Open Journal of Marine Science, 2019, 9, 173-187
https://www.scirp.org/journal/ojms
ISSN Online: 2161-7392
ISSN Print: 2161-7384

Abundance and Distribution of Macroinvertebrates of the Affon River in Bénin

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How to cite this paper: Samon, O.S., Gouissi, F.M., Adje, D.D., Abahi, K.S., Tchaou, C.M., Okoya, J.G.A., Orou Piami, Z., Gnohossou, M.P., Omoniyi, G. and Piscart, C. (2019) Abundance and Distribution of Macroinvertebrates of the Affon River in Bénin. *Open Journal of Marine Science*, **9**, 173-187.
https://doi.org/10.4236/ojms.2019.94013

Received: August 17, 2019
Accepted: October 5, 2019
Published: October 8, 2019

Abstract

This study focuses on the biodiversity of macroinvertebrates of the Affon River. To reach this goal, eight stations were sampled and physical parameters such as temperature, pH, conductivity, transparency, depth, total dissolved solids (TDS) and dissolved oxygen were measured. Chemical parameters such as ammonium nitrite and phosphate were measured in the laboratory. We identified 9755 macroinvertebrates belonging to 4 classes, 14 orders, and 49 families. Chironomidae were the most abundant family whereas other sensitive insect's orders such as Ephemeroptera, Trichoptera, and Plecoptera were rarely found, suggesting a poor water quality of the Affon River. The principal components analysis yielded three groups of stations: the first group (Tenéka 2 and 3) characterized by high values of ammonium and phosphate and low values of conductivity and TDS; the second group (Tanéka 1 and Kolokondé 1) with low values of pH, transparency, ammonium and phosphate; and the third group of stations (Kolokondé 2, Kpébouko1, Kpébouko 2, and Affon) marked by high values of conductivity, TDS, transparency, depth and temperature. This study is a crucial step for any management and monitoring of the Affon River.

Keywords

West Africa, Freshwater, Water Quality, Monitoring

1. Introduction

Rivers are among the most complex and dynamic ecosystems [1]. They are extensively diversified and play a crucial role in the conservation of biodiversity.

However, these ecosystems are severely degraded from the effects of urbanization, industrialization and agricultural intensification. These anthropogenic and natural disturbances have direct impacts on the diversity and structure of macroinvertebrates and necessitate the need for better management of the systems. An effective surface water quality assessment must take into account biological criteria throughout bioindicators [2] [3] such as diatoms, macrophytes, benthic macroinvertebrates and fish [4]. In recent times, benthic macroinvertebrate communities have been the most widely used bioindicator to assess the overall health status of aquatic ecosystems [5] largely because of their sedentary lifestyle, varied life cycles, high diversity and variable tolerance to pollution and habitat degradation [6]. Consequently, this study evaluated their richness, diversity and taxonomic composition to assess the effects of human activities on the water quality of the river Affon in Benin [6]. Indeed, in Benin, the structure, diversity, composition and faunal characteristics of macroinvertebrates have been analyzed in various ecosystems [5] [7]-[12], but knowledge on freshwater biodiversity in this country remains very scarce. These studies highlighted important biodiversity of macroinvertebrates of certain groups such as Diptera, Gastropods, Oligochaetes and Coleoptera in Benin freshwaters. The dominance of certain taxa is indicative of the degradation of the water quality in most studied ecosystems [9] [10]. This degradation of the water quality led to the disappearance of several taxa, especially those that are pollution-sensitive to the detriment of pollution-tolerant taxa [9] [10]. In addition, according to a recent study [13], parameters that influence the distribution of macroinvertebrates in Benin were mainly nitrate, phosphate, conductivity and TDS, whereas transparency and depth were also found as important factors in other studies [10]. Therefore, in order to contribute to the knowledge of the macroinvertebrate fauna in Benin and the environmental factors explaining their distribution, we studied the diversity and distribution of macroinvertebrates and the water quality of the Affon River.

2. Materials and Methods

2.1. Study Area and Sampling Stations

The Affon River is located on the right bank and in the classified forest of upper Ouémé. This river is one of the tributaries of the Ouémé River. It has a length of 152 km and a catchment area of 4320 km^2. The river is located in the Sudano-Guinean zone and is under the influence of the tropical climate characterized by the succession in the year of a single rainy season from April to October and a single dry season from November to March, marked by the preponderance of the harmattan. On the Affon River, 08 stations were selected after prospecting. They were chosen based on the sustainability of the water, altitude, accessibility in all seasons, depth and speed of the water [14]. **Table 1** shows the characteristics of these different stations.

