



Journal Homepage: [-www.journalijar.com](http://www.journalijar.com)

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/12826
DOI URL: <http://dx.doi.org/10.21474/IJAR01/12826>



RESEARCH ARTICLE

AQUATIC MACROINVERTEBRATE STRUCTURE AND DIVERSITY IN ANGUÉDEDOU STREAM (ANGUÉDEDOUBASIN : CÔTE D'IVOIRE)

Mohamed Coulibaly, Idrissa Adama Camara, Mexmin Koffi Konan, Edia Oi Edia, Lassina Doumbia,
Allassane Ouattara and Dramane Diomande

Laboratoire d'Environnement Et De Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement
(SGE), Université Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02 (Côte d'Ivoire).

Manuscript Info

Manuscript History

Received: 10 March 2021
Final Accepted: 14 April 2021
Published: May 2021

Key words:-

Aquatic Macroinvertebrates, Diversity,
Anguededou Stream, Classified Forest,
Côte d'Ivoire

Abstract

Aquatic macroinvertebrates play an important rôle in ecosystems and are usually used as bioindicators to assess their health. This study aim to assess the structure and diversity of these organisms on one hand and the effect of the environmental variables on the characteristics of their communities in Anguededou Stream basin (Côte d'Ivoire) on the other hand. Six stations were monthly sampled during one year period (March 2018 - February 2019). A total of 171 taxa belonging to 77 families and 14 orders were recorded. The Insecta class was the most diversified with 150 taxa (87.20% of total species richness); followed by the Gasteropoda, Malacostraca, Acheta and one species in Oligocheta. The highest values of diversity indices were collected in the upstream station A1; while highest values of Sorensen similarity index were found between the midstream stations (i.e. A3, A4, A5). A strong positive correlation between conductivity, turbidity, salinity, and a negative correlation with dissolved oxygen was found with the Chironominae subfamily, and the species *Diplonychus* sp., *Hydrobius* sp., *Hydracharina* sp., *Hydrochara* sp. and *Physa marmorata*, while the Tanytopodiinae subfamily was highly associated with increased dissolved oxygen. Macroinvertebrates diversity and species composition was found significantly affected by anthropogenic disturbances.

Copy Right, IJAR, 2021.. All rights reserved.

Introduction:-

Aquatic macroinvertebrates have an important role in the trophic structure of aquatic ecosystems, feeding on living or decomposing organic matter and serving as food for other invertebrates and vertebrates (Moulton et al., 2010; Lancaster and Downes, 2013). Among the communities that are considered bioindicators of water quality, the most commonly used are the aquatic macroinvertebrates (Bonada et al., 2006), because they have several characteristics that make them easy to study, and show clear responses when faced with adverse environmental conditions (Moreno et al., 2009). The structure of the benthic communities in an aquatic ecosystem reflects its ecological conditions, including habitat heterogeneity (Heino et al., 2003) and water quality (Soldner et al., 2004). Indeed, in the aquatic systems, the decline of aquatic macroinvertebrates is largely due to anthropogenic impact in the form of habitat deterioration and nutrient overload. The diversity of this fauna is progressively simplified due to the decreased number of taxa (Yuan, 2010 ; Cai et al., 2012b ; Zhang et al., 2014). Furthermore, the habitat deterioration has led

Corresponding Author:- Mohamed Coulibaly

Address:- Laboratoire d'Environnement Et De Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Université Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02 (Côte d'Ivoire).

at habitat complexity that is one of the key environmental factors influencing aquatic macroinvertebrate communities. Consequently, habitat deterioration will severely depress the composition and diversity of macroinvertebrates communities. Thus, identifying the possible factors regulating macroinvertebrates structure, diversity, and distribution can aid the development of more prescriptive conservation and management strategies for freshwater ecosystems in highly developed regions.

In Côte d'Ivoire, Anguededou Stream basin is subject to many anthropogenic disturbances (municipal and industrial wastes, surface run-off, agricultural farms), various origins of wastewater and solid wastes discharged directly in the environment without any preliminary or adequate treatment coming from neighbouring cities of Anguededou watershed. This disturbance represents a threat for the stream integrity and the aquatic communities.

In Côte d'Ivoire, many studies have dealt about the composition and structure of aquatic macroinvertebrates in some streams (Camara et al., 2012 ;Camara et al., 2014; Simmou et al., 2015), but none of them dealt with aquatic macroinvertebrates of sub-urban streams such as Anguededou Stream.

The aims of this study were (i) to give the first inventory of aquatic macroinvertebrates of Anguededou Stream; (ii) assess the diversity and structure of this community; and (iii) investigate the relationships between aquatic macroinvertebrate and the environmental variables of Anguededou stream.

Material and Methods:-

Study area and sampling stations

The Anguededou Stream is a short stream (about 12 km long) located in the Anguededou watershed. Anguededou watershed (81 Km²area) is situated at the periphery of Abidjan (economic capital) between 5°20' - 5°28'N and 4°3' - 4°10'W (Fig. 1).

On this watershed, more than 37 % is occupied by several anthropogenic activities and about 60 % is covered by the Anguededou Classified Forest (ACF). This watershed is characterized by the presence of many industries of Yopougon citie. Moreover, Anguededou Stream basin is populated with a high number of anarchical building without adequate sanitation system. Anguededou Stream is also subject to domestic sewage, municipal waste waters, surface run-off, agricultural farms etc. coming from neighbouring cities of Anguededou.

The climate in this watershed is typical of equatorial rain forest, comprising four seasons: a great dry season (December-March), a great rainy season (April-July), a small dry season (August-September) and a small rainy season (October-November). The air temperatures of watershed average 26°C - 27°C (Environment and Development Group, 2000), with an annual precipitation average of 2004.29 mm (SODEXAM, 2014).

In order to assess the variability of environmental and biotic parameters of the stream, six sampling stations (A1-A6) were chosen. The sample stations were positioned according to the longitudinal gradient of the stream, the accessibility of water channel and the presence or absence of anthropogenic disturbances. Macroinvertebrates were sampling monthly from March 2018 to February 2019 at the six sampling stations. Station A1 is located in the upstream area, station A2 on the tributary. Three stations (A3, A4 and A5) are in the midstream area (on Anguededou Classified Forest) and the last one station A6 is positioned in the downstream area near the bay of Ebrié lagune (Fig. 1). At each station, the length of sampled area covered ten times the channel width (AFNOR, 1992; Lazorchak et al., 1998). Table 1 summarizes the main characteristics of these sampling stations.

Macroinvertebrate sampling

Aquatic macroinvertebrates were sampling monthly at the six sampling stations during twelve sampling campaigns with a kick-net (500 µm mesh size and 1 m length). For each sample, the net was dragged over the stream bed for a distance of 10 m, maintaining contact with the substrate. At each sampling campaigns, two replicate samples were collected by station, considering all possible microhabitats over representative sections of the stream. The materials that were collected in the sampling net were rinsed through a 1 mm sieve bucket, and large debris were examined for macroinvertebrates, rinsed into the sieve, and discarded. All macroinvertebrate individuals were sorted and preserved in plastic sampling bottles with 90 % ethanol. In the laboratory, all the macroinvertebrates recorded were identified to lowest possible taxonomic level under a stereomicroscope (Olympus SZ 40), with use of appropriate taxonomic keys. The keys used in this study are (Monod, 1980) and (Powell, 1980) for the Decapoda; (Brown, 1994)

for Mollusca; (Dejoux et al., 1981) and (Tachet et al., 2010) for Insecta and Oligochaeta. After the identification, the organisms were preserved in 70 % ethanol.

Environmental variable

Five environmental variables were used to describe physico-chemical water condition at each sampling station. Conductivity, pH, water temperature and dissolved oxygen were determined directly at the same sampling station using a portable multi-parameter (HANNA), turbidity was measured using a turbidimeter(HANNA). All these variables were measured monthly between 7 and 12 a.m in the field before aquatic macroinvertebrates sampling. The habitat variables included are current velocity, water depth, wetted channel width, canopy cover and the main substrate type. Current velocity (m/s) was measured in mid-channel on five occasions by timing a floating object (polystyrene cube) over five meters stretch of the river. It was determined as the average of the five trials. Water depth (m) and wetted channel width (m) were measured (five transects) to the nearest centimetre inside each station, using a decametre. Canopy cover (%) and the main substrate type (mud, sand, gravel and woody debris as % of station bottom area covered by each substrate type) were estimated visually at each sampling stations (Arab et al., 2004 ; Rios and Bailey, 2006).

