measured *in situ* using an alcohol thermometer, a HACH HQ11d pH-meter, and a HACH HQ14d oxymeter, respectively. Likewise, electrical conductivity (EC) was measured i*n situ* using a HACH HQ 14d conductimeter. Suspended solids (SS), turbidity, ammonium ($NH_4^+$), nitrites ($NO_2^-$), nitrates ($NO_3^-$), and phosphates ($PO_4^{3-}$) were measured in the laboratory using HACH DR/2800 spectrophotometer. The Biochemical Oxygen Demand (BOD5) was measured using a Liebherr BOD analyzer. In order to assess the organic pollution level at each sampling station, the Organic Pollution Index (OPI) was calculated according to the protocol described by Leclercq (2001). OPI is based on three ions concentrations resulting from organic pollution ($NH_4^+$, $NO_2^-$, and $PO_4^{3-}$) and one synthetic parameter (BOD5).

### *Sampling, identification and representationof aquatic insect species*

Insect samples were collected at each station using a long-handled kick net (30 cm x 30 cm side, 400 µm mesh-size, 50 cm depth). For each station, samplings were done in a 100 m stretch following protocol described by Stark et al. (2001). At each station, 20 drags of the kick net were done in different micro-habitat, each corresponding to a surface of 0.15 $m^2$ (30 cm × 50 cm). The materials that were collected in the sampling net were rinsed through a 400 µm sieve bucket and all macroinvertebrate individuals were sorted and preserved in plastics sampling bottles with 70% ethanol. In the laboratory, all aquatic insects belonging to the families Gyrinidae (Coleoptera), Gerridae and Veliidae (Hemiptera) were identified under a stereomicroscope using appropriate taxonomic keys (Dejoux et al., 1981; Durand & Levêque, 1981; De Moor et al., 2003; Stals & De Moor, 2007; Tachet et al., 2010), and counted.

The specimens intended for representation were prior immersed in 10% sodium hydroxide overnight, so as to soften their chitin and lighten their body. The drawings of general morphology of characteristic species were carried out under a stereomicroscope equipped with a drawing tube. Details of key appendages were drawn using an optical microscope 100× magnification, equipped with a drawing tube.

### *Data analyses*

Insect richness, abundances and occurrence frequencies were used to classify species according to Dajoz (2000). In order to study the relationships between environmental variables and the distribution and dynamic of the eight characteristic insect species, Canonical Redundancy Analysis (RDA) was performed based on the data matrix of species abundances and physicochemical parameters. 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 (Legendre et al., 2011). Monte Carlo permutations (499 permutations) were done so as to identify a subset of measured environmental variables, which exerted significant and independent influences on insect species distribution at $p < 0.05$. CANOCO for Windows 4.5 software (Ter Braak & Smilauer, 2002) was used for this analysis.

## RESULTS

### *Environmental variables*

The mean values and standard deviation (SD) of environmental variables measured at each sampling station are shown in Table 1. The lower mean values of water temperature were observed at forested sites (25.9° C), whereas at urbanized sites, higher values were recorded, especially downstream from the outlet of industrial effluents. The mean values of pH varied between 6.10 ($N_1$) and 8.16 ($AM_2$). The percentage of dissolved oxygen was overall higher at suburban sites (>75%) compared to urban sites, where waters were closed to the hypoxic condition, with mean values oscillating between 2.95% ($T_3$) and 21.3% ($AM_1$). Mean values of electrical conductivity ranged between 13.1 µS/cm ($N_2$) and

1559 µS/cm ($AT_1$). Turbidity and suspended solids were globally very low at forested sites, with mean values ranging from14 to 26 NTU and from 4.2 to 7.7 mg/L, respectively. Where as in urban zone, mean values of these parameters varied between 94.2 NTU ($AM_1$) and 259.7 NTU ($AT_1$), and between 47.9 mg/L ($AM_1$) and163.5 mg/L ($AT_1$), respectively for turbidity and suspended solids. The lowest mean values of nitrates (0.11mg/L), nitrites (0.006 mg/L), ammonium (0.09 mg/L) and phosphates (0.08 mg/L) were recorded at suburban station $N_1$, whereas the highest were registered at the urban stations $AT_1$ (6.98 mg/L), $AM_2$ (0.26 mg/L), $M_1$ (5.19 mg/L) and $AT_1$ (2.2 mg/L), respectively. Concerning BOD, the lowest value (13.08 mg/L) was observed in station $N_1$, while the highest values (218.1 mg/L) were obtained at station $AT_1$. Mean values of water's depth and current velocity fluctuated between 0.22 m ($M_1$) and 0.75 m ($AM_3$), and between 0.22 m/s ($AM_3$) and 0.89 m/s ($AT_1$), respectively. At the level of all the sampling stations situated in urban area, canopy was absent; meanwhile it was estimated to 69% and 73% respectively at the level of stations N1 and N2 located in forested sites. The organic pollution index (OPI) revealed that organic pollution ranged from low to null at the forested sites; whereas in urban streams, organic pollution level was very high.