2.2. Measurement of Water Physico-Chemical Parameters

At each station, the measurements of physical parameters (temperature, depth,

Table 1. Location, geographic coordinates and characteristics of sampling stations.

Stations	Codes	Geographic coordinates	Altitude	Pollution sources
Tanéka-Koko1	Tan1	N: 09˚51'21" E: 01˚32'34"	484 m	Artisanal extraction of gold
Tanéka-Koko2	Tan2	N: 09˚53'89" E: 01˚47'48"	429 m	Laundry, dishes, artisanal extraction of gold
Tanéka-Koko3	Tan3	N: 09˚52'40" E: 01˚30'80"	415 m	Laundry, dishes, artisanal extraction of gold
Kolokondé1	Kol1	N: 09˚53'94" E: 01˚47'44"	410 m	Agricultural waste, washing of motorcycles and laundry
Kolokondé2	Kol2	N: 09˚57'17" E: 01˚51'43"	369 m	Household waste, agricultural waste, washing of motorcycles and laundry
Kpebouco1	Kpe1	N: 09˚57'15" E: 01˚51'43"	365 m	Agricultural, household and livestock wastes
Kpebouco2	Kpe2	N: 09˚56'58" E: 01˚50'54"	363 m	Laundry, household and livestock waste
Affon	Aff	N: 09˚57'46" E: 01˚51'78"	348 m	Watering cattle, washing of motorcycles and laundry

transparency, TDS, conductivity, pH, oxygen) were carried out in situ very early in the morning between 08:00 and 12:00, before the sampling of the macroinvertebrates to avoid any disturbance of the environment. The water temperature, TDS and conductivity were determined using a portable conductivity meter (HANNA HI 99300). The pH was measured with a portable pH meter (HANNA HI 98107). A Secchi disk with a graduated rope was used to measure the transparency of the water and the depth of the stations. Water samples were made at each station in 500 ml plastic bottles decontaminated and stored in a cooler containing ice for transport to the laboratory for analysis of the dissolved substances. The determination of the concentration of dissolved elements of the water samples was carried out in the Laboratory of Hygiene, Sanitation, Ecotoxicology and Environmental Health (HECOTES) using a spectrophotometer DR 6000. Chemical parameters such as ammonium, nitrite and phosphate were respectively measured by the Nessler method [15], the iron sulphate method and the Vanadomolybdic method with persulfate digestion.

2.3. Sampling of Macroinvertebrates

The benthic macroinvertebrates were sampled at the 08 stations. They were taken using a Surber sampler with a 500-µm mesh. This material was placed on the bottom of the river, the opening of the net facing watercourse and the substrate is scraped a few centimeters with the hand. Twelve samples with a unit area of 1/20 m^2 were done per station: (08) eight on the dominant habitats and (04) on the marginal habitats as recommended by the standard IBGN and already used in the North of Benin by Abahi *et al.* (2018) [10]. The organisms collected in the surber sampler were spilled in labeled jars and fixed to 10% formaldehyde and then sent to the laboratory.

2.4. Macroinvertebrates Identification

In the laboratory, the captured macroinvertebrates were rinsed to rid them of the formalin and were subsequently sorted station by station under a binocular dissecting microscope. After sorting, they were grouped according to their class up to the family level apart from oligochaetes, nemathelmintes, hydracarians, hydrozoans, sponges, bryozoans and nemerteans which were kept aside such as Abahi *et al.* (2018) [10]. The taxonomic determination was made using the following keys: Benthic macroinvertebrates of the streams of "la Nouvelle-Calédonie" by Mary (2017) [16], Identification guide of the main benthic macroinvertebrates of freshwater from Quebec written by Moisan (2010) [17], "Freshwater invertebrates: Systematics, biology, ecology" by Tachet *et al.* (2000) [18] and "Aquatic entomology" by McCafferty (1981) [19] after which macroinvertebrates were enumerated and then stored in pillboxes containing 70% alcohol.

2.5. Data interpretation

The identified data allowed us to calculate the following metrics and indices:

Taxonomic richness (S) = number of taxa present in each station

Abundance (N) = number of individuals from a taxonomic group in each station

Relative abundance (Nr) = ratio as a percentage of the number of taxon individuals in a station to the total number of individuals of all species from all stations.

Frequency of family observation (FO) = ($F_i \times 100$)/F_t. In such, F_i = number of stations containing the family and F_t = total number of stations studied. Three families were thus distinguished as Abahi *et al.* (2018) previously demonstrated. We have very frequent families ($F \geq 50\%$), frequent families ($25\% \leq F \leq 50\%$) and rare families ($F \geq 25\%$).