Data analysis

Aquatic macroinvertebrates structure was described through taxonomic richness, frequency of occurrence, Sorensen similarity index and diversity index (Shannon-Weaver diversity index, Pielou evenness and Rarefied richness). Taxonomic richness was rarefied in each station per sampling period. Rarefied richness was used to avoid any bias related to differences in abundance between samples (Grall and Coïc, 2005). The Sorensen similarity index was used to evaluate similarity of aquatic macroinvertebrate richness between sampling station. The frequency of occurrence (FO) was calculated using the following formula: $FO = (Ni/Nts) \times 100$; with Ni = number of samples containing a given species i , and Nts = total number of samples collected. The FO was used to classify taxa following (Dajoz, 2000): $FO > 50$ = very frequent taxa; $25 < FO \leq 50$ = frequent taxa; $FO \leq 25$ = rare taxa.

Before performing comparison analyses, data normality was checked using Shapiro test. As the biotic and environment data distribution follow non-normal distribution ($P < 0.05$), the non-parametric test of Kruskal-Wallis was performed to compare data variability between sampling stations. The Kruskal-Wallis test followed by the multiple comparison rank test of Tukey were performed to verify significant differences in environmental variables and entomofauna metrics among sampling stations. Analyses were conducted using STATISTICA 7.1 computer package. A level of $p < 0.05$ was considered significant.

Focused Principal Component Analysis (FPCA) (Falissard, 1999) was used to assess relationships between the very frequent taxa ($FO > 50\%$) and environmental variables. FPCA is a variation of the traditional principal component analysis. It uses the same types of matrix as the PCA but differs from it because it is centred or focused on a variable x_i . Indeed, it allows a graphical representation of the correlations that exist between this variable x_i and the other variables. The graph provides access not only to the nature (positive or negative) but also to the significance ($p < 0.05$) of the correlations between variable x_i and the other variables. It is also possible to observe on the graph the correlations between the other variables. In this study, the FPCA was used to determine the variables that influence the presence of the very frequent macroinvertebrate taxa along the stream bed. Twelve environmental parameters and eight taxa were returned for the analysis. This analysis was performed using the psy package on the R software.

Results:-

Environmental variables

The pH in Anguededou Stream basin varied between 5.24 (A1) to 9.89 (A2 ; tributary)(Tab.2). In the main channel stations, the pH values are significantly higher at midstream station A3, than those in the other sampling stations (Kruskal-Wallis, $p < 0.05$). Regarding water temperature, except the tributary station A2, the main channel stations values are not significantly different (Kruskal-Wallis, $p < 0.05$) and varied between 25.9°C (A3) and 30.8°C (A2). Concerning the water conductivity, it ranged from 38.1 $\mu\text{S}/\text{cm}$ (A1) to 1017 $\mu\text{S}/\text{cm}$ (A2). Relatively to water turbidity, the highest value (1000 UTN) was observed on the tributary (A2) whereas the lowest value (2.4 UTN) was registered at upstream station A1. Water salinity (NaCl) varied from 0.1 % (A1) to 2 % (A2). In the whole, pH, conductivity, turbidity and salinity values were significantly higher in the tributary station (A2) than in the main channel stations (Kruskal-Wallis, $p < 0.05$). Regarding the main channel stations conductivity, turbidity and salinity values were significantly lower at upstream station A1 than those reported in the other stations (Kruskal-Wallis, $p < 0.05$). Inversely, the dissolved oxygen values are significantly higher at upstream station A1 (4.38 – 7.18

mg/L) than that registered in the other main channel stations (A5 = 1.15 mg/L; A3 = 5.39 mg/L). Tributary station A2 recorded the most lower values of dissolved oxygen. Current velocity, water depth and wetted channel width varied from upstream to downstream (Kruskal-Wallis, $p < 0.05$). Current velocity varied from 0.12 m/s (A5) to 0.87 m/s (A6). Water depth ranged from 0.11 m (A2) to 1.45 m (A3) and Wetted channel width varied between 2.1 m (A4) and 13.6 m (A5).

Composition, distribution and frequency of occurrence of macroinvertebrates

A total of 171 macroinvertebrates taxa were recorded in this study. They were distributed among 77 Families and 14 Orders and six Classes : Insecta (150 taxa ; 87.20% of total richness), Gasteropoda (twelve taxa), Malacostraca (five taxa), Acheta (three taxa) and Oligocheta (one taxa) (Tab.3).

In terms of taxa richness, samples were dominated by Insecta: Odonata (21.51 %), Diptera and Heteroptera (16.27 % each one), Coleoptera (13.95%) and Trichoptera (10.46%). Concerning the group ETP (Ephemeroptera, Trichoptera and Plecoptera), ten taxa of Ephemeroptera were collected in this study. All these taxa were found in the upstream station A1. Three taxa of Plecoptera (*Neoperlaspio*, *Perlodes* sp., *Chloroperla* sp.) were recorded only at upstream station A1. Concerning the Trichoptera, 18 taxa were identified along the stream, but ten species were found only at station A1. Six pollution-tolerant taxa among Diptera (*Acanthocnema* sp., *Clogmia* sp., Culicinae, *Eristalis* sp., *Odontomyia* sp., Sciomyzidae) were recorded only at station A2 (on tributary) and downstream station A6.

Regarding the Gasteropoda, 11 taxa were found in this study. Among them, Basommatophora with seven taxa (*Biomphalaria pfeifferi*, *Bulinus forskalii*, *Bulinus globosus*, *Bulinus truncatus*, *Indoplanorbis exustus*, *Lymnaea natalensis*, *Physa marmorata*) was the most diversified, following by Cenogasteropoda with four taxa (*Pila africana*, *Melanoides tuberculata*, *Gabiella africana*, *Bythiospeum* sp.). None taxa of Gasteropoda was recorded at upstream station A1.

Five species of freshwater Decapoda belonging to three families (Desmocarididae, Palaemonidae, Potamonautidae) were identified in Anguededou stream basin. Desmocarididae (*Desmocarid trispinosa*) and Potamonautidae (*Liberonautes chaperi*) were represented by one species each one. Concerning Palaemonidae, three species (*Macrobrachium equidens*, *Macrobrachium macrobrachium*, *Macrobrachium thysi*) were recorded. The four shrimp species were present at all sampling stations except the station A2 (tributary). The only one crab taxa (*Liberonautes chaperi*) was recorded at upstream station A1.

Relatively to Acheta, three taxa (*Helobdella* sp., *Glossiphonia* sp., *Haementeria* sp.) belonging to Glossiphoniidae family were found along the stream. Concerning the Oligocheta, only one species (*Tubifex* sp.) from the Tubificidae family was recorded in Anguededou stream.

The high numbers of taxa were obtained at upstream station A1 (91 taxa) and downstream station A6 (102 taxa) in the main channel. The number of taxa recorded in the tributary station (A2) was low (61 taxa), than that in the main channel stations.

The analyses of the frequency of occurrence revealed that rare taxa (FO < 25%) are the most numerous at all the studied stations with more than 56 % of the taxa identified except station A1 (Tab.4). The high values of very frequent ($F \geq 50$ %) taxa were recorded in upstream station A1 (40) and downstream station A6 (26). Midstream stations A5, A4 and A3 registered 23, 16 and 8 very frequent taxa respectively. At the tributary station A2, they were registered 11 very frequent taxa. Concerning the frequent taxa ($25 \leq FO < 50$), the higher numbers were respectively recorded at stations A6 (27), A1 (24), A3 (24), A5 (23) and A4 (21). 17 frequent taxa were registered at station A2 (on the tributary). Thirteen taxa were common to the six stations (*Chalcostephia* sp., *Diplonychus* sp., *Mesovelina* sp., *Hydrochara* sp., *Enochrus* sp., *Hydrobius* sp., Chironominae, *Chaoborus* sp., *Mochlonyx* sp., *Tabanus* sp., *Bezzia* sp., *Hydracharina* sp., *Tubifex* sp.).

