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Family diversity of benthic macroinvertebrates and water quality of the Tendo lagoon (Southeast Côte d'Ivoire)

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Abstract

This study was conducted to assess the biological health of Tendo lagoon, which is the natural receptor of coastal streams and the Tanoe River by determining the Hilsenhof index. Macroinvertebrates samples were collected each month from February 2017 to March 2018 at 4 stations using a Van Veen grab. Abiotic variables (transparency, temperature, pH, dissolved oxygen, salinity, conductivity and depth) were measured *in situ*. Sampling captured 3765 benthic macroinvertebrates, belonging to 30 families, 12 orders and 6 classes. The class of Insect is the most diverse with 15 families of which the Chironomidae family has the highest abundance (1228 individuals, 49,16%). During the study, salinity was zero. Redundancy analysis revealed that benthic macroinvertebrates community composition and abundance variations were mainly controlled by the environmental parameters of Tendo lagoon. The values of the calculated hilsenhoff index range from 5.93 to 6.90. Two groups of stations emerge in the Tendo lagoon: the first group formed by the stations (Te1, Te2 and Te3) with Hilsenhoff indices between (5.76-6.50) has a fairly poor water quality; therefore substantial pollution likely. The second group consists of the Te4 station, with the Hilsenhoff index which is between (6.51-7.25) with poor water quality, what suggests very pollution likely substantial.

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Introduction

Most of the planet's ecosystems are now affected, in one way or another, by the development of human societies. Agricultural, urban and industrial discharges can lead to high levels of pollution of aquatic ecosystems (D'Adamo *et al.*, 2008, Everard and Powell, 2002); these modify communities and affect the organisms that make them up (Viaroli *et al.*, 2005, Warwick, 2005). As a result, most streams are subject to anthropogenic effects (declining species, declining fish stocks, depletion of groundwater, deterioration of water quality; flooding becoming more frequent and intense). In Côte d'Ivoire, these threats are represented by the destruction of the dense and humid forest resulting from logging, the establishment of industrial plantations such as cocoa, coffee but also oil palm and rubber. In addition, development requirements (hydroelectric and hydroelectric dams, industrial landfills, domestic waste dumps and agricultural leaching) have led to activities that are increasingly putting aquatic ecosystems at risk (Gourène *et al.*, 1999). In particular, the southeast of Côte d'Ivoire is a highly anthropized region in which farms have replaced natural vegetation on more than half of its surface, the main sources of deterioration of aquatic habitat (Sankaré and Ettien, 1991, Hauhouot, 2004). This strong agricultural activity in the region on the river catchment area involves the recurrent use of phosphatic fertilizers, fungicides and insecticides by farmers and eventually ends up in the Aby-Tendo-Ehy lagoon complex (Yapi, 2014, Miyittah *et al.*, 2020). As a result, agricultural activities are the main cause of degradation of rural aquatic ecosystems (Sass *et al.*, 2010) and have serious ecological impacts on bodies and streams (Hepp *et al.*, 2010). Special attention should therefore be paid to monitoring these aquatic ecosystems to ensure their sustainability. This monitoring must be done using reliable and adequate indicators, such as biological indicators (Ben Moussa *et al.*, 2014). Among the bioindicators, macroinvertebrates are the most commonly used organisms for biological monitoring and assessment of the overall health of aquatic systems (Ben Moussa *et al.*, 2014, Camara *et al.*, 2014, Sanogo *et al.*, 2014). The main benefit of using these macroinvertebrates is their sensitivity to physicochemical variables and environmental disturbances (Adandedjan, 2012). Monitoring the level of pollution in an aquatic environment using bioindicators such as macroinvertebrates has been the subject of numerous studies in several countries (WFD, 2003). In Cote d'Ivoire, several studies have been carried out on the diversity and structure of macro-invertebrates in lagoons (Sankaré and Etien, 1991, Kouadio *et al.*, 2008, Allouko *et al* 2016, Appiah *et al.*, 2017, Simmou *et al.*, 2019, Yoboué *et al.*, 2020) and work on water quality assessment by biotic parameters in rivers (Aboua, 2012, Camara *et al.*, 2014, Edia *et al.*, 2007, Diomande *et al.*, 2009, Simmou *et al.*, 2015). However, there is little work on the assessment of the biological quality of the waters of the Lagoons of Côte d'Ivoire by the use of macroinvertebrates. The purpose of this study is to evaluate the biological quality of the waters of Tendo lagoon, a natural receptor of the waters of coastal streams and the Tanoe River, as determined by the Hisenhoff Index.