2.6. Statistics Analysis of Data

The data obtained were processed using Excel 2010 software and R3.4.4 software [20]. The taxonomic richness, the taxonomic abundance, the average values of the physico-chemical parameters were calculated per station. Parametric and non-parametric tests (test t student and test of Kruskal-Wallis) were used to evaluate the variability of the taxonomic richness of the abundance and diversity indices at the 5% threshold with the R3.4.2 software [20]. Moreover, the factorial correspondence analysis (FCA) was used for grouping the stations according to the similarity association of macroinvertebrates families. In addition, a canonical correspondence analysis (CCA) was performed using PAST statistical package [21].

3. Results

3.1. Physico-Chemical Quality of the Affon River Water

3.1.1. Water Quality of the Affon River

The analyzed results of the physico-chemical parameters of the Affon River waters are shown in Table 2. It indicates that the lowest temperature value of 22.5˚C was recorded at Tanéka 1 (upstream) and the highest 30.3˚C at Kpébouco 2. Depth and transparency increased from upstream to downstream. Thus, the maximum values were measured at Tanéka 1 while the minimum values were recorded at the Affon. The pH ranged between 6.5 and 8.5, with the minimum value recorded at Tanéka 2 while the maximum value was observed at Tanéka 1 and Kolokondé 1 stations. As for the conductivity and the TDS, they presented the same trend with average values that increased overall from upstream to downstream. Conductivity values ranged from 6.3 to 98.0 µS/cm and TDS values ranged from 3.0 to 49.0 mg/l. The low values of these parameters were recorded at Tanéka 2 and the high values at Affon. The low values of phosphates (7.11 mg/l) were recorded at Affon and the high values (14.8 mg/l) at Tanéka 2 while the high values of ammonium are recorded at Tanéka 3 (1.35 mg/l) and the low values are obtained at Képébouco (0 mg/l). The Affon River is free of any trace of nitrite. In general, all the physico-chemical parameters studied except ammonium, varied significantly between the stations.

3.1.2. Typology of Stations

An abiotic typology of the stations carried out using a principal component analysis (PCA) reveals that most of the information contained in the variables are controlled at 86.25% by the first two dimensions (1 and 2) (Figure 1). Temperature, conductivity, TDS, transparency, depth and ammonium contributed more to the formation of the first axis while pH, phosphate and temperature are more related to the second axis. The correlation circle (Figure 2) indicates that ammonium ($r = -0.74$; $p = 0.03$), temperature ($r = 0.78$; $p = 0.02$), transparency ($r = 0.89$; $p = 0.002$), depth ($r = 0.85$; $p = 0.007$), conductivity and TDS ($r = 0.90$;

Table 2. Physico-chemical characteristics of the Affon River waters.

Stations	Tan1	Tan2	Tan3	Kol1	Kol2	Kpe1	Kpe2	Aff	p
Temperature	22.5	23.3	25.6	24.0	26.7	25.1	30.3	29.5	0.00
Conductivity	56.0	6.3	13.3	57.3	45.3	56.0	51.3	98.0	0.00
TDS	28.0	3.0	6.7	28.7	22.7	28.0	25.7	49.0	0.00
Transparency	13.3	14.3	15.3	17.0	17.3	19.7	23.0	24.3	0.00
pH	6.5	8.5	7.5	6.5	7.7	7.7	8.1	8.0	0.00
Depth	13.3	15.3	17.0	17.3	26.7	28.3	30.0	32.7	0.00
Nitrites	0	0	0	0	0	0	0	0	-
Ammonium	0.06	0.97	1.35	0.04	0.06	0.18	0	0.09	0.10
Phosphates	7.58	14.8	10.3	7.5	8.55	14.29	7.74	7.11	0.00