Diversity index

Overall, the Shannon-Weaver index is higher at station A1, where the median value is greater than 2.5 (Fig. 2A). It gradually decreases at stations A2, A3, A4 and A5 where the median remains below 2, before growing up slightly at downstream station A6 with a median higher to of 2.3. The Shannon - Weaver index obtained at upstream station A1 is significantly higher than those observed at other sampling stations (Kruskal-Wallis, $p < 0.05$). Pielou's Evenness Index evolution is similar to Shannon - Weaver index. This index is higher at upstream station A1, with a median

greater than 0.60 (Fig. 2B). This index decreases at stations A2, A3, A4 and A5 where the median remains below 0.4, then rises again at downstream station A6 with a median of 0.46. The Pielou's Evenness Index obtained at upstream station A1 is significantly higher than those observed at others sampling stations (Kruskal-Wallis, $p < 0.05$). Concerning the Rarefied richness, it is higher at station A1 (median > 9) (Fig. 2C). It decreases through stations A2, A3, A4 and A5 (median less than 7.5), before going up slightly at downstream station A6 with a median higher to 7.8. The Rarefied richness is significantly higher than those observed at others sampling stations (Kruskal-Wallis, $p < 0.05$). Table 5 shows the values of the Sorensen similarity index between the studied stations. The high values of this Sorensen similarity index were found between the midstream stations A4-A5 (66.97 %), between the stations A3-A5 (66.67 %), and between the tributary station A2 and downstream station A6 (64.67 %). The low values were recorded between the upstream station A1 and the tributary station A2 (31.37 %). It is also low between the upstream station A1 and downstream station A6 (38.34 %).

Taxa relationships with environmental variable

Focused Principal Component Analysis (FPCA) was performed using environmental variables with a focus on the eight very frequent taxa (FO > 50 %) recorded along the stream (*Diplonychus* sp., *Hydrochara* sp., *Hydrobius* sp., Chironominae, Tanyptodiinae, *Chaoborus* sp., *Hydracharina* sp., *Physa marmorata*) (Fig. 3). *Diplonychus* sp. is significantly and positively correlated with parameters such as conductivity (CND), turbidity (Turb), salinity (NaCl), pH and woody debris (Wdeb), and significantly and negatively correlated with dissolved oxygen (DO) and canopy (Cano) ($P < 0.05$). *Hydrochara* sp. is significantly and positively correlated with turbidity, salinity, width (Width) and conductivity ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by dissolved oxygen, canopy (Cano) and gravel (Grav). *Hydrobius* sp. is significantly and positively correlated with sand, temperature, turbidity, salinity and conductivity ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by dissolved oxygen and canopy (Cano). Chironominae is significantly and positively correlated with sand, temperature, turbidity, salinity and conductivity ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by dissolved oxygen. Tanyptodiinae is significantly and positively correlated with dissolved oxygen, gravel, canopy and woody debris ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by sand. *Chaoborus* sp. is significantly and positively correlated with sand, woody debris ($P < 0.05$) and significantly and negatively influenced ($P < 0.05$) by current velocity, turbidity, pH and temperature. *Hydracharina* sp. is significantly and positively correlated with gravel, temperature, salinity and turbidity ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by dissolved oxygen and depth. *Physa marmorata* is significantly and positively correlated with temperature, conductivity, turbidity, salinity, width, mud and pH ($P < 0.05$), and significantly and negatively influenced ($P < 0.05$) by dissolved oxygen, canopy and gravel.

Discussion:-

Environmental variables analyses revealed that in the whole, pH, temperature, conductivity, turbidity and salinity values were highest in the tributary station A2 than in the main channel stations. High values of these parameters were surely due to the rough effluent of many industries of Yopougon city, to stormwater and municipal wastes from Abobo N'dotr  city discharged upstream of this station. Indeed, the anarchic land used, overpopulation, domestic and industrial activities are factors that interfered hypoxic condition of water, very high values of pH, temperature, conductivity, turbidity and salinity. All these conditions testified the highly polluted state of the water sampling at station A2 (tributary) of stream. These results corroborate those of (Camara et al., 2014) conducted in Banco Stream (C te d'Ivoire). In other tropical regions (Cameroon), our results corroborate those of (Tening et al., 2013a) conducted in Douala-Edea mangrove ecosystem and (Tchakont  et al., 2014) in five urban streams of Douala. Dissolved oxygen values are significantly higher at upstream station A1 than that registered in the other main channel stations. This highest oxygenation of the Angu d dou Stream at station A1 is surely due to its location in the upstream area located in forest. Indeed, in upstream of forest zone high photosynthetic activities of stream 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 (Onana et al., 2016). Furthermore, the low conductivity, turbidity and salinity recorded throughout the study period at upstream station A1, 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 this station. These results are in accordance with those obtained by (Camara et al., 2014) in upstream area of Banco Stream (C te d'Ivoire). Similar observations were documented by (Wang et al., 2012) in the tributaries of Qiangtang River (China), (Foto et al., 2013) in a suburban forest stream of the Yaound  city, and (Tchakont  et al., 2015) in a suburban forest stream of Douala (Cameroon). Furthermore, the most lower values of dissolved oxygen recorded at tributary station A2 could be attributed to the activities of microorganisms involved in the mineralization

process of the important quantity of organic matter landed in the Anguededou Stream; knowing that this process consume dissolved oxygen.

This study represents the first published data on aquatic macroinvertebrates in Angédédou Stream basin. A total of 171 taxa belonging to 77 families, 14 orders and six class were recorded. The taxonomic richness registered in this study is high when compared with earlier studies from West Africa, particularly in Côte d'Ivoire. For example, (Simmouet et al., 2015) used a Van Veen sampler to collect 137 taxa from four small coastal streams in South east. This difference in taxonomic richness can probably be explained by the sampling methods used and the types of habitats sampled. On the other hand, the number of taxa found in the Anguededou Stream is also higher compared with studies using the same sampling methods in other ivoirien streams, such as Banco Stream (132 taxa) in Banco National Park (Camara et al., 2014). This difference in taxonomic richness was probably due to the stream sizes. In fact, Anguededou Stream is long (12 km length) compared with Banco Stream (09 km length). Of the taxa collected in this study, aquatic insects were the most diversified, corresponding to 87.20 % of 171 taxa sampled. Insecta represent one of the most important groups of freshwater invertebrates especially due to its diversity (Tachet et al., 2010). Among insects, Odonata are best represented with 37 taxa. The high diversity of Odonata is primarily related to the great diversity of aquatic macroinvertebrates on the stream which they feed. Indeed, Odonata are predators and consume other organisms using different strategies to capture them (Ramírez and Gutiérrez-Fonseca, 2014). In this study, many taxa of Ephemeroptera, Trichoptera and Plecoptera (ETP) were frequently found in the upstream station A1. This confirms the good water quality of this station. Indeed, this station presents the high values of dissolved oxygen and low values of conductivity, turbidity and salinity. According to (Qu et al., 2010), these taxa are often used as indicators of good water quality. Diptera taxa such as *Acanthocnema* sp., *Clogmia* sp., Culicinae, *Eristalis* sp., *Odontomyia* sp. and Sciomyzidae were recorded only at station A2 (tributary) and downstream station A6. The presence of these Diptera confirms their great degradation level of water at these stations. According to (Rueda et al., 2002), these Diptera taxa were commonly found in sewage-polluted stream. Furthermore, *Eristalis* sp. (Syrphidae) ability to survive is the result of using their retractile anal respiratory siphons (Tachet et al., 2010; Camara et al., 2012). Concerning Gasteropoda, most of taxa identified were mainly recorded at downstream station A6. On the tributary station A2, the most recorded Gasteropoda were *Bulinus truncatus*, *Melanooides tuberculata* and *Physa marmorata*. The high frequency of these taxa in these two stations can be explained by the fact that these waters are subjected to many anthropogenic disturbances and heavy organic matter load coming from neighbouring cities. Gasteropoda are known as tolerant organisms, they live in such disturbed environments and these organisms have developed special adaptations. Similar observations were documented by (Camara et al., 2012), who found that in the Banco National Park (Côte d'Ivoire) snails were present only at one site which received domestic sewage, and by (Tchakonté et al., 2014) in the urban streams of Douala (Cameroon). Moreover, experimental works carried out by (Marsden and Swinscoe, 2014) showed the prominence of a pulmonate snail at the most contaminated site close to a waste treatment discharge point in New Zealand. Tchakonté et al. (2014) confirmed that the pulmonate snails (*Bulinus*, *Melanooides*, *Physa*) were mainly encountered in main discharge point for storm waters, urban sewages, household refuse and industrial effluents. Four shrimp species were identified in this study and their frequency of occurrence revealed that they are very frequent at upstream station A1. The only crab species (*Liberonautes chaperi*) was recorded at this station. The presence of these species in this station is undoubtedly related to substrate nature, canopy and good water quality. At this station, the bed is rich in large amounts of litter which constituted essential food resources of shredder Decapoda. Tenkiano Doumbou (2017) showed that macroinvertebrates associated with litter in Guinea's rivers were largely dominated by shredder Decapoda. The low number of taxa recorded in the tributary station A2 compared with those observed in the main channel stream stations can be explained by the highly polluted state as indicated by the results of physico-chemical analysis. In the whole, the highest values of Shannon-Weaver index, Pielou's Evenness index and rarefied richness are respectively observed in the upstream station A1 and downstream station A6 along the main channel stations of Anguededou stream. This would reflect a good biological quality of the stream (Camargo et al., 2004 ; Peterson, 2006). However, in downstream station A6, this organization of the aquatic macroinvertebrate population results essentially from the diversification and proliferation of pollution-tolerant taxa. This could be related to anthropogenic activities influencing the watercourse. Indeed, the anthropogenic practiced in the area, as well as domestic discharges in this station could contribute considerably to the installation of particular conditions favorable to the presence of a diversified population of polluted taxa. The high value of those index observed in the upstream station A1 show that the waters had good ecological health, the distribution of aquatic macroinvertebrates taxa is more or less balanced, rich in taxa and therefore the least impacted. Furthermore, the three diversity metrics are lower at midstream stations (A3, A4, A5), thus confirming the influence of anthropogenic pressure, namely the intensification of pig farming, the organic fertilizer plant in areas and as well as the domestic discharges, urban and industrial wastes, municipal untreated