Materials and methods

Study site

This study was carried out in the Tendo lagoon in the southeast of Côte d'Ivoire (Fig. 1). This area is characterized by 4 seasons: a long rainy season (April to July), a short dry season (August to September), a short rainy season (October to November) and a long dry season (December to March). The Tendo lagoon is part of the vast Aby lagoon system. The Tendo lagoon is formed by a band stretched from West to East. It has a length of 22km, a width of 3.5km and an area of 73.7km^2. It receives significant water supplies from the small rivers and directly from the Tanoé River. The Tanoe River drains a watershed of 16,074km^2 of which 14,870km^2 are located in Ghana. It is 600km long. Its average flow rate is 1323m^3/s. The interannual balance of the volume of water supplied by Tanoé is 4.5 109 m^3, or 63% of the total freshwater supply of the Aby lagoon system. The Aby lagoon in the north and south is the largest and deepest part. It covers an area of 305.8km^2, with a maximum length and width of 24.5km and 15.5km respectively.

Concerning the Ehy lagoon, it is located at the eastern end of the Aby lagoon system. It is 4.5km long, 1km wide and covers an area of 45.8km².

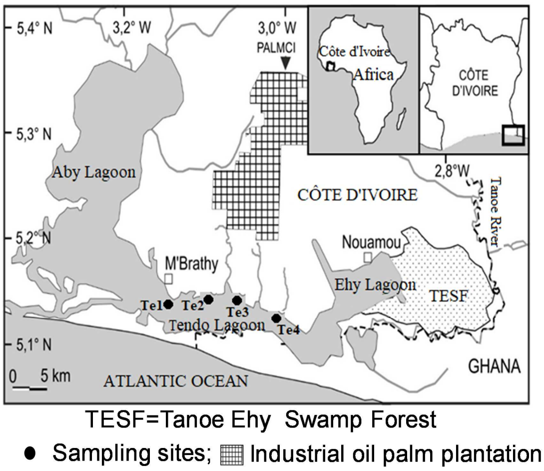

Fig. 1. Location of the sampling sites in Tendo lagoon.

Measure of environmental variables

A total of 4 stations, namely (Te1, Te2, Te3 and Te4) were selected on the Tendo lagoon. On each sampling date, environmental variables such as temperature (°C), dissolved oxygen (mg/l); conductivity (µs/cm) and pH were measured *in situ* using a Sper scientific multiparameter. Salinity (‰) and transparency (cm) were recorded with hydrobios refractometer and Secchi disc respectively. The depth (cm) was also recorded at each sampling station.

Sampling protocol

Benthic macroinvertebrates samples were collected from the four sampling stations in six sampling periods during the dry and rainy seasons . Sampling sites (Te1, Te2, Te3 and Te4) were selected in Tendo lagoon using criteria such as accessibility, water depth and sediment characteristics and in order to reflect the lagoon's different sedimentary and watershed habitats. Benthic macroinvertebrates samples were collected monthly from february 2017 through march 2018. Samples were collected using a 0.05 m² Van Veen grab. At each station, ten samples were collected for analyses. Each sample was sieved *in situ* through a 1 mm mesh. The organisms retained by the sieve were fixed in formaldehyde 10% solution. At the laboratory, macroinvertebrates were wash, sorted and identified to the lowest possible taxonomic resolution (family level) and counted. The identification keys of Durand and Levêque (1981), Tachet *et al.* (2010) and Moisan (2010) were used.

Data analysis

The structure of the macroinvertebrate stand was studied by taxa richness (S), abundance (A), the Shannon-Weaver diversity index (H) which was used to assess the diversity of macroinvertebrate taxa. The regularity index of Pielou (E) was used to show the organization of the structure, regardless of the species richness. Pollution tolerance indices are generally calculated taking into account the tolerance values of benthic macroinvertebrate taxa and their abundance within the sample. The Hilsenhoff index is widely used to assess the biotic integrity of benthic macroinvertebrate communities (Hilsenhoff, 1982). The variant used is based on family identification (FBI). Each family is associated with a pollution tolerance indicator. For each family, the number of individuals sampled is multiplied by its tolerance index. The results per family are added together. This number is then divided by the total number of organisms in a sample. The final index score (one per station) is then reported on the Hilsenhoff scale (Table 1) to associate it with water quality. The formula for calculating the Biotic Index is:

$$\mathrm{HBI} = \frac{\sum \mathrm{X_i t_i}}{\mathrm{n}}$$

x_i = total number of individuals belonging taxon I, t_i = tolerance of taxon and n = Total number of individuals in the sample.