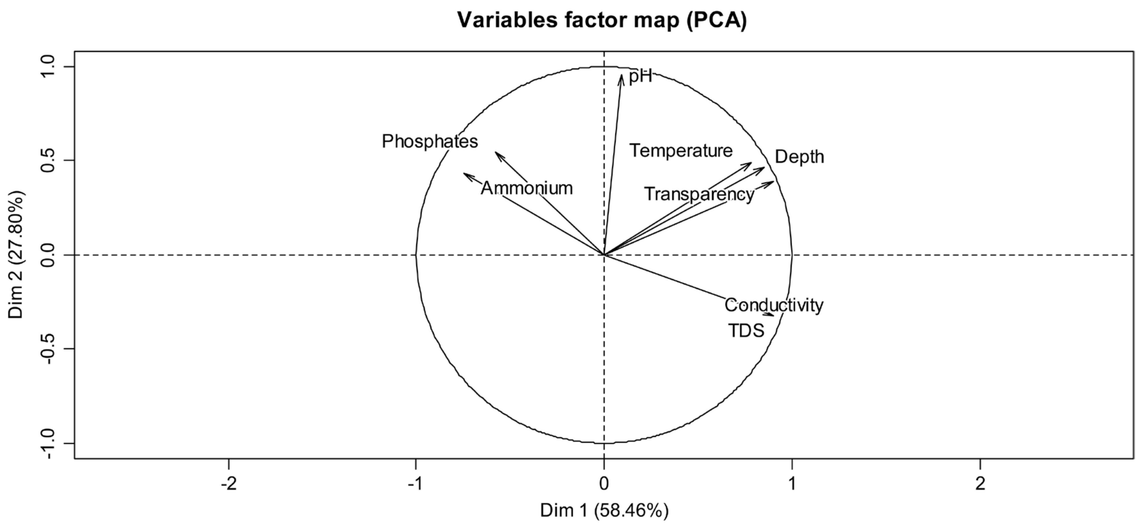

Figure 1. Positioning of the physico-chemical parameters on the axis.

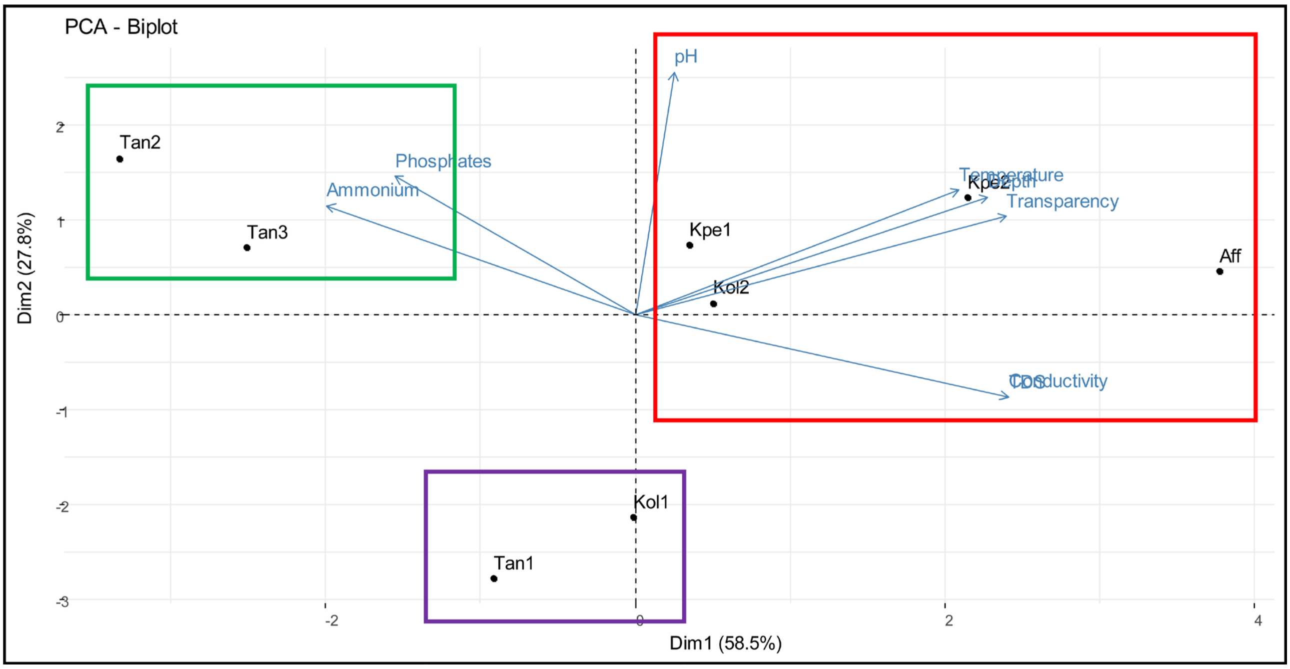

Figure 2. Distribution of physico-chemical parameters and stations.

p = 0.002) are strongly and significantly correlated with dimension 1. pH (r = 0.95; p = 0.0002) is strongly, positively and significantly correlated with dimension 2. Figure 3 on the distribution of parameters and stations allowed the stations to be grouped into three groups and to highlight the following associations: 1) the group of Tanéka 2 and Tanéka 3 stations characterized by high ammonium and phosphates; and low values of conductivity and TDS; 2) the group of Tanéka 1 and Kolokondé 1 stations with low pH, transparency, ammonium and phosphates; and 3) the group of Kolokondé 2, Kpébouko1, Kpébouko 2 and Affon stations marked by high values of conductivity, TDS, transparency, depth and temperature.