### *Composition and distribution of species*

Overall, 20 species were identified for the three studied aquatic insect families (Table 2). The family Gerridae (Hemiptera) was the most diversified with 11 species, followed by the family Veliidae (Hemiptera) with 5 species, and the family Gyrinidae (Coleoptera) which accounted 4 species. All these species were caught only at the two forested sites (N1 and N2); no species were found at any of the ten sampling stations located in urban streams, all over the study period. Among the taxa identified 3 species of Gyrinidae (*Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp. 1 and *Orectogyrus* sp.2), 5

| Variables | | Forested sites | | Urbanized sites | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $N_1$ | $N_2$ | $T_1$ | $T_2$ | $T_3$ | $AT_1$ | $AT_2$ | $M_1$ | $M_2$ | $AM_1$ | $AM_2$ | $AM_3$ |
| Temperature (°C) | Mean | 25.9 | 25.9 | 29.4 | 29.2 | 30.1 | 32.7 | 30.54 | 29.1 | 29.54 | 28.8 | 29.23 | 29.4 |
| | SD | 0.79 | 0.98 | 1.7 | 1.61 | 2.36 | 2.24 | 2.12 | 2.63 | 2.23 | 1.78 | 1.73 | 2.28 |
| pH (UC) | Mean | 6.10 | 6.19 | 7.01 | 6.98 | 6.72 | 7.93 | 6.71 | 6.92 | 6.79 | 6.75 | 8.16 | 7.01 |
| | SD | 0.71 | 0.93 | 0.52 | 0.53 | 0.73 | 1.11 | 0.84 | 0.63 | 0.72 | 0.66 | 0.91 | 0.86 |
| DO (%) | Mean | 75.4 | 80.3 | 14.6 | 17.7 | 2.95 | 4.65 | 5.5 | 6.32 | 5.7 | 21.3 | 10.51 | 5.64 |
| | SD | 8.3 | 10.9 | 10.1 | 11.8 | 1.66 | 2.47 | 3 | 8.73 | 5.89 | 12 | 7.86 | 6.62 |
| EC (µS/cm) | Mean | 13.2 | 13.1 | 397.9 | 401.1 | 475.3 | 1559 | 624.2 | 403.1 | 677.5 | 291.3 | 478.9 | 443.7 |
| | SD | 6.82 | 3.09 | 115 | 117 | 152 | 1159 | 277.5 | 148 | 636.6 | 79 | 417.1 | 170 |
| Turbidity (NTU) | Mean | 14 | 26 | 102.2 | 116.3 | 131.6 | 259.7 | 173 | 125.1 | 119.9 | 94.2 | 122.6 | 106.9 |
| | SD | 10.5 | 17.2 | 108 | 71 | 66 | 187.4 | 100.6 | 40 | 69.6 | 18.7 | 86.59 | 60 |
| SS (mg/L) | Mean | 4.2 | 7.7 | 62.9 | 54.9 | 100.5 | 163.5 | 99.2 | 77 | 71.62 | 47.9 | 72.69 | 86.9 |
| | SD | 3.8 | 4.09 | 101 | 85.5 | 84 | 112.3 | 66.1 | 39.7 | 27.3 | 25.9 | 41.72 | 72.7 |
| $NO_3^-$ (mg/L) | Mean | 0.11 | 0.2 | 2.79 | 1.53 | 3.7 | 6.98 | 4.43 | 2.24 | 3.22 | 1.91 | 3.24 | 3.1 |
| | SD | 0.16 | 0.17 | 5.26 | 0.58 | 2.92 | 4.9 | 3.32 | 2.14 | 1.49 | 1.18 | 3.99 | 1.3 |
| $NO_2^-$ (mg/L) | Mean | 0.006 | 0.008 | 0.23 | 0.21 | 0.13 | 0.21 | 0.041 | 0.04 | 0.08 | 0.12 | 0.26 | 0.2 |
| | SD | 0.0 | 0.0 | 0.46 | 0.39 | 0.26 | 0.31 | 0.025 | 0.06 | 0.1 | 0.15 | 0.65 | 0.29 |
| $NH_4^+$ (mg/L) | Mean | 0.09 | 0.1 | 4.5 | 4.56 | 4.4 | 4.04 | 3.12 | 5.19 | 4.15 | 3.1 | 2.49 | 3.29 |
| | SD | 0.07 | 0.08 | 2.53 | 2.73 | 2.31 | 2.93 | 1.04 | 3.16 | 0.32 | 2.39 | 1.86 | 1.52 |
| $PO_4^{3-}$ (mg/L) | Mean | 0.08 | 0.14 | 1.21 | 1.06 | 1.3 | 2.2 | 1.4 | 1.53 | 1.17 | 0.9 | 0.88 | 1.39 |
| | SD | 0.13 | 0.2 | 0.41 | 0.38 | 0.58 | 1.73 | 0.69 | 0.91 | 0.73 | 0.43 | 0.37 | 0.45 |
| $BOD_5$ (mg/L) | Mean | 13.08 | 16.2 | 96.9 | 156.2 | 158.5 | 218.1 | 176.2 | 89.6 | 105 | 94.6 | 121.15 | 139.6 |
| | SD | 6.9 | 10.2 | 50 | 53 | 67 | 63.23 | 46.24 | 31.3 | 27.39 | 29 | 22 | 33 |
| WD (m) | Mean | 0.31 | 0.66 | 0.37 | 0.48 | 0.65 | 0.26 | 0.62 | 0.22 | 0.43 | 0.35 | 0.26 | 0.75 |
| | SD | 0.07 | 0.05 | 0.07 | 0.06 | 0.04 | 0.04 | 0.05 | 0.03 | 0.05 | 0.06 | 0.05 | 0.03 |
| CV (m/s) | Mean | 0.64 | 0.48 | 0.75 | 0.78 | 0.57 | 0.89 | 0.71 | 0.38 | 0.37 | 0.46 | 0.45 | 0.22 |
| | SD | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 | 0.05 | 0.05 | 0.04 | 0.05 |
| OPI **Values** | Mean | 4.63 | 4.14 | 1.67 | 1.73 | 1.69 | 1.48 | 1.81 | 1.81 | 1.87 | 1.98 | 1.94 | 1.77 |
| | SD | 0.53 | 0.55 | 0.30 | 0.26 | 0.31 | 0.37 | 0.25 | 0.37 | 0.32 | 0.31 | 0.34 | 0.40 |
| Pollution level | | Null | Low | Very high | | | | | | | | | |