Table 1. Water quality associated with the Hilsenhoff Index (Hilsenhoff 1988).

Family biotic index	Water quality	Degree of organic pollution
0.00 - 3.75	Excellent	Organic pollution unlikely
3.76 - 4.25	Very good	Possible slight organic pollution
4.26 - 5.00	Good	Some organic pollution probable
5.01 - 5.75	Fair	Fairly substantial pollution likely
5.76 - 6.50	Fairly poor	Substantial pollution likely
6.51 - 7.25	Poor	Very pollution likely Substantial
7.26 - 10.00	Very poor	Sever organic pollution likely

In order to determine the possible factors influencing the benthic macroinvertebrate assemblages, a Redundancy analysis (RDA), ter Braak ,1986) was performed taking into account the abundance of the dominant taxa as biotic variable and the abiotic factors. In this analysis, we considered only the major families whose relative abundance was at least 10% at a station (Bachelet *et al*., 1996). RDA was performed using CANOCO 4.5 (ter Braak and Smilauer, 2002) whereas STATISTICA 7.1 computer package was used for the other tests. In the ordination diagram produced by CANOCO, the importance of environmental factors is indicated by the relative length of vectors, i.e. the longer of the vector, the greater the influence on species distribution (ter Braak and Verdonschot, 1995). The results of this analysis are presented as ordination diagrams containing continuous explanatory variables plotted as vectors with points for sites and taxa. The parametric and nonparametric analysis of variance tests (One way ANOVA and Kruskal-Wallis) were used to compare physical and chemical parameters values between stations, The level of statistical significance was maintained at 95% ($P < 0.05$).

Results

Physical and chemical variables

The minimum, maximum and average standard deviation seasonal values of the physicochemical parameters measured in Tendo lagoon are reported in (Table 2). Water temperatures, on average, ranged from 28.15ºC to 28.6ºC during the rainy season and from 28.3ºC to 28.91ºC during the dry season. Seasonal variations in dissolved oxygen levels are not significant, however, with dry season values (55.66mg.l^{-1} to 75.68mg.l^{-1}) being relatively higher than those obtained during the rainy season (50.22mg.l^{-1} to 71.16mg.l^{-1}).

The pH values observed in Tendo lagoon indicate that the water was slightly acidic. The minimum and maximum wet season pH was 5.31 and 7.58 at stations (Te4) and (Te1), respectively. During the dry season, the minimum pH 5.41 was also recorded at station Te4, while the maximum pH (7.34) was recorded at station Te1. Observed zero salinity at all stations during the wet and dry season.

The maximum conductivity of 722 µS/cm during the wet season and 819 µS/cm during the dry season was observed at stations Te2 and Te4 respectively. The minimum conductivity values were 85.2 µS/cm and 15.37 µS/cm during the dry and wet seasons recorded at stations Te4 and Te2 respectively. Regarding transparency, the values are on average higher during the dry season than during the wet season, in all stations of Tendo lagoon.

Maximum water depth values were observed during the rainy season at all stations. Maximum depths of 501cm during the wet season and 483cm during the dry season were observed at stations Te1 and Te2 respectively. The minimum depth values were 78cm and 68cm during the dry and wet seasons at Te3.

Diversity of benthic macroinvertebrates

The Macroinvertebrate taxa found in Tendo lagoon are presented in table 3. In the present study, a total of 3765 macroinvertebrate specimens were collected. These organisms belong to 6 class divided into 13 orders, 30 families. Insects were the most abundant and diversified class with 15 families (69.90% of individuals), Gastropoda, Crustaceans and Polychaeta contain respectively 7 families (15.85% of individuals), 4 families (10.41% of individuals) and 2 families (1.80% of individuals) the other class, namely Oligochaeta and Bivalvia, are represented by only one family. Among insects, Diptera are the most abundant order with 1294 specimens (49.16%).