3.2. Composition and Distribution of Macroinvertebrates

3.2.1. Abundance and Relative Abundance of Macroinvertebrates

During the study, 9755 macroinvertebrate individuals were captured belonging to 49 families, 14 orders and 04 classes. Insects were the most dominant class of macrofauna with 9501 individuals or 97.40% of the total abundance (**Figure 3**). They were followed by worms (2.23%), molluscs (0.22%) and arachnids (0.15%).

Among the fourteen orders, Diptera, made up of 76.90% of the total population, were the most dominant. Then come Trichoptera, Odonata and Ephemeroptera with 9.06%; 5.06% and 4.25% of the total number of individuals harvested respectively. The remaining orders: Oligochaetes, Coleoptera, Heteroptera, Nemathelminthes, Gastropods, Hydracarina, Lepidoptera, Achaetes, Plecoptera and Hydracarians are the marginal communities with relative abundances lower than 02% (**Figure 4**).

Figure 5 shows the relative abundance of different families captured in the Affon River. It indicates that only one family, Chironomidae (Nr = 73.17%) is

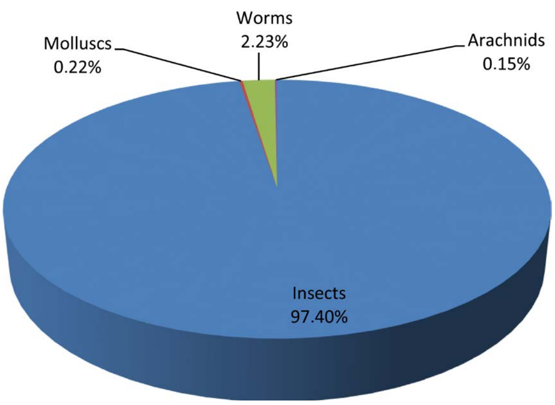

Figure 3. Relative abundance of taxonomic groups.

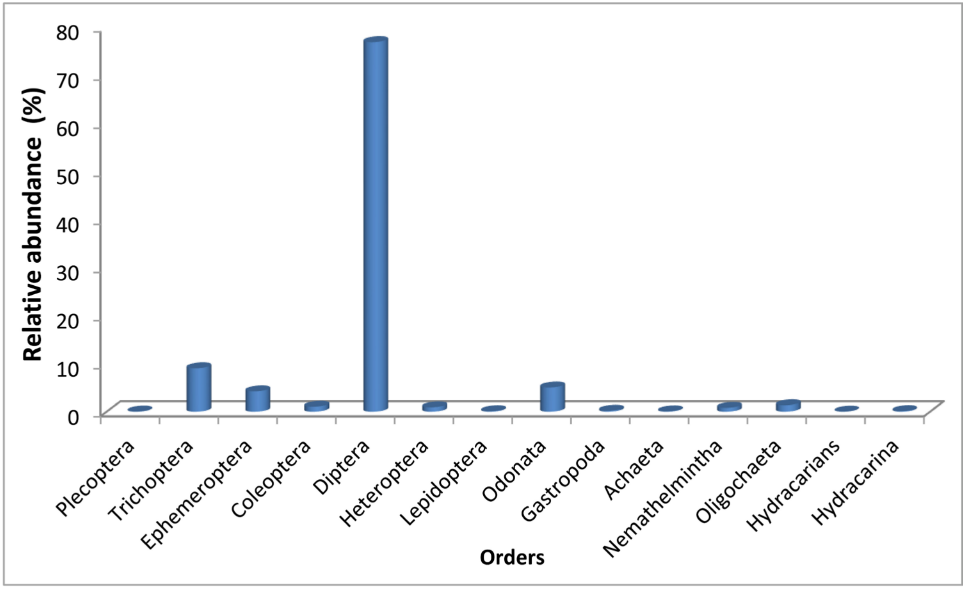

Figure 4. Relative abundance of macroinvertebrate orders.