waste waters and surface run-off from station A2 (on tributary). The high values of Sorensen similarity index were recorded between the midstream stations (A3, A4, A5). However, the lowest values were registered between the upstream station A1 and the station A2 (tributary) and the station A6 (downstream). This high similarity between the midstream stations is undoubtedly due to their proximity and the fact that they are subjected to same anthropogenic pressures. Furthermore, lower similarity can be explained by the fact that in the stations A2 and A6, non-treated domestic sewage are regularly discharged into the stream, causing water quality deterioration whereas the station A1 is not subject at same anthropogenic pressures. The results of Focused Principal Component Analysis (FPCA) on the seven very frequent taxa (*Chaoborus* sp., Chironominae, *Diplonychus* sp., *Hydrobius* sp., *Hydracharina* sp., *Hydrochara* sp., *Physa marmorata*, Tanypodiinae) recorded along Anguededou stream revealed that in the whole Chironominae, *Diplonychus* sp., *Hydrobius* sp., *Hydracharina* sp., *Hydrochara* sp. and *Physa marmorata* were significantly and positively correlated with conductivity, turbidity and salinity and negatively correlated with dissolved oxygen. That correlation can be explained by the fact that those taxa are more widespread in waters polluted and is known to live in degraded environments. Indeed, according to (Adriansens et al. (2004) and Simião-Ferreira et al. (2009), Chironominae sub-familie is one of the most resistant benthic organisms to organic pollution, and (Alba-Tercedor, 1996) revealed that Hydrophilidae (*Hydrobius* sp., *Hydrochara* sp.) is one of the families of Coleoptera more tolerant to pollution. Camara et al. (2012) and Tchakonté et al. (2014) confirmed that the genus *Physa* was most frequently encountered in water bodies polluted by high amounts of human and animal excrements, as well as domestic sewage. Furthermore, Tanypodiinae was highly associated with increased of dissolved oxygen, gravel, canopy and woody debris, this could be explained by the fact that it dwell in water no polluted, thus it is suggested that this species can be used as indicator species for aquatic ecosystem status. *Chaoborus* sp. presented a positive and significant correlation with sand, woody debris and significantly and negatively influenced by current velocity, turbidity, pH and temperature. Considering that taxa belong to the trophic guild of the predator, it can be suggested the prey availability, as well as the presence of the predator, regulate the distribution of these organisms that have migratory ability and a varied diet. *Chaoborus* sp. eat mainly planktonic organisms and usually migrates daily in the water column (Castilho-Noll and Arcifa, 2007).

Conclusion:-

This study identifies for the first time a wide range of aquatic macroinvertebrates in the Anguededou Stream and identifies differences in taxonomic between areas affected to some degree by more human activities. Our study revealed that upstream station A1 with naturally vegetated had higher biological integrity, while others stations were adversely affected by household disposals, and municipal and industrial wastes; and showed great shifts and profound modifications in their aquatic macroinvertebrates communities.

Acknowledgements:-

The authors are extremely grateful to the 'Office Ivoirienne des Parcs et Réserves' and the 'Direction des eaux et Forêts de Côte d'Ivoire' for permitting access to the classified forest. The authors would like to express their gratitude to the staff of the Laboratoire d'Environnement et de Biologie Aquatique, Université Nangui Abrogoua (Ivory Coast). We are grateful to Dr. N'golo Abdoulaye KONE and Dr. Kanvaly DOSSO for their help and improving the English in the manuscript.

Conflict of interest

The author declare no conflict of interests.