This order is followed by Ephemeroptera (19.52%), Odonates (12.57%), Heteroptera (9.49%) and Coleoptera (9. 23%). Concerning families, the Chironomidae were the most abundant family with 1238 individuals (47.03%) of the class of Insects. The families of Baetidae and Belostomidae followed with respectively (418 individuals or 15.88%) and (246 individuals or 9.34%). Ephemeroptera (19.52%), Odonates (12.57%), Heteroptera (9.49%) and Coleoptera (9.23%).

Table 2. Mean (standard deviation) values, minimum and maximum seasonal values of physical and chemical parameters at four sampling stations of Tendo lagoon in Southast Ivory Coast during the study.

Parameters	Seasons (Descriptive statistics)	Sampales stations Te1	Te2	Te3	Te4
Temperature (°C)	Dry (Mean ±SD)	28.3±1.23	28.48±2.07	28.91±1.91	28.71±0.99
	Dry (Min-Max)	26.4-29.6	26.3-31.5	31.6-26.1	27.4-30.2
	Wet(Mean ±SD)	28.65±1.19	28.15±2.29	28.08±1.97	28.6±2.71
	Wet(Min-Max)	27.3±1.19	25.3-30.3	25.3-29.8	25.4-31.8
Dissolved oxygene (mg/l)	Dry (Mean ±SD)	75.68±7.04	70.6±11.58	55.66±17.40	60.73±12.18
	Dry (Min-Max)	68.9-87.7	60.2-87.4	26.4-77.5	42.3-79.5
	Wet(Mean ±SD)	64.7±7.88	71.16±14.39	52.73±12.20	50.22±7.84
	Wet(Min-Max)	59.1-76.2	60.1-90.5	41.7-69.4	41.98-59.7
pH	Dry (Mean ±SD)	6.94±1.04	7.42±0.80	7.03±0.63	6.725±0.83
	Dry (Min-Max)	5.61-7,34	5.89-7.14	6-7.68	5.41-7.66
	Wet(Mean ±SD)	6.49±0.76	7±0.38	6.81±0.50	6.43±0.95
	Wet(Min-Max)	5.41±7.58	6.4±7.5	6.24±7.41	5.31±7.2
Salinity (‰)	Dry (Mean ±SD)	0	0	0	0
	Dry (Min-Max)	0	0	0	0
	Wet(Mean ±SD)	0	0	0	0
	Wet(Min-Max)	0	0	0	0
Conductivity (µS/cm)	Dry (Mean ±SD)	288.15±285.27	210.13±22.44	343.96±262.15	291.8±274.64
	Dry (Min-Max)	102.9-811	89.7-354	125.1-792	85.2-819
	Wet(Mean ±SD)	81.85±19.70	193.8±259.06	74.81±33.99	197.77±184.43
	Wet(Min-Max)	60-107	75.50-722	15.37-109	75.2-472
Secchi Disck transparency (cm)	Dry (Mean ±SD)	57.63±14.26	43.4±15.98	45.16±20.15	49.6±14.32
	Dry (Min-Max)	37-69	29-73	31-82	26-61
	Wet(Mean ±SD)	34.25±6.23	42.83±13.13	36.91±7.97	39.75±9.67
	Wet (Min-Max)	26-40	24-61	28-50	32-52
Depth(cm)	Dry (Mean ±SD)	312.66±88.21	429.33±54.06	134.5±93.67	180.25±67.37
	Dry (Min-Max)	143-367	343±384	78-284	105-501
	Wet(Mean ±SD)	429±71.17	446.5±54.06	142.16±82.44	249±134.57
	Wet(Min-Max)	362-501	354±483	68-308	124-262

Table 3. List and number of benthic macroinvertebrates families collected from the study sites (Tendo lagoon) during this study.