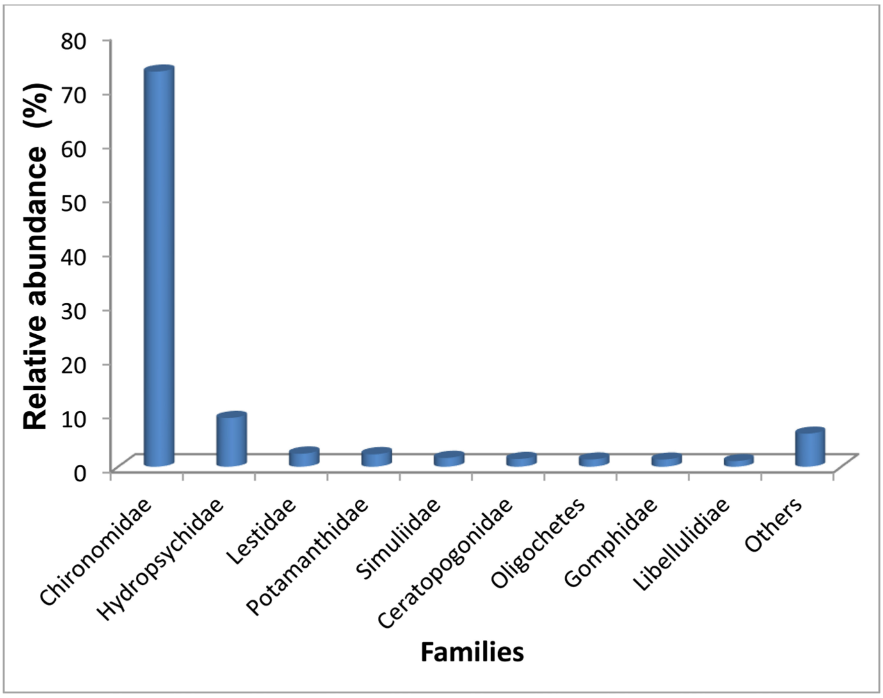

Figure 5. Relative abundance of macroinvertebrate families.

dominant in this watercourse, followed by Hydropsychidae (Nr = 9.03%). About 95.92% of captured families have a relative abundance of less than 3%.

3.2.2. Taxonomic Composition of Macroinvertebrate Classes

1) Class of Insects

The class of insects was very rich with 9501 individuals, 39 families and 08 orders. This class is dominated by Diptera containing 9 families and 7502 individuals, or 78.96% of the insect richness. They were followed by Trichoptera and Odonata with 2 families, 884 individuals; and 4 families, 494 individuals, thus constituting 9.30% and 5.20% of the insect richness respectively. Ephemeroptera, Coleoptera, Heteroptera, Lepidoptera and Plecoptera represent respectively 4.37%; 1.07%; 0.94% and 0.12%; 0.04% of the insect richness.

2) Class of Worms

The worms are made up of three orders, namely the order of the Achetes (3.21%), the order of the oligochaetes (61.01%) and the order of the nemathelmintes (35.78%).

3) Class of Molluscs

Molluscs consist of one order and 5 families, the most dominant of which are: Hydrobiidae (42.86%) and Physidae (28.57%). They are followed by Viviparidae (19.05%), Limnaeidae and Bithynidae each constituting 4.76% of the mollusc richness.

4) Class of Arachnids

Hydracarians and Hydracarina are the two orders of captured Arachnids. Hydracarina accounts for 86.67% of arachnid richness compared with 13.33% for Hydracarians.

3.2.3. Evolution of Richness and Taxonomic Abundance per Station

The highest taxonomic richness (30 families) was obtained at Tanéka 1 which is upstream while Tanéka 3 has the lowest taxonomic richness (6 families). As for the highest abundance, 2940 individuals or 30.14% of the total number of macroinvertebrates inventoried were obtained at Kolokondé 2 while Tanéka 3 was the station with the lowest abundance (43 individuals), or (0.44%). In addition, values of richness and abundance showed significant differences between stations (**Figure 6**).

3.2.4. Frequency of Occurrence of Macroinvertebrates

Table 3 presents the frequency of occurrence of macroinvertebrate families. It shows that 19 families (38.78%) are very frequent families while 9 families are frequent families (18.37%). Finally, the 21 other families are rare families and constitute 42.85% of captured families. It is noted that only the Chironomidae