Table 1. Mean values and standard deviation (SD) of environmental variables measured at each sampling station during the study period.

species of Gerridae (*Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1, *Eurymetra* sp. 2, *Limnogonus chopardi* Poisson, 1941 and *Limnogonus* sp.) and 3 species of Veliidae (*Microvelia* sp., *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp.) were present simultaneously at the two sub-urban stations and are considered as characteristic species. Each of the other species was caught either at the station $N_1$ or at the station $N_2$, exclusively.

### *Morphological description of some characteristic species*

DESCRIPTION OF SPECIES OF THE GENUS *ORECTOGYRUS* RÉGIMBART, 1884 (COLEOPTERA GYRINIDAE). The aquatic insects of the family Gyrinidae are all holometabolous. Adult Gyrinidae (whirligig beetles) are highly adapted to the aquatic environment, being the only beetles that normally use the water surface film for support. They are, however, equally at home under the water. Both adults and larvae of all Gyrinidae are strictly aquatic. The adult gyrinids are true water beetles with medium-sized to moderately large, ranging from 4–17 mm in length. The body shape of the adults is ovate or elongate-ovate, convex, with a sharp lateral edge around the whole body. This edge separates the hydrofuge dorsal surface of the insect from its wettable ventral surface. The lateral edge divides the compound eyes into dorsal and ventral halves (Fig. 7), with the dorsal part looking up out of the water, whereas the ventral part looks down into the water. The antennae of adult gyrinids are short, stout and highly sensitive (Fig. 5). The front legs of gyrinids are long and adapted for seizing prey. The middle and hind legs are adapted for swimming: they are shot and dorsoventrally compressed, with fringes of swimming hairs (Fig. 6).

The adult specimens of the genus *Orectogyrus* are recognized with their elongate-ovate-convex body and their last abdominal segment elongate extending beyond the elytra edge.The upper side of

| ORDERS/FAMILIES | SPECIES | $N_1$ | $N_2$ | All urban stations |
|---|---|---|---|---|
| **COLEOPTERA GYRINIDAE** | *Aulonogyrus* sp. | 3* | - | - |
| | *Orectogyrus specularis* Aubé, 1838 | 9* | 6* | - |
| | *Orectogyrus* sp.1 | 8* | 15* | - |
| | *Orectogyrus* sp.2 | 27** | 19* | - |
| **HEMIPTERA GERRIDAE** | *Aquarius distanti* Horvath 1899 | - | 2* | - |
| | *Eurymetra manengolensis* Hoberlandt, 1952 | 64*** | 69** | - |
| | *Eurymetra* sp.1 | 18* | 13* | - |
| | *Eurymetra* sp.2 | 4* | 6* | - |
| | *Gerris swakopensis* Stål, 1858 | - | 3* | - |
| | *Gerris* sp. | - | 2* | - |
| | *Hynesionella aethiopica* Poisson, 1949 | - | 2* | - |
| | *Limnogonus chopardi* Poisson, 1941 | 9** | 7* | - |
| | *Limnogonus* sp. | 2* | 8** | - |
| | *Neogerris* sp. | 3* | - | - |
| | *Tenagogonus* sp. | - | 5* | - |
| **HEMIPTERA VELIIDAE** | *Carayonella hutchinsoni* Poisson, 1948 | 1* | - | - |
| | *Microvelia gracillima* Reuter, 1882 | 2* | - | - |
| | *Microvelia* sp. | 12** | 6* | - |
| | *Rhagovelia reitteri* Reuter, 1884 | 162*** | 90** | - |
| | *Rhagovelia* sp. | 31** | 42** | - |

Table 2. Distribution, abundances and occurrence frequencies of insect species of the families Gyrinidae, Gerridae and Veliidae in different sampling stations; * = rare, ** = accessory, *** = frequent, (-) = absent. For undefined species, the descriptor author's name of the genus is given.