Class	Orders	Families	Numbers of individuals Te1	Te2	Te3	Te4	Total
Bivalvia	Eulamellibranchia	Sphaeridae	-	36	-	-	36
Crustacean	Amphipoda	Corophiidae	-	36	-	-	36
		Gammaridae	24	38	34	-	96
	Decapoda	Desmocarididae	-	54	99	35	188
		Paleamonidae	-	-	56	16	72
Gasteropoda	Basommatophora	Physidae	76	-	64	4	144
		Planorbidae	-	-	-	47	47
	Mesogasteropoda	Lymnaeidae	68	-	-	4	72
		Physidae	-	5	-	-	5
		Planorbidae	-	-	40	44	84
		Potamididae	-	52	12	58	122
		Thiaridae	-	63	36	24	123
Insecta	Coleoptera	Curculionidae	28	-	64	72	164
		Dytiscidae	-	-	32	-	32
		Hydrophilidae	28	-	-	19	47
	Diptera	Ceratopogonidae	56	-	-	-	56
		Chironomidae	663	264	132	179	1238
	Ephemeroptera	Baetidae	166	65	128	119	478
		Caenidae	-	4	12	8	24
		Ephemerellidae	-	4	-	-	4
		Leptophlebiidae	-	8	-	-	8
	Heteroptera	Belostomidae	60	21	92	73	246
		Notonectidae	-	4	-	-	4
	Odonata	Coenagriidae	56	-	48	114	218
		Corduliidae	-	4	-	-	4
		Libellulidae	13	16	32	-	61
		Macromiidae	-	-	48	-	48
Oligochaeta	Haplotaxida	Lumbricidae	36	-	4	-	40
Polychaeta	Nereidiformia	Eunicidae	28	4	-	16	48
		Nereidae	16	-	4	-	20
Total of number taxa (families)		30	14	17	18	16	3765
Total of number individuals			1318	678	937	832	

Spatial and seasonal variation of Shannon-weaver diversity and Evenness

The spatial variations of the Shannon-Weaver index and Equitability at the various stations in Tendo lagoon are presented in table 4. The minimum (2.78) and maximum (3.08) values were recorded at stations Te4 and Te3, respectively. Spatially, the Kruskal-Wallis test revealed that diversity does not vary significantly between stations ($p > 0.05$). Equitability recorded in the Tendo lagoon stations ranged from 0.87 (Te1) to 0.90 (Te3) for all stations. Spatially, the Kruskal-Wallis test revealed that Equitability does not vary significantly from station to station ($p > 0.05$).

Table 4. Values of metrics to describe the structure of benthic macroinvertebrates during the study period.

Stations	Te1	Te2	Te3	Te4
Taxa	14	17	18	16
Abundance	1318	678	937	832
Shannon-Weaver	2.91	2.89	3.08	2.78
Equitability	0.87	0.87	0.90	0.88

The seasonal variation in the Shannon-Weaver index shows no significant difference between the seasons at the different stations in the Tendo lagoon (Kruskal-Wallis p test > 0.05). This index ranges from 2.57 (Te2) to 2.92 (Te1). Additionally, during the dry season the high values of this index were obtained at stations Te1 and Te2 while the values are higher during the rainy season at stations Te3 and Te4.

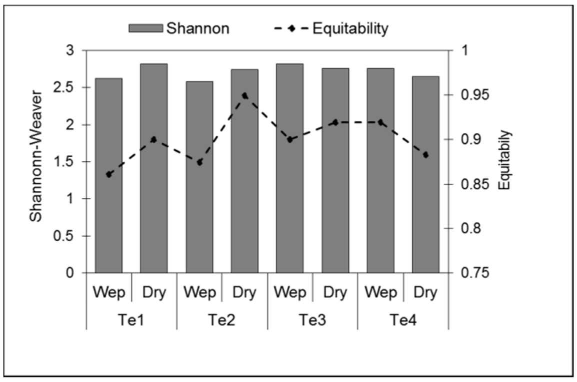

Fig. 2. Seasonal variation of Shannon-weaver diversity and Evenness of Benthic macroinvertebrate in Tendo lagoon.

The lowest value (0.86) of Equitability at Te1 was observed during the wet season while the highest value (0.94) was observed during the dry season at Te2 (Fig. 2). The Equitability values obtained during the dry season in stations Te1, Te2 and Te3 are higher than those obtained during the rainy season, while the wep season recorded the maximum value at station Te4.The Kruskal-Wallis test revealed that Equitability does not vary significantly from season to season at each station of the Tendo lagoon studied ($p > 0.05$).