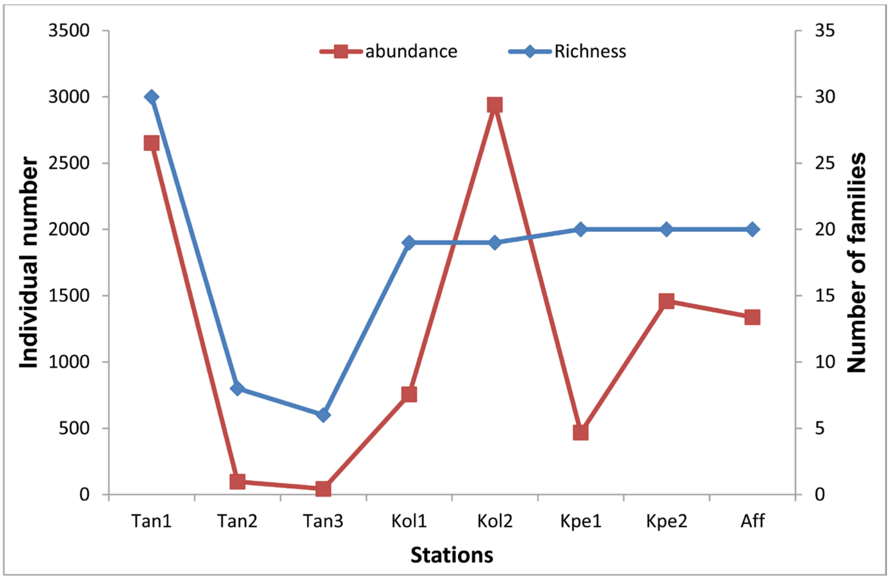

Figure 6. Spatial variation of taxonomic richness and abundance.

Table 3. Frequency of observation (FO) of macroinvertebrate families.

Very frequente families (F ≥ 50%)	Frequente families (50% > F ≥ 25%)	Rares families (F < 25%)
Baetidae, Ephemerellidae	Hydrophilidae	Perlidae, Hydrobiidae
Leptophlebiidae, Culicidae	Notonectidae	Nemouridae, Eubriidae
Simuliidae, Gerridae	Pyralidae	Elmidae, Taeniopterygidae
Veliidae, Araignées	Physidae	Leptoceridae, Nepidae
Caenidae, Potamanthidae	Glossiphoniidae	Tabanidae, Bithynidae
Hydropsychidae, Lestidae	Hydracariens	Ephemeridae, Isonychiidae, Viviparidae, Limnaeidae, Heptageniidae, Sciomyzidae Chaoboridae, Tricorytidae,
Ceratopogonidae	Tipulidae	
Corixidae, Libellulidae	Aeschnidae	Gyrinidae, hydrophiloidae
Oligochetes, Dytiscidae	Nemathelmintes	
Gomphidae, Chironomidae		

family has a frequency of occurrence equal to 100%.

4. Discussion

4.1. Physico-Chemical Quality of Affon River

The majority of physico-chemical parameters studied except phosphates and ammonium tend to follow an altitudinal zonation. Indeed, the average values of transparency, depth and temperature recorded on the stations of the Affon River are inversely proportional to the altitude. The recorded temperatures (22.5˚C and 30.3˚C) are slightly higher than those obtained by Zinsou *et al.* (2016) [22]. Guigemde *et al.* (2003) [23] observed similar values for the Massili Basin in Burkina Faso (18.6˚C to 39.2˚C). As for the water pH values, they are between 6.5 and 8.5, perfectly within the tolerable limit (6.5 and 8.5) which characterizes aquatic life [24]. These results corroborate those recorded by Koudenoukpo *et al.* (2017) [25] on the Sô River in Benin and Buhungu *et al.* (2018) [26] on the Kinyankonge River in Burundi. The recorded conductivity and TDS values are in the range of reported values (59.8 and 238 μS/cm and 28 and 119.5 mg/l) in the Ouémé delta [22]. These values are much lower than the values reported on the Sô River [25], but they are higher than those obtained on the Ogba River in Nigeria [27]. Mean values of conductivity and TDS increase with decreasing altitude and are within the range that characterizes natural water [24]. Regarding the values of nitrites, phosphates and ammonium, they do not follow a specific trend in relation to the altitude. The phosphate values recorded in this study (7.11 - 14.8 mg/l) are higher than those for surface waters with an average value of 0.02 mg/l [28] [29]. These observed values classify the waters of Affon River in a general state that is bad with respect to their trophic state [30]. The phosphate values obtained in this water are much higher than those reported on the Ogba River in Nigeria [27] and on the Agnéby River in Côte d'Ivoire by Diomandé *et al.* (2009) [31]. Phosphate is the most limiting factor and the most important for aquatic productivity whose absence could lead to the depletion of aquatic ecosystems [32]. Conversely, high concentrations of phosphate can indicate the presence of pollution and are responsible for eutrophication conditions [28]. The recorded ammonium values are lower than the values reported by Zinsou *et al.* (2016) [22] in the Ouémé delta. Except for the value of Tanéka 3, the values recorded are below the standard set for surface water (0.2 mg/l) [28] and WHO, which is 0.5 mg/l for drinking water [33].