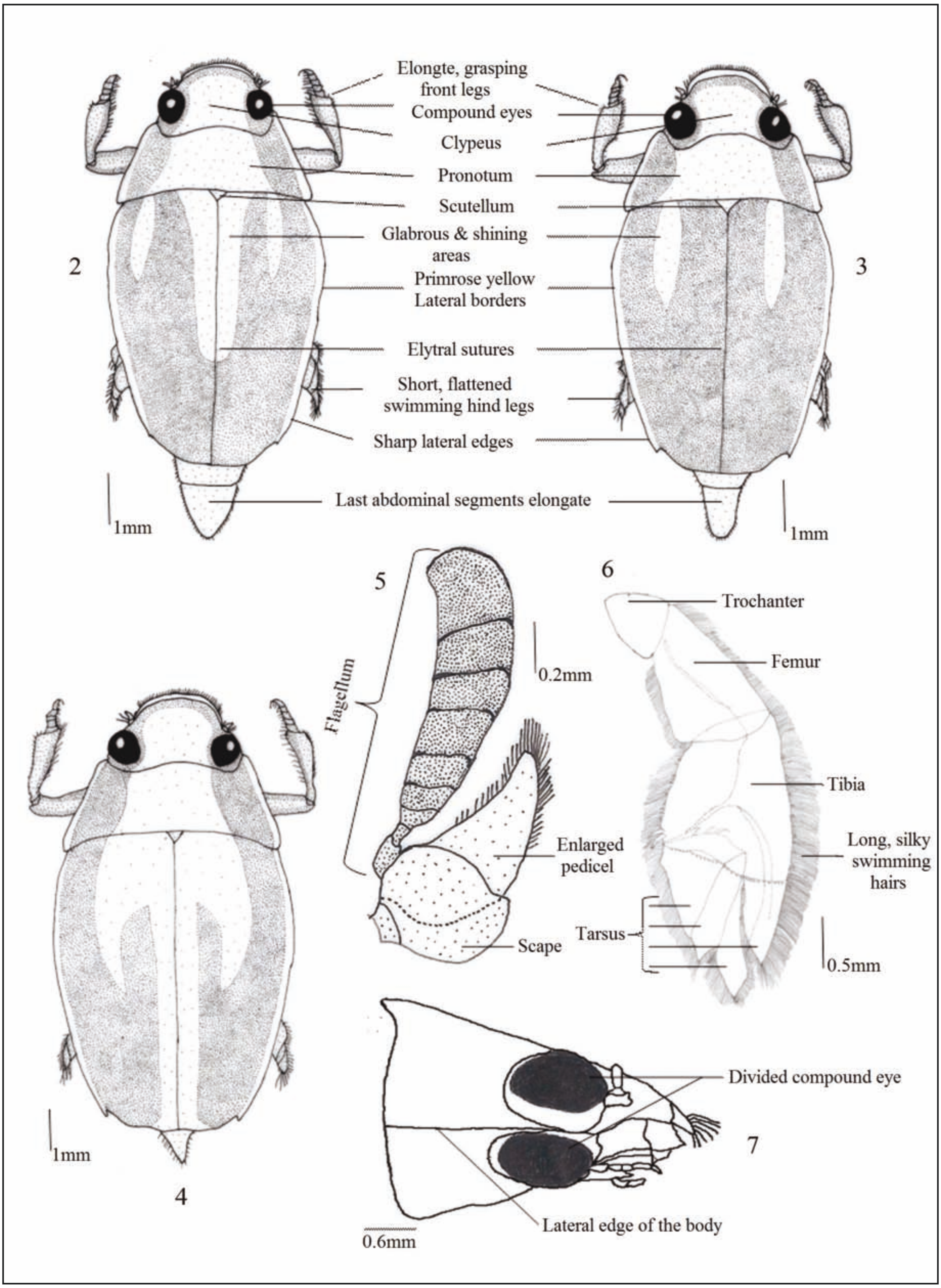
elytra is glabrous or (partly) pubescent, black in color, with distinct metallic shiny portions used as systematic character. The specimens that we recorded have a pale yellow lateral border on the pronotum and elytra. The hindmost two abdominal sternites are more-or-less laterally compressed and movable,with a ventral median row of long hairs used as a rudder for swimming. Three species, *Orectogyrus specularis* Aubé, 1838, *Orectogyrus* sp. 1 and *Orectogyrus* sp. 2 were identified. In *O.* sp. 1 (Fig. 4), only the last abdominal segment is extended beyond the elytra, whereas in *O. specularis* and *O*. sp. 2 (Figs. 2, 3), it is the two last ones. Moreover, the ornateness of elytra permitted to clearly separate these three species. The specimens of *O. specularis* measure 9.4 ± 0.1 mm in length and 4.16 ± 0.02 mm in width; the inter-ocular space measures 1.6 ± 0.001 mm and the pronotum is 1.2 ± 0.02 mm in length. For *O.* sp.1, the body is 7.08 ± 0.11 mm in length and 3.6 ± 0.01 mm in width; the inter-ocular space measures 1.12 ± 0.002 mm and the pronotum is 0.92 ± 0.08 mm in length. Concerning *O.* sp. 2, the specimens caught measure 9.54 ± 0.26 mm in length and 4.2 ± 0.02 mm in width; the mean length of the inter-ocular space is 1.4 ± 0.01 mm and the pronotum is 1.2 ± 0.04 mm in length. The median silky swimming hairs of the last abdominal sternite are longer in *O. specularis* and *O.* sp. 2 (800 - 850 μm) as compared to *O.* sp. 1 (520-680 μm).