Figures:-

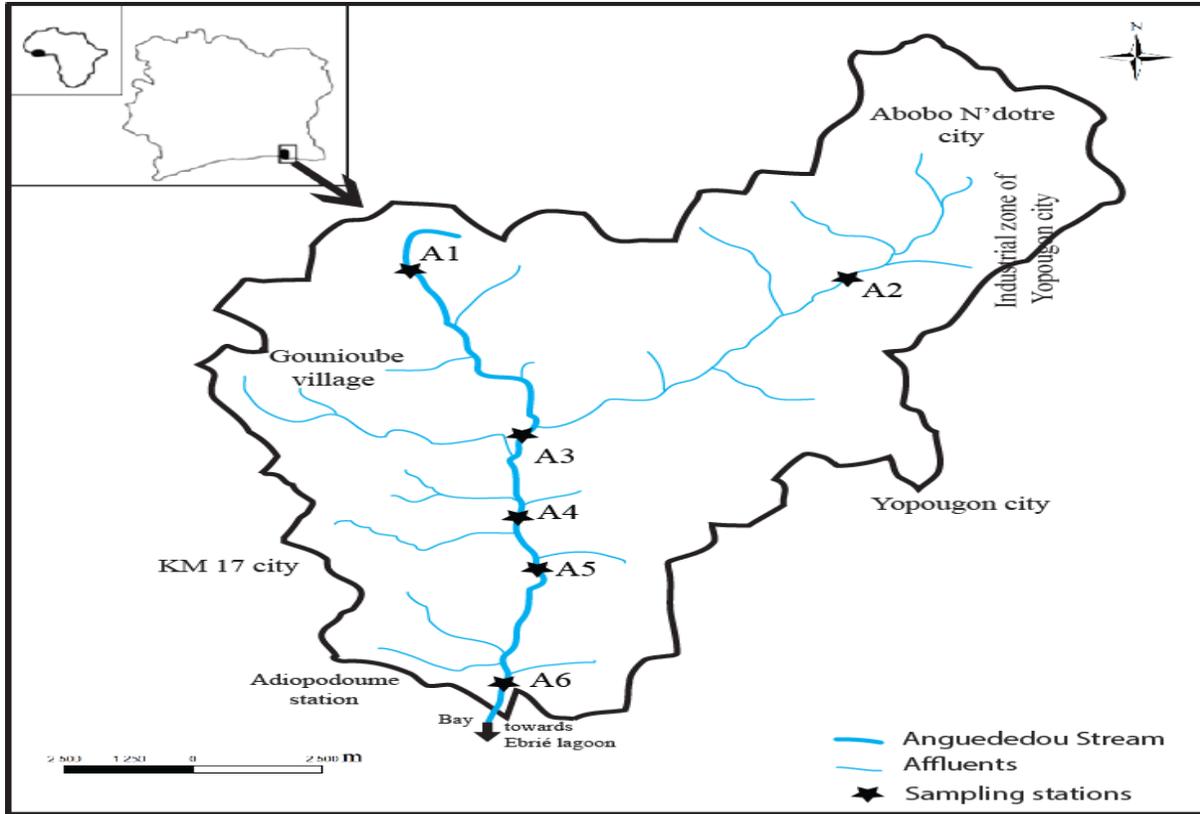


Figure.1:-

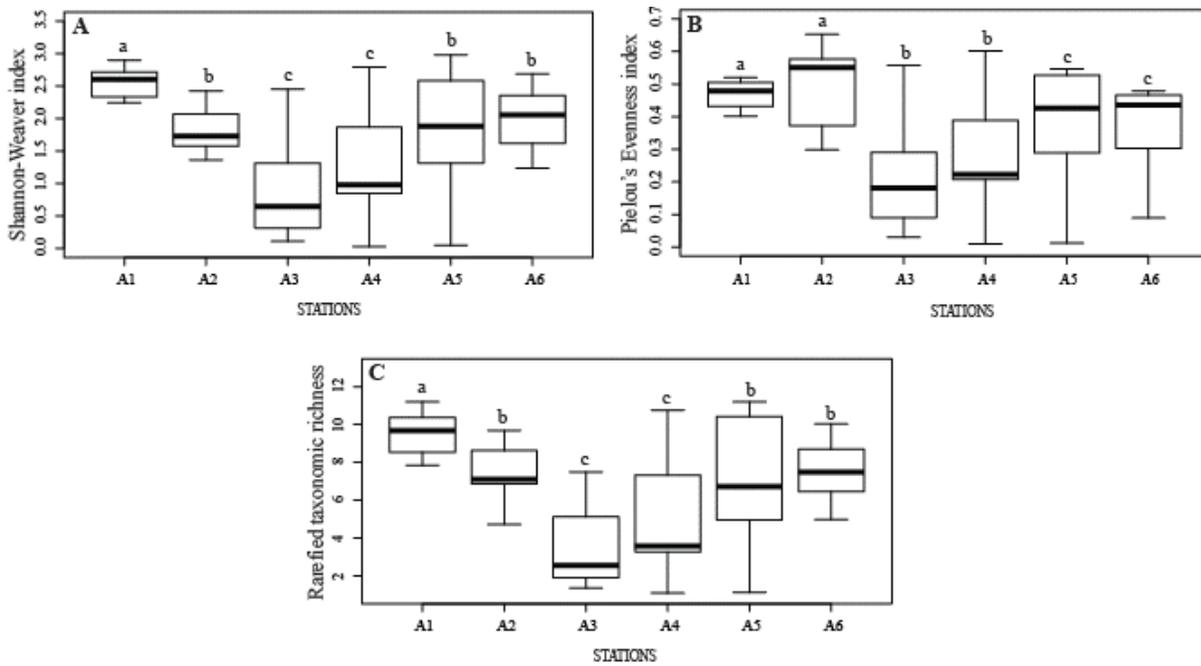


Figure. 2:-

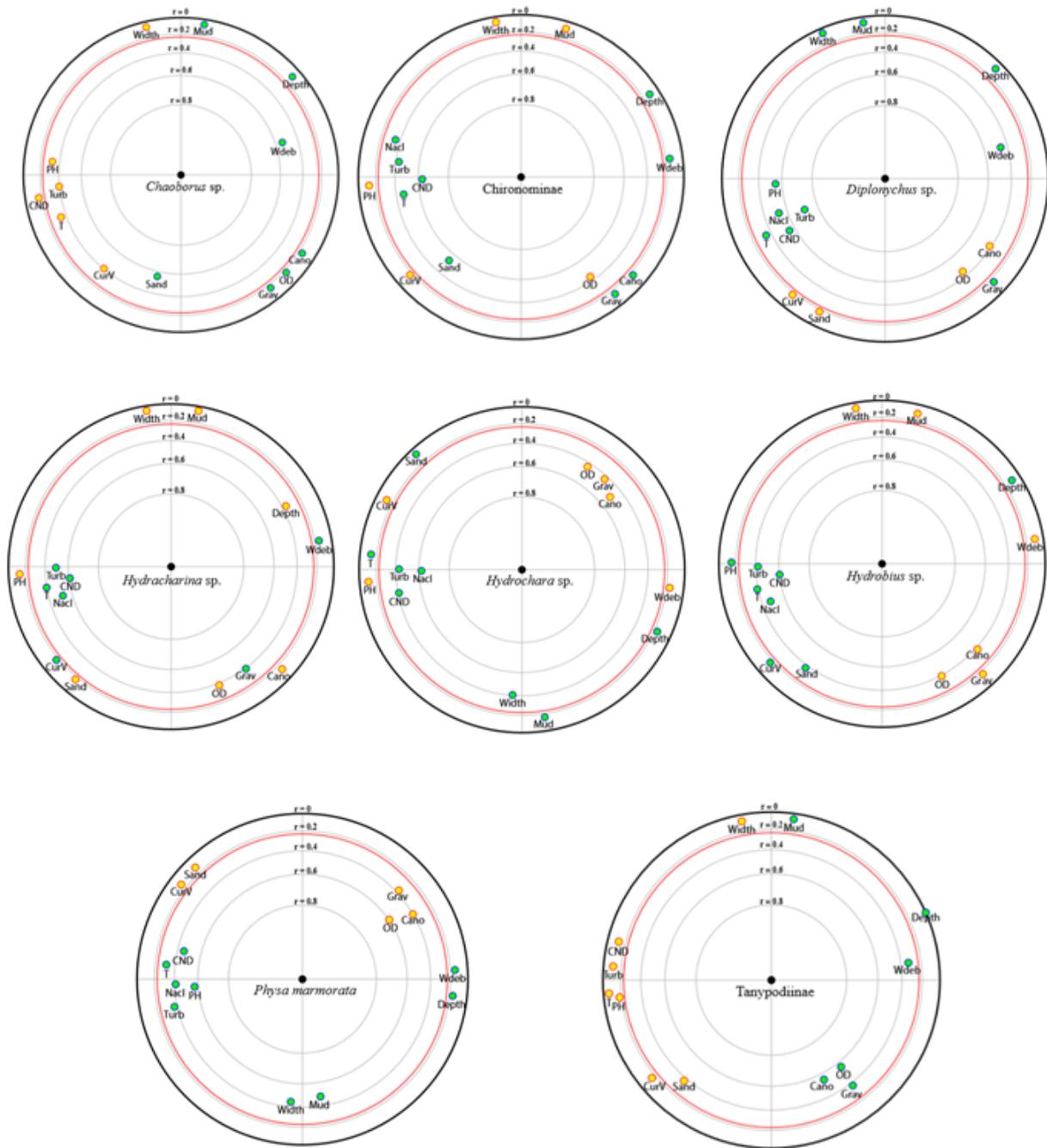


Figure 3:-

Fig.1 : Location of the study area showing the six sampling stations (A1 – A6) of aquatic macroinvertebrates in Anguedou Stream basin (Côte d’Ivoire)

Fig. 2 Box-plots showing variation of Shannon-Weaver index (A), Pielou’s Evenness index (B) and Rarified taxonomic richness (C) of aquatic macroinvertebrates in Anguedou Stream basin: Different letters (a, b and c) on box-plots denote significant differences between sampling stations (A1-A6) (Kruskal-Wallis, $p < 0.05$).

Fig. 3 Graphs showing the results of the Focused Principal Component Analysis (FPCA) based on the very frequent taxa (FO>50%) as a dependent variable and environmental variables as independent variables. Yellow dots correspond to items negatively correlated to taxa occurrence; green dots indicate items positively correlated to taxa occurrence. The dots inside the red circle represent items significantly correlated ($p < 0.05$) with taxa abundance. T = temperature; CND = conductivity; pH = hydrogen potential; Turb = turbidity; DO = dissolved oxygen; Grav = gravel; Wdeb = woody debris; ; CurV = current velocity; Cano = canopy.

Tab. 1:- Characteristics of the six sampling stations (A1 – A6) of aquatic macroinvertebrates in Anguededou Stream basin (Côte d’Ivoire).

Sampling stations	Geographical positions (Degree decimal)		Land use or main activities	Canopy (%)	Dominant substrates
	X	Y			
A1	4°134	5°422	Riparian forest	90	Sand, Woody debris
A2	4°088	5°416	Riparian vegetation, industries wastes, domestic wates	30	Sand
A3	4°122	5°39	Pigs and poultry farming and a lot of waste materials from agricultural and domestic sources	70	Sand
A4	4°123	5°379	Laundry, toilet, pigs and poultry farming, and a lot of waste materials from agricultural and domestic wastes	60	Sand
A5	4°122	5°369	stock farming, washing, place of spiritual rite	50	Mud, Woody debris
A6	4°125	5°339	Sipofu mortuary, market gardens, car washes and surrounding neighbourhoods	0	Sand, Woody debris

Tab. 2:- Medians (minimum-maximum) values of the environmental variables mesured at the six sampling stations (A1 – A6) of aquatic macroinvertebrates in Anguededou Stream basin (Côte d’Ivoire) : different superscript letter (a,b,c,d) in a row show significant differences (Kruskal-Wallis, $p < 0.05$).