Spatial and seasonal variation of Abundance and taxa richness

Abundance at Tendo lagoon stations ranged from 678 individuals (Te2) to1318 individuals (Te1) for all surveyed stations. Station Te3 had the highest taxa richness (18) with 937 individuals, followed in this order by station Te2 with (678 individuals), station Te4 with 16 taxa (832 individuals). Station Te1 with 14 taxa had the highest abundance (1318 individuals) (Table 4). The results of the statistical analysis showed that there is no significant difference between the stations (Kruskal-Wallis test). In Tendo lagoon, minimal (218 individuals) and maximum (740 individuals) abundances are recorded during the station's dry season (Te2) and during the wet season (Te1), respectively. In stations Te2 and Te3 are abundances obtained from macroinvertebrates are higher in rainy seasons than in dry season. In stations Te1 and Te4 the high abundances are obtained during the dry season. The low taxonomic richness, 11 taxa is noted during the rainy season at station Te1 and at station Te2 during the dry season. A high abundance (15 taxa) is recorded at stations Te3 and Te4 in the dry season (Fig. 3).

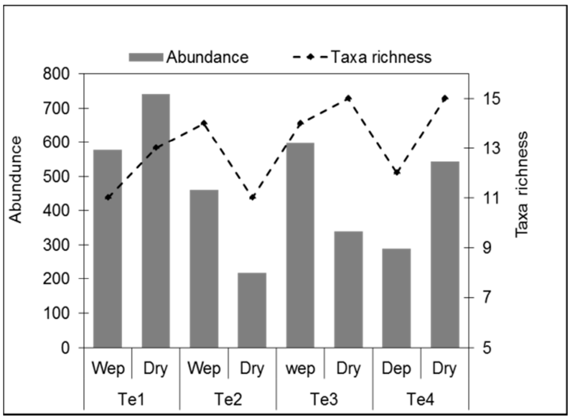

Fig. 3. Seasonal variation of abundance and Richness of Benthic macroinvertebrate in Tendo lagoon.

Relationship between main families of benthic macroinvertebrates and physicochemical variables

A canonical redundancy analysis (RDA) was carried out in order to relate environmental parameters to the distribution of macroinvertebrate families in Tendo lagoon. In this analysis, we considered only the major families whose relative abundance was at least 10% at a station. The total percentage of variance explained is 98.1% for the first two axes, of which 59.9% for the first and 38.2% for the second. The first two axes are therefore considered in the expression of the results. The Redundancy Analysis (RDA) diagram clearly dissociates the samples into two groups (Fig. 4). Group I contains samples from stations Te3 and Te4. These samples are distinguished from others by waters with high conductivity and transparency values These parameters are favorable to the abundance of the families Baetidae, Physidae, Paleamonidae, Belostomidae, Curculionidae, Coenagriidae and Planorbidae.Group II consists of samples from stations Te1 and Te2.These samples are characterized by temperature, dissolved oxygen, depth and pH.The families that abound in these conditions are Desmocrididae,Gammaridae, Thiaridae, Sphaeridae, Chironomidae and Lymnaeidae.

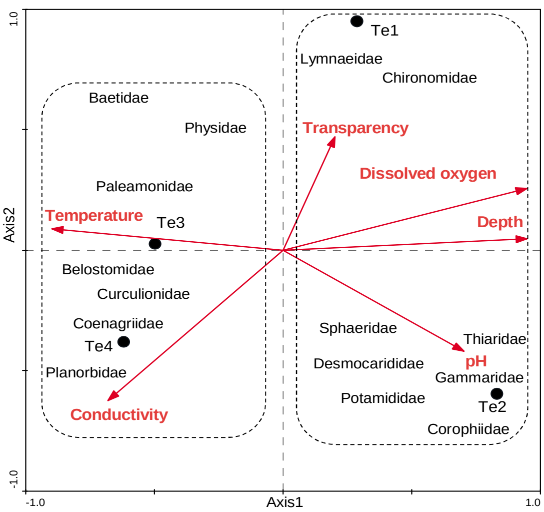

Fig. 4. Redundancy analysis showing correlation between environmental variables and main families collected in the Tendo lagoon.