DESCRIPTION OF SPECIES OF THE GENUS *RHAGOVELIA* MAYR, 1865 (HEMIPTERA VELIIDAE). The Veliidae are hemimetabolous insects gliding or treading on the surface of the water. They are typically characterized by their jointed mouthparts, modified to form a rostrum or "beak", which is adapted for piercing and sucking. The head is short, less than two times longer than wide, bent downward, and triangular. It has a distinct longitudinal sulcus mid-dorsally, a jointed rostrum with 3 segments, a pair of four-segmented antennae longer than the head, and no ocellus. The legs are nearly equidistant and the hind-coxae are distinctly moved apart from each other, with mid-femora not exceeding or very slightly the end of the abdomen. The tarsal claws are subapical.

The adult specimens of the genus *Rhagovelia* Mayr, 1865 are distinguishable with their body surface matt and blackish or brownish; all tarsi three-segmented with the basal segment very short; mid-tarsi deeply cleft with leaf like claws and hairy swimming fans arising from the base of the cleft (Fig. 10). The mesoscutellum is not exposed, covered by posteriorly-extended pronotal lobe. Two species, *Rhagovelia reitteri* Reuter, 1884 and *Rhagovelia* sp. were identified for this study.

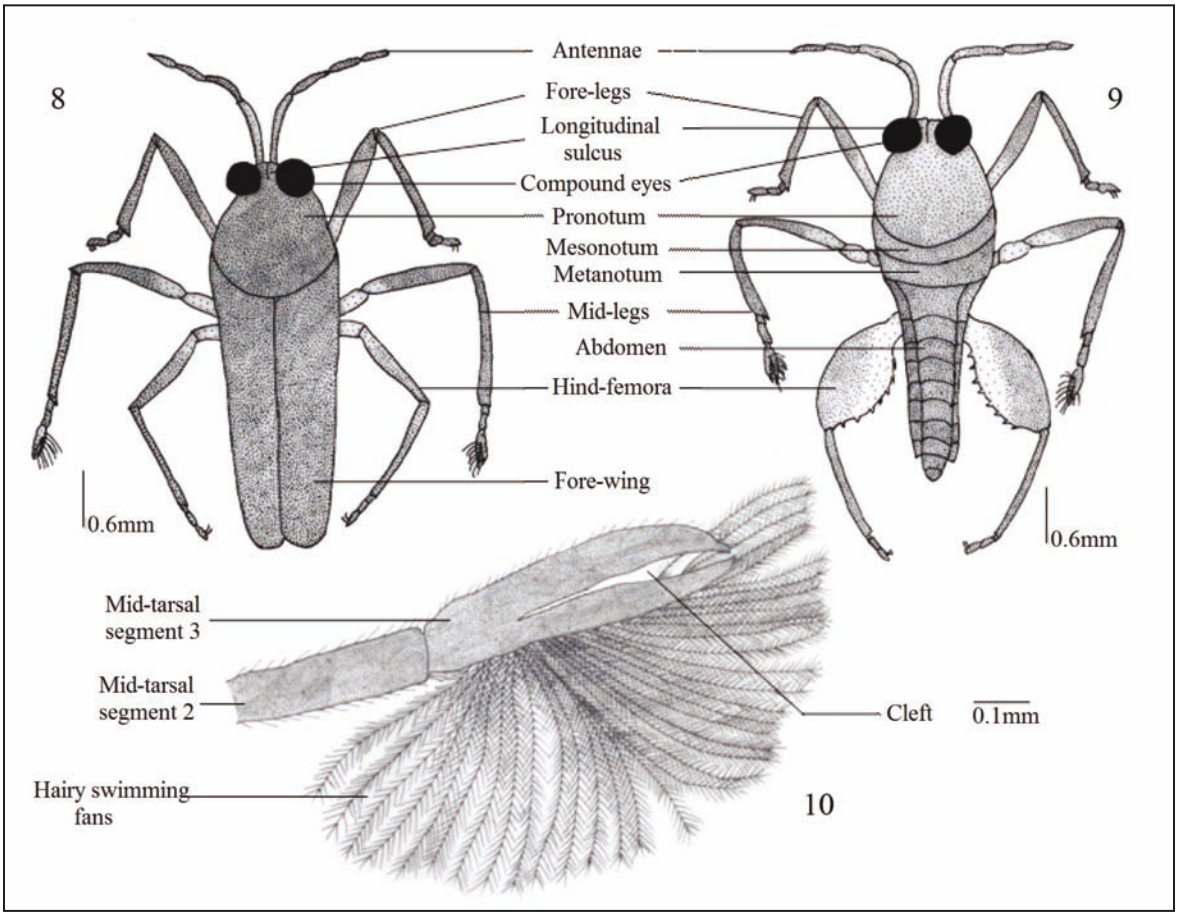
Adult specimens of *R. reitteri* collected are macropterous and their fore-wings (hemelytra) are not divided into corium and membrane (Fig. 8). However, these hemelytra can detach during sampling or identification processes. The specimens of *R. reitteri* measure 4.15 ± 0.15 mm in length and 1.05 ± 0.002 mm in width; the inter-ocular space measures 0.24 ± 0.001 mm and the pronotum is 0.82 ± 0.02 mm in length. Inversely, the individuals of *Rhagovelia* sp. are apterous, with stout hind femora bearing small distinct spines on the inner margins (Fig. 9). Their body is 4.12 ± 0.2 mm in length and 1.2 ± 0.01 mm in width; the inter-ocular space measures 0.23 ± 0.01 mm. The lengths of the pro-, meso- and metanotum are 0.81 ± 0.03 mm, 0.24 ± 0.001 mm and 0.24 ± 0.004 mm, respectively. The body is mainly black; pronotum anteriorly completely yellow, posteriorly variably colored, usually black, but in some specimens with yellowish hind margin, and in smallest specimens uniformly light reddish brown; connexiva (most lateral areas of sternites and laterotergites) usually brown, in smaller specimens yellow; anteclypeus, rostrum, and proepisterna mainly yellowish; antenna and legs mainly black, basal half of first antennomere, all coxae and trochanters, basal half of all femora, inner margins of hind femora yellow.