Environmental variables	Sampling stations					
	A1	A2	A3	A4	A5	A6
pH	5.59 ^a (5.24 - 6.14)	7.22 ^b (6.31 - 9.69)	6.94 ^b (6.06 - 7.5)	6.24 ^a (5.04 - 6.74)	6.17 ^a (4.94 - 7.3)	6.31 ^a (5.57 - 6.87)
Water temperature (°C)	26.65 ^a (26.3 - 27.6)	29.31 ^b (26.4 - 30.8)	26.4 ^a (25.9 - 26.9)	26.6 ^a (26.1 - 27.43)	26.65 ^a (25.8 - 27.73)	26.5 ^a (26 - 26.8)
Conductivity (µS/cm)	41.5 ^a (38.1 - 59.6)	592 ^b (210 - 1017)	101.6 ^c (52.7 - 201)	89.2 ^c (45.1 - 176.3)	91.9 ^c (49.7 - 117.4)	148.55 ^d (68.4 - 177.7)
Turbidity (UTN)	5.92 ^a (2.4 - 11.8)	489.5 ^b (63.2 - 1000)	70.8 ^c (28.5 - 105)	69.31 ^c (26.1 - 98.1)	81.8 ^c (45.4 - 157.67)	65.23 ^c (27 - 256)
Nacl (%)	0.1 ^a (0.1 - 0.1)	1.2 ^b (0.4 - 2)	0.2 ^c (0.1 - 0.3)	0.2 ^c (0.1 - 0.3)	0.2 ^c (0.1 - 0.2)	0.3 ^d (0.2 - 0.4)
Dissolved oxygen (mg/L)	6.34 ^a (4.38 - 7.18)	2.78 ^{bd} (1.04 - 4.39)	3.4 ^{cd} (1.62 - 5.39)	2.62 ^{bd} (1.76 - 4.72)	2.46 ^b (1.15 - 4.65)	2.31 ^b (1.16 - 3.69)
Current velocity (m/s)	0.44 ^a (0.31 - 0.58)	0.24 ^b (0.08 - 0.4)	0.51 ^{bd} (0.41 - 0.69)	0.35 ^{cc} (0.24 - 0.47)	0.21 ^c (0.12 - 0.51)	0.54 ^d (0.37 - 0.87)
Water depth (m)	0.33 ^a (0.26 - 0.51)	0.13 ^b (0.11 - 0.16)	0.65 ^c (0.51 - 1.45)	0.56 ^{de} (0.35 - 0.81)	0.6 ^{cc} (0.46 - 0.76)	0.47 ^{cc} (0.31 - 0.92)
Wetted channel width (m)	3.38 ^a (2.41 - 3.8)	7.34 ^b (7.02 - 7.76)	5.59 ^b (3.58 - 8.63)	3.46 ^a (2.1 - 5.2)	12.4 ^c (11.4 - 13.6)	11.75 ^c (11.1 - 12.8)
N	12	12	12	12	12	12

Tab. 3:- Liste of aquatic macroinvertebrates taxa recorded at the six sampling stations (A1 – A6) in Anguededou Stream basin (Côte d'Ivoire) with their occurrences : *** Very frequent (%OF>50); ** frequent (25<%OF ≤50); * rare (%OF≤25)

Class	Orders	Families	Taxa	A1	A2	A3	A4	A5	A6	
Malacostraca	Decapoda	Desmocarididae	<i>Desmocarid trispinosa</i>	** *		**	*	** *	*	
		Paleomonidae	<i>Macrobranchium thysi</i>	** *		*		**		
			<i>Macrobranchium macrobranchium</i>	** *		**	**	** *	*	
			<i>Macrobranchium equidens</i>	** *		*	*	** *	** *	
		Potamonautidae	<i>Liberonautes chaperi</i>	**						
Insecta	Odonata	Caloptégyridae	<i>Phaon sp.</i>	**		**	**	*	**	
			<i>Phaon iridipennis</i>	**				**	*	
			<i>Sapho bicolor</i>					*	*	
		Gomphidae	<i>Ictinogomphus sp.</i>	*		**	**			
			<i>Neurogomphus sp.</i>			*	*	*		
			<i>Phyllogomphus aethiops</i>	**			*	*		
			<i>Microgomphus sp.</i>				*	*		
			<i>Lestinogomphus sp.</i>	**		*	*	*		
			<i>Crenigomphus sp.</i>	** *						
			<i>Notogomphus sp.</i>	*			*			
			<i>Ceratogomphus pictus</i>	** *		**	**			
			<i>Paragomphus genei</i>	** *			*			
		Coenagrionidae	<i>Paragomphus sp.</i>	**						
			<i>Pseudagrion wellani</i>	** *		**	*	*	**	**
			<i>Pseudagrion sp.</i>	**		**	**	**	**	** *
Class	Orders	Families	Taxa	A1	A2	A3	A4	A5	A6	
Insecta	Odonata	Coenagrionidae	<i>Ceragrion sp.</i>	** *		**	**	**	*	
			<i>Enallagma sp.</i>						*	
		Lestidae	<i>Lestes plagiatus</i>		*			*	*	
		Chlorocyphidae	<i>Chlorocyphasp.</i>			*	*			
		Synlestidae	<i>Chlorolestes sp.</i>						**	
		Platycnemididae	<i>Allocnemis sp.</i>			**		*	*	
		Libellulidae	<i>Diplacodes sp.</i>	*		*	*	** *	**	**
			<i>Libellula sp.</i>	*						
			<i>Orthetrum cafferum</i>			*	** *	*		
			<i>Orthetrum sp.</i>	*	*		**	*		
<i>Chalcostephia sp.</i>	*		*	*	**	**	** *	*		

			<i>Oplagastra</i> sp.			*	*		
			<i>Zyxomma</i> sp.	**		*			*
			<i>Parazyxomma flavicans</i>	** *			*	*	
			<i>Brachythemis</i> sp.	**				*	
			<i>Crocothemis</i> sp.				*		
			<i>Rhyothemis</i> sp.				*		
			<i>Trithemis</i> sp.				*	**	
			<i>Pantala</i> sp.						*
			<i>Tramea</i> sp.						*
		Cordulidae	<i>Cordula</i> sp.			*			
		Macromiidae	<i>Phyllomacromiasp.</i>	**			**	**	
	Heteroptera	Belostomatida e	<i>Diplonychus</i> sp.	** *	**	** *	** *	** *	** *
			<i>Limnogeton</i> sp.			*	*	*	*
Class	Orders	Famillies	Taxa	A1	A2	A3	A4	A5	A6
Insecta	Heteroptera	Gerridae	<i>Eurymetrasp.</i>	** *			**	**	*
			<i>Néogerris</i> sp.	*		**	*	**	*
			<i>Rhagadotarsus</i> sp.			*		**	*
			<i>Aquarius</i> sp.	**		*		**	**
			<i>Tenagogonus</i> sp.	*		*	*	**	*
			<i>Limnogonus</i> sp.		*				
			<i>Gerris</i> sp.		*	*		*	**
		Naucoridae	<i>Naucoris</i> sp.		*			*	**
			<i>Laccocoris</i> sp.						*
		Nepidae	<i>Laccotrephes ater</i>	*	** *			*	*
			<i>Laccotrephes</i> sp.				*		
			<i>Nepa</i> sp.		** *	**	*	*	*
			<i>Ranatra linearis</i>						**
			<i>Ranatra</i> sp.	*				*	
		Notonectidae	<i>Anisops</i> sp.		**	*		**	**
			<i>Enithares</i> sp.		**	*		**	**
			<i>Nychiasp.</i>						*
		Pleidae	<i>Plea</i> sp.						**
		Mesoveliidae	<i>Mesovelia</i> sp.	**	** *	**	**	**	**
		Veliidae	<i>Microveliasp.</i>	*		**		**	**
			<i>Ocellovelia</i> sp.	**			**		
			<i>Rhagovelia</i> sp.	*		*	**		

			<i>Rhagovelia reitteri</i>	** *		** *	** *	** *	
		Corixidae	<i>Micronectasp.</i>				*		** *
			<i>Stenocorisea sp.</i>						**
Class	Orders	Famillies	Taxa	A1	A2	A3	A4	A5	A6
Insecta	Heteroptera	Hydrometridae	<i>Hydrometra sp.</i>	*		*		*	
	Coleoptera	Dytiscidae	<i>Hydrovatus sp.</i>				*		** *
<i>Hyphydrus sp.</i>								**	
<i>Platambussp.</i>					*	*		*	
<i>Neptosternus sp.</i>						*		*	
<i>Ilybius sp.</i>								*	
<i>Yola sp.</i>				*				**	
<i>Hydaticus sp.</i>				**			*	*	
<i>Dytiscus sp.</i>			*	**	**			*	
Dryopidae		<i>Dryops sp.</i>	*	**				*	
Elmidae		<i>Limnius sp.</i>	*	*				*	
		<i>Oulimnius sp.</i>	*					*	
		<i>Potamophilus sp.</i>	** *	*					
Noteridae		<i>Noterus sp.</i>						*	**
		<i>Hydrocanthus sp.</i>							** *
Chrysomelidae		<i>Donaciasta sp.</i>		*	*				*
Curculionidae		<i>Pseudobagous longuls</i>			*				*
Gyrinidae		<i>Aulonogyrus sp.</i>						*	
Haliplidae		<i>Halipilus sp.</i>							*
Hydrochidae		<i>Hydrochus sp.</i>						*	**
Hydraenidae		<i>Mesoceration sp.</i>		**		*	*	*	*
Hydrophilidae		<i>Hydrochara sp.</i>	*	** *	** *	** *	** *	** *	** *
		<i>Enochrus sp.</i>	**	**	**	**	**	**	**
		<i>Hydrobius sp.</i>	**	** *	** *	** *	** *	** *	** *
	<i>Amphiops sp.</i>	*	*		*	*	**	** *	
Class	Orders	Famillies	Taxa	A1	A2	A3	A4	A5	A6
Insecta	Diptera	Chironomidae	Chironominae	** *	** *	** *	** *	** *	** *
			Tanypodiinae	** *	**	**	** *	** *	
			Orthocleriinae	** *			**	*	