Spatial variation of Hilsenhoff

The values of the Hilsenhoff's Index calculations during the study are recorded in table 5. The Hilsenhoff value for station Te3 (5.93) is low in comparison with Te1 (6.32) and Te2 (6.37). The maximal value of the Hilsenhoff Index was obtained at Te4 station (6.9). The stations of the Tendo lagoon can thus be grouped into two groups ; the group formed by the stations Te1, Te2 and Te3 with Hilsenhoff indices between 5.76- 6.50 have rather poor water quality. The group comprised of station Te4 with poor quality water with a Hilsenhoff index of 6.51-7.25.

Table 5. Biotic index of families of stations in Tendo lagoon.

	Hilsenoff Biotic Index			
Stations	Te1	Te2	Te3	Te4
	6,32	6,37	5,93	6,90

Discussion

The spatial variation of the various abiotic descriptors in Tendo lagoon revealed that these parameters don't vary significantly from station to station. This could be explained by a permanent exchange of the waters of the various stations considered under the impulse of the waves on the surface of the lagoon, resulting in large movements of water bodies. This movement would be the basis for a certain homogenization of water at a given period. For this purpose, Salencon and Calmels (1994) showed that the circulation of water bodies plays a fundamental role in the transport and redistribution of nutrients. These observations are similar to those of Kouamé (2014) who observed a low spatial variability of the physico-chemical parameters of Lake Taabo.

In Tendo lagoon, the temperature records the highest values in practically all stations during the dry season. The same trend was observed in Aby lagoon by Chantraine (1980), Simmou (2017). This seasonal variation in the temperature of the waters of this lagoon is comparable to that of other lagoons in tropical areas outside Côte d'Ivoire ; Açu lagoon (Brazil) (Chagas and Suziki, 2005) and Lake Nokoué lagoon (Benin) (Gnohoussou, 2006. Indeed, in the tropical zone, during the dry season, the air temperature, linked to solar radiation, is at its maximum while it is at its minimum during the rainy season period with overcast weather (Dufour and Durand, 1982).

Dissolved oxygen levels are higher in the dry season at all stations in Tendo lagoon. This result is contrary to those found by Kouassi *et al.* (2006) in the study of hydrology and water pollution in the Grand Lahou lagoon. Indeed, many factors such as water temperature, nutrient availability, biological factors (respiration and oxidation), etc. may be responsible for changes in oxygen levels in an environment (IBGE, 2005). pH values are high during the dry season in Tendo lagoon. These high values may be due to high temperature values and increased photosynthetic activity during this season in the surveyed lagoon system. These results were also reported by Durand and Skubich (1982) in the Ebrié lagoon's complex, by Dahbi (1988) at the Bou Regreg estuary (Morocco).

The salinity in Tendo lagoon was zero in this study. The level of salinity of coastal lagoons depends on freshwater inputs. The Tanoe River, which flows into the Tendo lagoon, contributes 63% of the freshwater supply (Hauhouot, 2004;). This result corroborates that of Koné *et al.* (2008) on all Ivorian lagoons. These authors argue that parameter fluctuations in these areas are highly dependent on the importance of continental inputs.

In general, in Tendo lagoon, the maximum average conductivity value was recorded during the dry season at all stations. This is due to the concentration of ions as a result of reduced water volume (Bony, 2007). The low values obtained during the rainy season would therefore be related to the dilution phenomenon (Horeau *et al.*, 2005) because during rainy seasons, inland water supplies are important and contribute to a dilution of most abiotic variables.

The values of the transparency of the Tendo lagoon show that the waters are turbid in the great rainy season. This turbidity could be related to suspended solids and to the primary fluvial production brought by the water at that time. The same results were found by Komoe (2009) in the Grand Lahou lagoon complex.