DESCRIPTION OF SPECIES OF THE GENUS *EURYMETRA* ESAKI, 1926 (HEMIPTERA GERRIDAE). The Gerridae are hemimetabolous insects gliding or treading on the surface of the water. They are typically characterized by their jointed mouth parts, modified to form a rostrum or 'beak', which is adapted for piercing and sucking. The head is short, less than two times longer than wide, bent downward, and triangular; it has no longitudinal sulcus, a jointed rostrum with 4 segments, a pair of four-segmented antennae longer than the head, and no ocellus. The mid and hind-legs are distant from fore-legs and longer than these formers, and their femora are clearly extended beyond the abdomen. The hind-coxae are distinctly moved apart from each other.

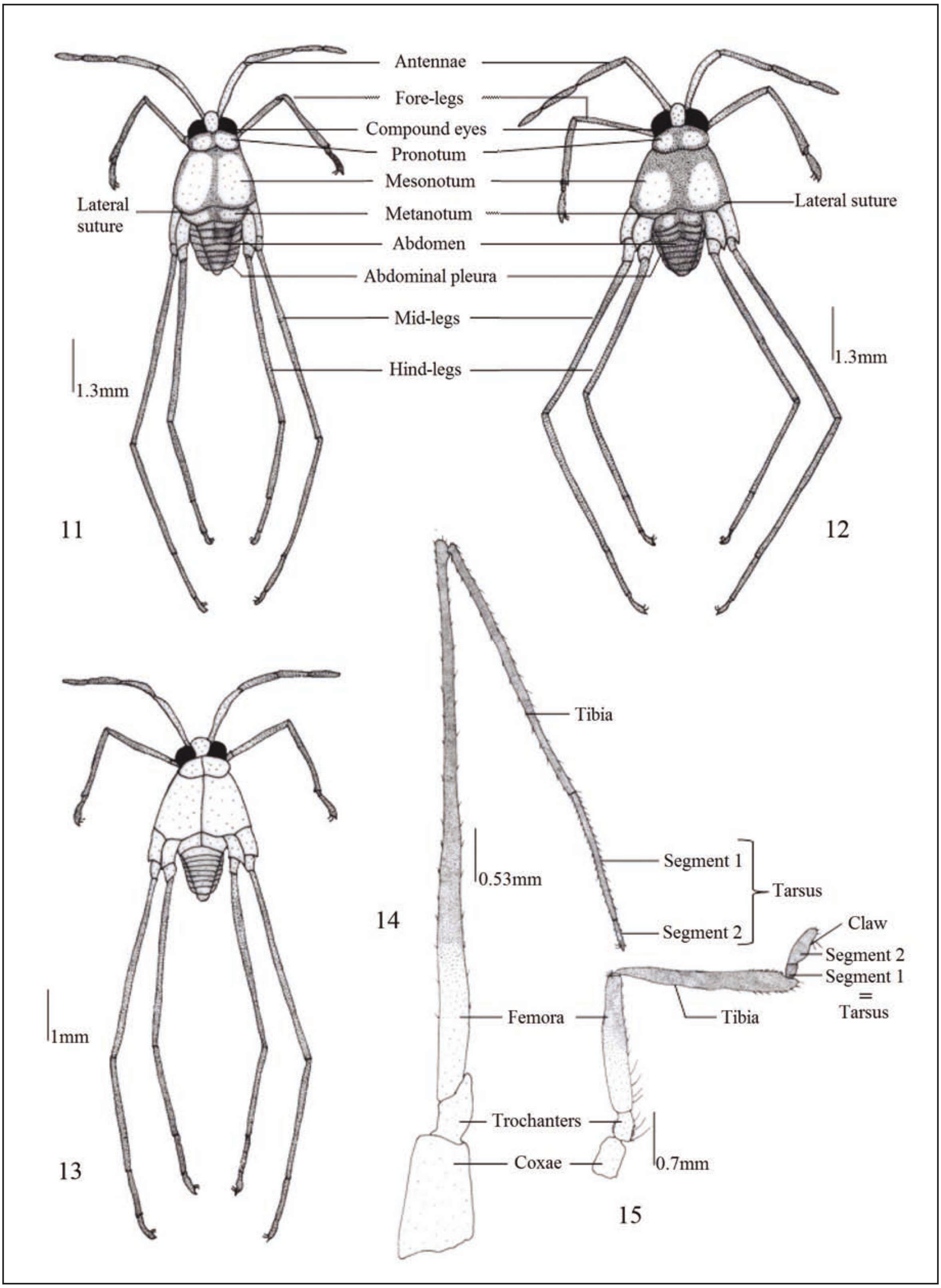



Figures 2–7. *Orectogyrus* adult. Morphology in dorsal view of *O. specularis* (Fig. 2), *O.* sp. 2 (Fig. 3) and *O.* sp. 1 (Fig. 4); Fig. 5, antenna; Fig. 6, hind leg; Fig. 7, lateral view of the head showing divided compound eye.