4.2. Composition and Distribution of Macroinvertebrates

The study has identified in the Affonriver, 9755 macroinvertebrates belonging to 49 families. The observed abundance is very low compared to that reported by Agblonon Houelome *et al.* (2017) [8] on the Alibori River (39,718). On the other hand, it is higher than that of the upper Ouémé River, where there were 3657 individuals of macroinvertebrate [10]. As for the taxonomic richness, it is identical to that reported on the Niger River [34] and on the Agnéby River in Côte d'Ivoire [31]. While it is much higher than that obtained by Abahi *et al.* (2018) [10] on the upper Ouémé River. The differences observed with the study by Abahi *et al.* (2018) [10] in the same area are due to the Surber sampler and the sampling period. In fact, during this study, we used the Surber sampler with a 500 micrometer mesh rainy season, while Abahi *et al.* (2018) [10] used the Surber sampler with a 100 micrometer mesh in low water. The diversity of the macroinvertebrate community harvested in the Affon River is marked by the importance of Diptera (76.90%) dominated by the Chironomidae family which represent 73.17% of the total abundance. In Benin, the study conducted by Abahi *et al.* (2018) [10] on the upper Ouémé River, also revealed the predominance of Insects (85.23%), Diptera (81.65%) and Chironomidae (67.35%). Similarly, in Burkina Faso, Sanogo *et al.* (2014) [35] and Kabré *et al.* (2000) [36] reported the dominance of Chironomidae in their studies. In addition, the study revealed the low diversity of pollution-sensitive orders (Ephemeroptera, Trichoptera and Plecoptera) both in terms of richness (14 families) and in terms of numbers (1,303 individuals), which would probably reflect the poor quality of the waters in the study area. These results, which are characteristic of rivers located in anthropized zones, corroborate well with the results obtained by (Abahi *et al.*, 2018) [10] on the upper Ouémé River, by Imorou Toko *et al.* (2012) [9] in the Benin cotton basin and by OrouPiami (2018) [37] on the Sota River. Most encountered families are represented by only a few individuals. But Chironomidae (Diptera) are frequently and abundantly represented at all stations. Thus, the diversity of the Diptera Order observed and especially of the Chironomidae family reveals an accumulation of nutrients in the ecosystem; consequences of intense human activities [38] [39]. Anthropogenic activities near ecosystems disturb benthic communities and contribute to reduced species richness and even species distribution [35] [40]. In addition, the correlations established between families and the physicochemical parameters show a strong positive correlation between Nemouridae and ammonium on the one hand and between Perlidae, Taeniopterygidae, Ephemeridae, Heptageniidae, Isonychiidae, Elmidae and phosphate on the other hand, where there was a strong positive correlation. These correlations show the invulnerability of these families, which are mostly pollution-sensitive families, at the doses of phosphate and ammonium measured in this study.

5. Conclusion

The study of the water quality of Affon River reveals that the main physico-chemical parameters except phosphate have values that are relatively compatible with aquatic life. The absence of traces of nitrite in the watercourse supports good quality but is invalidated by the high levels of phosphorus compounds, responsible for the eutrophication of rivers. The present study inventoried 9755 macroinvertebrate individuals belonging to four classes, fourteen orders and forty-nine families. Insects were the most dominant with 97.40% of the total richness. Taxonomic richness and abundance tend to follow an altitudinal gradient. The analysis of the indices reveals an undiversified population and the environmental stress that this river undergoes. The strong positive correlations observed between Nemouridae and ammonium on the one hand and between Perlidae, Taeniopterygidae, Ephemeridae, Heptageniidae, Isonychiidae, Elmidae and phosphate show the invulnerability of these families, which are mostly pollution-sensitive families, at the doses of phosphate and ammonium measured in this study. Nevertheless, certain protection and recovery measures must be taken to preserve and improve the ecological status of the waters of Affon River. It involves the implementation of a sustainable river management plan, the promotion of organic farming, the awareness of the population on the importance of water and its quality. In addition, a long-term investigation based on biomonitoring and a sustainable management program are recommended to conserve the biodiversity of this river and develop a biotic index specific to the country.

Acknowledgements

We thank the people of our sampling places for their participation in the study. Special thanks go to the team of the Laboratory of Hygiene, Sanitary, Ecotoxicology and Environmental health (HECOTES) and the team of the Laboratory of Ecology, Health and Animal Production (LESPA).

Conflicts of Interest

The authors declare that they have no conflict of interest.

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