The taxonomic composition of the macroinvertebrate communities of the Tendo lagoon is characterized by Insecta, Bivalvia, Crustaceans, Gastropoda, Oligochaeta and Polychaeta grouped in 13 orders and 30 families, with a dominance of the class of Insects (69.90% individuals). In this study, the identification of macroinvertebrates was limited to the family. In fact, such a level of identification provides information similar to that obtained by much more in-depth analysis down to the gender level, although at the gender level more taxa bioindicators are found (Jones *et al.*, 2007, Masson *et al.*, 2010). Moreover, according to Usseglio-Polatera and Beisel (2003), the family corresponds to the systematic level generally recommended for standardized methods of assessing the biological quality of streams. The Insects class is the most diverse with 15 families. Among insects, the Chironomidae family contains the highest abundance (1228 specimens; 49.16%). This faunistic composition is similar to that of freshwater macroinvertebrates in Africa (Diomandé and Gourène, 2005). In fact, this wildlife structure is similar to that mentioned by some authors (Tchakonté, 2016 ; Onana *et al.*, 2016, Nyamsi *et al.*, 2014, Foto *et al.*, 2011, Diomandé *et al.*, 2009) in anthropized streams in tropical Africa regions. The salinity of Tendo Lagoon being zero, it behaves like fresh water. In addition, Chironomidae are present in all stations and constitute the most abundant family (47.03%). Similar results (40.72%) were observed by Diomandé *et al.* (2009) in the Agnéby River. The abundance of these so-called pollutant-tolerant taxa in these environments overall indicates that the ecological integrity of Tendo lagoon would be impaired (Barbour *et al.*, 1999).

The Shannon-Weaver Diversity Index and the Equitability Index between 2.78 and 3.08 and 0.87 and 0.90 respectively in Tendo lagoon are relatively high. These values indicate that the studied stand is relatively diverse and balanced. According to Frontier (1983), in exceptionally diverse environments, the Shannon-Weaver Diversity Index does not exceed 4.5. Furthermore, according to Dajoz (2000), the closer the equitability is to 1, the more balanced and stable the stand is. On the contrary, a low equitability (close to 0) reflects an imbalance of settlement following the proliferation of a limited number of species due to a natural or anthropogenic cause.

In Tendo lagoon, low abundances (218 individuals) and high abundances (740 individuals) are recorded during the dry season (Te2) and wet season (Te1), respectively. The highest abundances in wet season could be explained by an important sedimentation of organic matter with recirculation and the habitat productivity (Kisielewski, 1986, Zebaze Togouet, 2000). In return, lowest values in the dry Season could be attributed to the intense environmental stress such conditions probably affected the physiological responses of the organisms, leading to a reduction in the number (Posey *et al.*, 1998).

The ordination technique used to characterize Tendo lagoon from the distribution of benthic macroinvertebrates as a function of abiotic parameters revealed that conductivity, temperature, dissolved oxygen, pH, depth, water transparency are the most important variables that explain the macroinvertebrate distribution.

This finding appears to be consistent with several studies that have shown that the richness, abundance, and distribution of benthic macroinvertebrate assemblages is greatly influenced by the physical-chemical quality of the water (Morrissey *et al.*, 2013, Colas *et al.*, 2014, Arimoro *et al.*, 2015). The influence of these parameters is a good indicator of organic inputs from effluents and agricultural activities at most of the stations studied. Parameters such as pH, conductivity and TDS are closely associated with the nature and concentration of dissolved substances in the environment (Simmou, 2017).

In the present study, a comparison of the Hilsenhoff index across the stations showed that the highest value of this index recorded (6.90) at station Te4 indicates poor water quality, very pollution likely substantial. This station had a relatively low Shannon diversity index value followed by stations Te3, Te1 and Te2, due to the presence of tolerant taxa such as Diptera, Gastropoda.

The ecological health of these stations was probably due to the impacts of anthropogenic activity including the application of synthetic fertilizers and pesticides in agriculture and industrial effluents in this highly agricultural area. The index values for the other stations varied between 5.93 to 6.37, indicating a fairly poor water quality; substantial pollution likely. The biodiversity of macroinvertebrates communities in a given ecosystem often reflects environmental conditions. Sensitive species colonizing these habitats due to adverse environmental conditions are progressively eliminated and tolerant species establish colonies and develop in abundance (Rosenberg and Resh, 1993).

Conclusion

The present study inventoried 3765 macroinvertebrates, belonging to 30 families, 12 orders and 6 classes in the Tendo lagoon. The physicochemical parameters have an impact on the water quality and therefore have influenced the distribution of macroinvertebrates in the Tendo lagoon. The salinity value was zero during both sampling seasons in Tendo Lagoon. The taxonomic composition of the samples analyzed revealed that insects were the most dominant class with a predominance of Chironomidae family the high number of pollutio tolerant macroinvertebrate in the stations testifies to pollued state of the Tendo lagoon as all the calculated hilsenoff biotic index indicate. This work therefore provides basicline information for the management and conservation of Tendo lagoon.

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