The adult specimens of the genus *Eurymetra* Esaki, 1926 are apterous and distinguishable with their short, stout and rounded abdomen. Their body is shiny and rounded, and generally does not exceed 4.5 mm in length. The meso and metanotum are well distinct and separated by a lateral suture, whereas the metasternum is reduced to a small triangular plaque. All tarsi are two-segmented and the tarsal claws are modified (straight or 'S'-shaped) in some specimens. At the level of fore-tarsi, segment 1 is shorter than segment 2 (Fig. 15), whereas in the mid- and hind-tarsi, segment 1is 3 to 4 times longer than segment 2 (Fig. 14). Three species, *Eurymetra manengolensis* Hoberlandt, 1952, *Eurymetra* sp. 1 and *Eurymetra* sp. 2 were identified for this study (Figs. 11–13). The specimens of *E. manengolensis* and *E*. sp.1 measure 4.1 ± 0.1 mm in length over 2.48 ± 0.04 mm in width, and 4.04 ± 0.12 mm in length over 2.76 ± 0.07 mm in width, respectively. For *E. manengolensis*, the lengths of the pro, meso- and metanotum are 0.23 ± 0.01 mm, 0.94 ± 0.006 mm and 0.24 ± 0.02 mm, respectively. Where as in *E.* sp. 1, the pro-, meso- and metanotum are 0.25 ± 0.02 mm, 0.94 ± 0.01 mm and 0.22 ± 0.04 mm in length, respectively. For these two species, 8 abdominal segments are visible in dorsal view; the edges of thoracic and abdominal tergites are black in color; a mid-dorsal longitudinal band is observed on the thoracic and the first two abdominal tergites. Abdominal pleura are well developed in *E. manengolens* as compared to *E.* sp. 1. Concerning *E.* sp. 2, the individuals caught measure 3.11 ± 0.41 mm in length and 2.17 ± 0.02 mm in width; 9 abdominal segments are visible in dorsal view. Their pro-, meso- and metanotum measure 0.22 ± 0.02 mm, 0.97 ± 0.04 mm and 0.23 ± 0.02 mm in length, respectively. Their body is pale yellow with median sulcus on thoracic tergites.




Figures 8–10. *Rhagovelia* adult. Morphology in dorsal view of *R. reitteri* (Fig. 8), *R.* sp. (Fig. 9) and detail of mid-tarsal fan (Fig. 10).




Figures 11–15. *Eurymetra* adult. Morphology in dorsal view of *E. manengolensis* (Fig. 11), *E.* sp.1 (Fig. 12) and *E.* sp.2 (Fig. 13); Fig. 14, mid-leg; Fig. 15, fore-leg.

### *Relationships between environmental variables and insect species*

The results of redundancy analysis (RDA) revealed that the relationships between the 8 characteristic aquatic insect species and their habitat conditions follow mainly the first two axes (F1=94.9 %; F2=3.6 %) which accounted for 98.5 % of the total variance expressed (Fig. 16). Following the first axis (F1) in positive coordinates the presence and abundances of the 8 characteristic insect species (*Orectogyrus specularis*, *Orectogyrus* sp. 1, *Orectogyrus* sp. 2, *Rhagovelia reitteri*, *Rhagovelia* sp., *Eurymetra manengolensis*, *Eurymetra* sp. 1 and *Eurymetra* sp. 2) are positively and significantly influenced by water depth, high dissolved oxygen content, important canopy coverage and higher values of OPI (i.e., very low organic matter input). *Rhagovelia* sp. seems to quite appreciate moderate water flow. Inversely, in negative coordinates, the presence of these sensitive aquatic insects is impeded by the polluted status of water with high values of temperature, pH, turbidity, electrical conductivity, suspended solids, ammonium, nitrites, nitrates, phosphates and BOD.

## DISCUSSION

This study achieved in Douala watershed permitted to identify 20 species, all present only at the two forested sites (N1 and N2); no species being found in urban streams. The absence of these

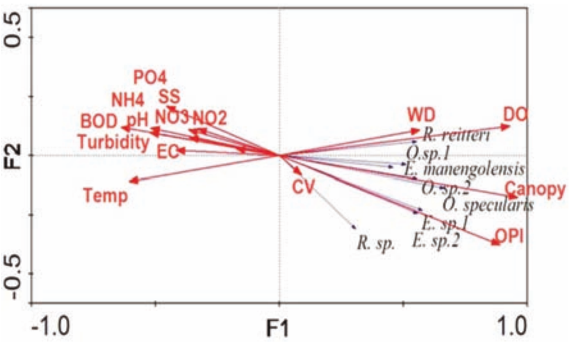



Figure 16. Redundancy analysis biplot showing gathering of characteristic aquatic insect species in response to environmental variables; NH4 = ammonium, NO2 = nitrites, NO3 = nitrates, and PO4 = phosphates. See "Materials and methods" section for other abbreviations.