		Chaoboridae	<i>Chaoborus</i> sp.	** *	** *	** *	** *	** *	** *
			<i>Mochlonyx</i> sp.	** *	* *	** *	** *	** *	** *
		Ephydriidae	<i>Scatella</i> sp.		** *	* *	* *		** *
		Muscidae	<i>Muscasp.</i>		*			*	*
		Psychodidae	<i>Clogmia</i> sp.		*				**
		Scatophagidae	<i>Acanthocnemas</i> sp.		**				*
		Sciomyzidae	IND		*				*
		Stratiomyidae	<i>Odontomyia</i> sp.		*				*
			IND						** *
		Rhagionidae	IND						*
		Syrphidae	<i>Eristalis</i> sp.		**				**
		Culicidae	<i>Culex</i> sp.		**	*			**
			<i>Aedes</i> sp.		*				
			Culicinae			**			
		Tabanidae	<i>Tabanus</i> sp.	* *	** *	** *	** *	** *	** *
		Tipulidae	<i>Limnophila</i> sp.	*		**	** *	** *	**
		Ceratopogonidae	<i>Bezzia</i> sp.	** *	* *	** *	** *	** *	** *
			Ceratopogoninae				**		**
			<i>Dasyhelea</i> sp.						**
			<i>Culicoides</i> sp.				*	*	** *
		Leptoconopidae	<i>Leptoconops</i> sp.		*	*	**	**	** *
		Simuliidae	<i>Simulium</i> sp.	** *	*				
Class	Orders	Families	Taxa	A1	A2	A3	A4	A5	A6
Insecta	Diptera	Thaumaleidae	<i>Thaumalea</i> sp.		*				*
		Limoniidae	<i>Dicranota</i> sp.		**				**
		Empididae	<i>Clinocera</i> sp.			*		*	
	Ephemeroptera	Baetidae	<i>Baetis</i> sp.	** *	*	*	**	**	
			<i>Baetopus</i> sp.	**					
			<i>Cloeon</i> sp.	** *			*	**	*
			<i>Proclleon</i> sp.	** *					*
		Leptophlebiidae	<i>Adenophlebiodes</i> sp.	**		*			
			<i>Choroterpes</i> sp.	**					
		Caenidae	<i>Caenis</i> sp.	** *					

			<i>Brachycerus</i> sp.	*					
		Ameletidae	<i>Ameletus</i> sp.	** *				*	
		Oligoneuriidae	<i>Oligoneuriella</i> sp.	** *					
	Plecoptera	Perlidae	<i>Neoperla</i> spio	** *					
		Perlodidae	<i>Perlodes</i> sp.	** *					
		Chloroperlidae	<i>Chloroperla</i> sp.	**					
	Trichoptera	Ecnomidae	<i>Ecnomus</i> sp.	** *			*	*	
		Hydroptilidae	<i>Hydroptila</i> sp.	** *					
		Leptoceridae	<i>Setodes</i> sp.	** *		*			
			<i>Setodes barnardi</i>	** *					
			<i>Athripsodes</i> sp.	** *					
			<i>Leptocerus</i> sp.	**					
			<i>Triaenodes</i> sp.	** *		*			
<i>Oecetis</i> sp.			*		*				
<i>Ceraclea</i> sp.	** *			**	*				
Class	Orders	Families	Taxa	A1	A2	A3	A4	A5	A6
Insecta	Trichoptera	Hydropsychidae	<i>Diplectronella medialis</i>	** *		*			
			<i>Cheumatopsyche</i> sp.	** *		*	*		
			<i>Hydropsyche</i> sp.			*			
			<i>Protomacronema</i> sp.	**					
			<i>Polymorphanus</i> sp.	** *					
			<i>Macrostemum capense</i>	** *					
			<i>Leptonema natalense</i>	*					
		<i>Amphipsyche</i> sp.	**						
	Beraeidae	<i>Beraea</i> sp.	** *						
Lepidoptera	Pyralidae	<i>Parapoynx</i> sp.	**		*		**		
		<i>Elophila</i> sp.	*	*	**	**	**		
Arachnida	Trombidiforma	Arachnidae	<i>Hydracarina</i> sp.	*	** *	**	** *	** *	** *
Gasteropoda	Basommatophora	Physidae	<i>Physa marmorata</i>		**	**	** *	** *	** *
		Lymnaeidae	<i>Lymnae natalensis</i>		*	**	** *	** *	** *

		Planorbidae	<i>Biomphalaria pfeifferi</i>		*	*		**	**
			<i>Indoplanorbis exustus</i>		*				*
			<i>Bulinus Globosus</i>						*
			<i>Bulinus troncatus</i>		**			*	**
			<i>Bulinus forskalii</i>		*			**	**
Cenogasteropoda		Ampullariidae	<i>Pila africana</i>		*				**
		Thiaridae	<i>Melanoides tuberculata</i>		**	**	**	**	**
		Bithyniidae	<i>Gabiella africana</i>		*		*		**
		Hydrobiidae	<i>Bythiospeum</i> sp.		*	*		*	*
Class	Orders	Families	Taxa	A1	A2	A3	A4	A5	A6
Oligocheta	Tubificinas	Tubificidae	Tubifex sp.	*	*	*	**	**	**
Acheta	Rhynchobdeliforma	Glossiphoniidae	<i>Helobdella</i> sp.		*	*	**	**	**
			<i>Glossiphonia</i> sp.		*	*			**
			<i>Haementeria</i> sp.				*		*
Total	14	77	171	91	61	72	72	79	102

Tab.4:- Proportion of very frequent, frequent and rare taxa of aquatic macroinvertebrates registered at the six sampling stations (A1-A6) in the Anguedou Stream basin (Côte d'Ivoire).

	STATIONS											
	A1		A2		A3		A4		A5		A6	
	Proportions (%)	Numbers										
Very frequent	43,96	40	17,74	11	10,96	8	21,92	16	28,75	23	28,43	29
Frequent	26,37	24	27,42	17	32,88	24	28,77	21	28,75	23	26,47	27
Rare	29,67	27	54,84	34	56,16	41	49,31	36	42,5	34	45,1	46

Tab.5:- Values of the Sorensen similarity index between the six sampling stations (A1-A6) of aquatic macroinvertebrates in Anguedou Stream basin (Côte d'Ivoire).

	A1	A2	A3	A4	A5	A6
A1						
A2	31.37					
A3	57.31	47.40				
A4	56.09	41.48	64.38			
A5	56.14	53.52	66.67	67.97		
A6	38.34	64.63	53.71	52.28	61.53	

References:-

- Adriansens, V.F., Simons L.T.H., Nguyen, B., Goddeeris, P.L.M., Goethals., DE Pauw, N., 2004. Potential of bio-indication of chironomid communities for assessment of running water quality in Flanders (Belgium). Belg. J. Zool., 134: 31-40.