Hemiptera (Gerridae Veliidae) and Coleoptera (Gyrinidae) families in Douala's urban waterways is undoubtedly due to their polluted status caused by the uncontrolled discharge of domestic, municipal and industrial wastes and sewages in the rivers.

Indeed, the hypoxic condition of water, the very high values of water temperature, conductivity, turbidity, suspended solids, diverse ions ($NO_3^-$, $NH_4^+$, $PO_4^{3-}$), organic matter input and BOD were registered at urban stations, and could have been responsible for the extinction of these aquatic insects. These observations allowed us to assume that species of these families might be sensitive to water pollution and in-stream habitat degradation, since we hypothesized that these taxa would have historically been present at these streams before urbanization, as they do in suburban streams. Similarly, Foto Menbohan (2012) reported that species of these aquatic insect families were absent (or very rare) in the most of urban streams of the Mfoundi river basin in Yaoundé (Cameroon). Our results are consistent with those of Compin & Céréghino (2003) and Song et al. (2009) who showed that a decrease in Coleoptera species richness in human-impacted streams is clearly related to changes in water quality and habitat suitability. Moreover, aquatic Coleoptera species, especially those belonging to Elmidae, Gyrinidae, and Haliplidae have also been recognized as good water quality indicators (Hilsenhoff, 1988; Bote et al., 2002; Sánchez-Fernández et al., 2006). Hauer & Resh (1996) added that many species of these Coleoptera families have been shown to be sensitive to increase in sediment and organic pollution. Concerning the aquatic Hemipteran's families (Gerridae Veliidae), their use in stream biomonitoring programs is still worldwide limited.

In this study, these aquatic bugs occurred only at forested sites and presented high diversity; we believe that these Hemiptera could be sensitive to water pollution and their use as bioindicators might enhance the accuracy of water quality assessments in urban impaired streams. Our results are in line with those of Zettel & Tran (2004) who found that in Vietnam, *Rhagovelia polymorpha* a congener species of *R. reitteri* and *Rhagovelia* sp. identified in Douala forested stream, also inhabit small stream in a forested area, with a moderate to slow water flow, in partial shade, bottom with rock or sand. Moreover, the canonical redundancy analysis

(RDA) revealed that the presence and abundance of the most characteristic species of these aquatic bugs are positively and significantly influenced by high dissolved oxygen content, important canopy coverage, low mineralization, very low organic matter input and current velocity.

Concerning morphological features of the Gyrinidae, this study revealed that *Orectogyrus* sp.1 and *Orectogyrus* sp. 2 differ from the Afrotropical *Orectogyrus specularis* Aubé, 1838 and *O. camerunensis* Ochs, 1924 known to occur in Cameroon, particularly by the distinct metallic shiny ornateness of the elytra. However, these species are to be compared to other Afrotropical allotype or paratype occurring elsewhere, to know whether we are face to new records or new species. As for the Veliidae, *Rhagovelia* sp. described here differs drastically from *R. reitteri*, as it lacks wings. Additionally, *Rhagovelia* sp. has stout hind femora bearing short distinct spines on the inner margins. This former character makes *Rhagovelia* sp. to be closer to *R. polymorpha* describe by Zettel & Tran (2004), but in *R. polymorpha* the body including legs is silky, with numerous black, semi-erect setae and with short, appressed yellow pubescence; legs with very long black setae. Moreover, *R. polymorpha* is smaller in size (body length 3.2-3.6 mm) as compared to our specimen (body length 4.12 ± 0.2 mm). The specimens of *Eurymetra* sp.1 and *Eurymetra* sp.2 that we recorded in this study differ significantly from the typical *E. manengolensis* described by Hoberlandt (1952) in Cameroon Manengouba mount. Abdominal connexiva (pleura) are well developed in *E. manengolensis* as compared to *E.* sp. 1.

In addition, mid- and hind-coxae are larger in *E.* sp. 1 than in *E. manengolensis*. As for E. sp. 2, the specimen described here shows some similarities with the genus *Eurymetropsis* examined by Poisson (1965) in terms of morphology (especially size and color). However, in *Eurymetropsis* body is more flattened and often lustrous above, the lateral suture between the meso- and metanotum is not so keeled, all tarsal segments are also nearly equal in length, what distinguish it from our specimen.

## CONCLUSIONS

This biological assessment permitted to identify 20 species, all present only at the forested sites; no species being found in urban streams. This study highlights that species richness and distribution of aquatic insect of the families Gyrinidae, Gerridae and Veliidae in Douala watershed are highly and negatively influence by polluted status of its urban streams due to anthropogenic activities which cause the extinction of the sensitive taxa.We thus believe that these aquatic Coleoptera and Hemiptera species are sensitive to water pollution and we suggest that their use as bioindicators might enhance the accuracy of water quality assessments in Cameroon.

Morphological description of our specimens revealed many undescribed taxa which are probably new records or new species.This testified that in Cameroon, biodiversity of aquatic insects is yet entirely to be investigated, and that there is an urgent need for a modern taxonomic revision and establishment of a complete key to the Cameroonian species.

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