2. AFNOR. 1992. Qualité de l'eau, Recueil des Normes Françaises, 1994. Essai des eaux. Détermination de l'indice biologique global normalisé (IBGN). NF T 90-3. 684–692.
3. Alba-Tercedor, J. 1996. Macroinvertibrados acuáticos y calidad de las aguas de los rios. In Anais do Simposio Del Agua en Andalucía - SIAGA, 1996. Almeria.,2: 203-213.
4. Arab, A., Lek, K., Lounaci, A., Park, Y.S., 2004. Spatial and temporal patterns of benthic invertebrate communities in an intermittent river (North Africa). *Ann. Limnol.-Int. J. Lim.*, 40: 317–327.
5. Bonada, N., Prat, N., Resh, V.H., Statzner B., 2006. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Ann Rev of Entom.*, 51:495-523.
6. Brown, D.S., 1994. *Freshwater Snails of Africa and their Medical Importance*. Taylor & Francis, London.
7. Cai, Y., Jiang, J., Zhang, L., Chen, Y., Gong, Z., 2012b. Simplification of macrozoobenthic assemblages related to anthropogenic eutrophication and cyanobacterial blooms in 2 large shallow subtropical lakes in China. *Aquat Ecosyst Health Manag.*, 15: 81–91
8. Camara, A.I., Diomandé, D., Bony, Y.K., Ouattara, A., Franquet, E., Gourène, G., 2012. Diversity assessment of benthic macroinvertebrate communities in Banco National Park (Banco Stream, Côte d'Ivoire). *Afr Jour Ecol.*, 50: 205-217.
9. Camara, A.I., Diomandé, D., Gourène, G., 2014. Impact des eaux usées et de ruissellement sur la biodiversité des macroinvertibrés de la rivière banco (Parc National du Banco ; Côte d'Ivoire). *Rev CAMES.*, 2:58-68.
10. Camargo, J.A., Alonso, A., De La Puente, M., 2004. Multimetric assessment of nutrient enrichment in impounded rivers based on benthic macroinvertebrates. *Env Monit Publ.*, 96: 233-249.
11. Castilho-Noll, M.S.M., Arcifa, M.S., 2007. Chaoborus diet in a tropical lake and predation of microcrustaceans in laboratory experiments. *Acta Limnol. Bras.*, 19:163-174.
12. Dajoz, R., 2000. *Précis d'écologie*, 7 ème édition, Dunod, Paris, 615p.
13. Dejoux, C., Elouard, J.M., Forge, P., Maslin, J.L., 1981. *Catalogue iconographique des insectes aquatiques Ivory Coast*. Report ORSTOM, Bouake, Ivory Coast.
14. Environment and Development Group., 2000. *Etude de faisabilité pour l'aménagement du complexe naturel du Banco*. Rapport final, Oxford, UK, 141 p.
15. Falissard, B., 1999. Focused Principal Component Analysis: looking at a correlation matrix with a particular interest in a given variable. *Jour Comput GraphStat.*, 8: 906-912.
16. Foto Menbohan, S., Tchakonte, S., Ajeagah, G., ZebazeTogouet, S.H., Bilong Bilong, C.F., Njine, T., 2013. Water quality assessment using benthic macroinvertebrates in a periurban stream (Cameroon). *Int Jour Biotech.*, 2:91-104.
17. Grall, J., Coïc, N., 2005. *Synthèse des méthodes d'évaluation de la qualité du benthos en milieu côtier*. REBENT, 90p.
18. Heino, J., Muotka, T., Paavola, R., 2003. Determinants of macroinvertebrate diversity in headwater streams: regional and local influences. *Jour Ani Ecol.*, 72:425-343.
19. Lancaster, J., Downes, B.J., 2013. *Aquatic entomology*. OUP Oxford.
20. Lazorchak, J.M., Klemm, D.J., Peck, D.V., 1998. *Environmental Monitoring and Assessment Program- Surface Water: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams*. U.S. Environmental Protection Agency, Washington, DC, EPA/620/R-94/004F.
21. Marsden, I.D., Swinscoe, I., 2014. Does population structure and growth of an intertidal pulmonate snail reflect environmental conditions within a small estuary? *Hydrobiologia.*, 724:141–155.
22. Monod, T., 1980. Décapode. In: *Flore et faune aquatiques de l'Afrique sahélo-soudanienne*, Vol 44 (Eds J.R. Durand and C. Levêque). ORSTOM, Paris, Tome I.
23. Moreno, P., França, J.S., Ferreira, W.R., Paz, A.D., Monteiro, I.M., Callisto, M., 2009. Use of the BEAST model for biomonitoring water quality in a neotropical basin. *Hydrobiologia.*, 630:231-242.
24. Moulton, T.P., Magalhães-Fraga, S.A.P., Fraga, S.A.P., Brito, E.F., Barbosa, F.A.R., 2010. Macroconsumers are more important than specialist macroinvertebrate shredders in leaf processing in urban forest streams of Rio de Janeiro, Brazil. *Hydrobiologia.*, 638:55-66.
25. Onana, F.M., Zébazé Togouet, S.H., Koji, E., Nyamsi Tchatcho, N.L., Tchakonté S., 2016. Influence of municipal and industrial pollution on the diversity and the structure of benthic macro-invertebrates community of an urban river in Douala, Cameroon. *Jour Biodiv Env Sci.*, 8: 120–133.
26. Peterson, M., 2006. *Course materials: Biology 326, ecology lab*. Western Washington University, Department of biology, Bellingham, Washington.
27. Powell, C.B., 1980. The genus *Macrobrachium* in West Africa; I: *Macrobrachium thysi*, a new large-egged species from the Côte d'Ivoire (Crustacea Decapoda Palaemonidae). *Rev. Zool. Afr.*, 94: 317–326.

28. Qu, X., Wu, N., Tang, T., Cai, Q., Park, Y.S., 2010. Effets of heavy metals on benthic macroinvertebrate communities in high mountain streams. *Annales de Limnologie – Inter Jour Limn.*, 46: 291 – 302.
29. Ramírez Gutiérrez-Fonseca., 2014. Functional feeding groups of aquatic insect families in Latin America: a critical analysis and review of existing literature. *Int. J. Trop. Biol.*, 62: 155-167.
30. Rios, S.L., Bailey R.C., 2006. Relationships between riparian vegetation and stream benthic communities at three spatial scales. *Hydrobiologia.*, 553:153–160.
31. Rueda, J., Camacho, A., Mezquita, F., Hernandez, R., Roca J. R., 2002. Effect of episodic and regular sewage discharges in the water chemistry and macroinvertebrate fauna of a Mediterranean stream. *Water Air Soil Pollut.*, 140: 425-444.
32. Simião-Ferreira, J., Demarco Junior, P., Mazão, G.R. & Carvalho, A.R. (2009). Chironomidae community structure in relation to organic enrichment of an aquatic environment. *Neotrop. Entomol.*, 38: 464-471.
33. Simmou, Y.J., Bamba, M., Konan, Y.A., Kouassi K.P., Koné, T., 2015. Impact des Activités Anthropogéniques sur la Distribution des Macroinvertébrés Benthiques et la Qualité des Eaux de Quatre Petits Cours D’eaux de Côte D’ivoire. *Europ Jour Sci Resear.*, 136: 122-137.
34. Soldner, M., Stephen, I., Ramos, I., Angus, R., Wells, N.C., Grosso, A., Crane, M., 2004. Relationship between macroinvertebrate fauna and environmental variables in small streams of the Dominican Republic. *Wat Resear.*, 38: 863-874.
35. Tachet, H., Richoux, P., Bournaud, M., Usseglio-Polatera, P., 2010. *Freshwater invertebrates: taxonomy, biology, ecology*: CNRS Editions, Paris, 2010p.
36. Tchakonté, S., Ajeagah, G.A., Diomande, D., Camara I.A., Ngassam, P., 2014. Diversity, dynamic and ecology of freshwater snails related to environmental factors in urban and suburban streams in Douala-Cameroon (Central Africa). *Aquatic Ecology.*, 48: 379–395. 532
37. Tchakonté S, Ajeagah GA, Camara AI, Diomandé D, Nyamsi Tchatcho, N.L., Ngassam, P., 2015. Impact of urbanization on aquatic insect assemblages in the coastal zone of Cameroon: the use of biotraits and indicator taxa to assess environmental pollution. *Hydrobiologia.*, 755: 123–144.
38. Tening, A.S., Chuyong, G.B., Asongwe, G.A., Fonge, B.A., Lifongo, L.L., Mvondo-Ze, A.D., Bih Che, V., Suh, C.E., 2013a. Contribution of some water bodies and the role of soils in the physicochemical enrichment of the Douala-Edea mangrove ecosystem. *Afri Jour Envl Sci Techn.*, 7: 336-349.
39. Tenkiano Doumbou, N.S., 2017. Macroinvertébrés benthiques et hyphomycètes aquatiques : diversité et implication dans le fonctionnement écosystémique des cours d'eau de Guinée, Thèse de Doctorat, Université de Toulouse, France.
40. 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.
41. Yuan, L.L., 2010. Estimating the effects of excess nutrients on stream invertebrates from observational data. *Ecol Appl.*, 20: 110–125
42. Zhang, Y., Liu, L., Cheng, L., Cai, Y., Yin, H., Gao, J., Gao, Y., 2014. Macroinvertebrate assemblages in streams and rivers of a highly developed region (Lake Taihu Basin, China). *Aquat Biol.*, 23: 15–28.