Int. J. Adv. Res. Biol. Sci. (2026). 13(7): 53-64

International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
(A Peer Reviewed, Referred, Indexed and Open Access Journal)
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 13, Issue 7 - 2026

Research Article

2348-8069

DOI: http://dx.doi.org/10.22192/ijarbs.2026.13.07.005

Benthic macroinvertebrates as an indicator of the biotic quality of an anthropized watercourse in Ayamé (Southeast, Côte d'Ivoire)

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Abstract

This study assessed the water quality of the Ano-Assué River using benthic macroinvertebrates. Two samplings was carried out in 2019 during the short dry and rainy seasons, at five stations using a Van Veen grab. Composition and structure made it possible to determine the stability and distribution of macroinvertebrates across stations. 2765 macroinvertebrates belonging to 4 classes, 9 orders and 27 families were identified. Insects, witc 55.11% of the total number of individuals, are the most diverse.

Shannon and Equitability indices showed that the most stable and diverse Corridor station (H' = 2.902;E = 0.873: dry season and H' = 2.454; E = 0.774: rainy season) with a very regular distribution of macroinvertebrates. Benthic Composite Index (BCI) showed that upstream, water quality goes from "Low" in the dry season to 'Excellent' in the rainy season. At Petite Plage, it is "Mediocre" quality in the dry season and "Very low" in the rainy season. However, water quality at the other three stations did not vary during the two seasons. In the Corridor, is of 'Average' quality and 'Mediocre' quality at the Church and Fin Ano-Assué stations. Stations (Eglise, Petite Plage, Fin Ano-Assué) are the most polluted on the river.

Keywords: Macroinvertebrates, Ano-Assué River, water quality, Côte d'Ivoire

Introduction

Natural resources are important in human life because of the food and energy they provide to humanity for its basic needs. Unfortunately, these resources are under threat from strong anthropogenic pressures on the one hand, and subject to climatic hazards and the actions of invasive species on the other, leading to their degradation (**Amani and Barmo, 2010**). These strong anthropogenic pressures lead to various pollutions of both groundwater and surface water (**Malmqvist and Rundle, 2000**; **Bagalwa, 2006**) with the consequences of fish mortality and the development of pathogenic microorganisms, harmful to the environment (**Scheren *et al*., 2004**).

The city of Ayamé is not exempt from these sources of pollution. This locality therefore constitutes a highly anthropized area where agricultural operations have replaced natural vegetation. Population growth and of the agglomeration expansion have led to changes of the banks of the Ano-Assué river by accelerating its erosion. In addition, the riverbed has been transformed into a in wastewater outfalls and household waste. These factors constitute important sources of degradation of aquatic habitats, but also as a source of disease for humans (**Levallois, 2006**).

Water quality monitoring systems have been put in place (**Lévêque, 1994**). Among other things, the ecological assessment of water quality, a monitoring system that uses biological indicators such as aquatic macroinvertebrates to arrive at an overall diagnosis (**Hébert, 1997**) of the state of health of watercourses.

Despite the importance of these aquatic ecosystems in human life, the threat of their disappearance has never been so alarming in recent decades (**Lévêque and Mounolou, 2001**). To do this, a study was conducted to assess the quality of the Ano-Assué River from the composition of benthic macroinvertebrates.

Materials and Methods

Study area

This study focuses on the Ano-Assué River (**Figure 1**). It is located in the South-Comoé region of Côte d'Ivoire more precisely, in the city of Ayamé between 05°36’13.52’’ north latitude and 03°09’24.90’’ west longitude. Ano-Assué River originates north of the town of Ayamé, flows through it, and empties into the Soumié River. It extends over a length of about 9 km and on the slopes of 7 hills at a height of 130 m (**Anonyme, 2005**). This locality has an Attiean climate and benefits from four seasons (**Eldin, 1971**) including two dry seasons and two rainy seasons.

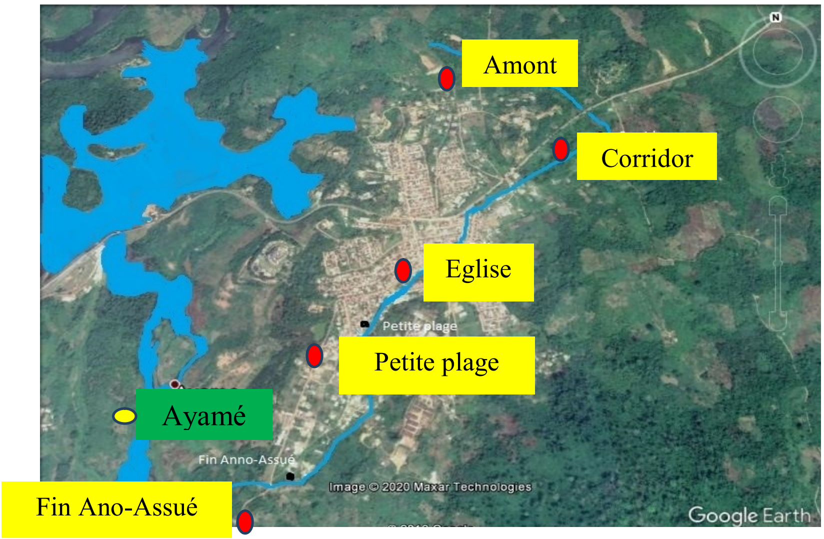

Figure 1 : Map showing sampling sites on the Ano-Assué River (Ayamé)

Five stations (**Figure 1**) were selected on the Ano-Assué river for the sampling of benthic macroinvertebrates. These are:

- ✓ The Amont station (A) which is closest to the source. It is located at the foot of the hills between the cocoa and coffee fields. The substrate of the bed is heterogeneous, but dominated by sand with silt in some places.
- ✓ The Corridor station (C), located in the corridor of the city of Ayamé, is characterized by the presence of banana trees. Its substrate consists of a mixture of clay and sand as well as dead leaves.
- ✓ The Eglise station (E) is located in the heart of the urban agglomeration and receives domestic wastewater as well as household waste. Its substrate is sandy.
- ✓ The Petite plage station (P) also located in the heart of the city, is fed by domestic effluents and household waste deposits. The substrate of this station consists of silt, clay and sand.
- ✓ The Fin Ano-Assué station (F) is located downstream from the station (P). The vegetation on the banks consists of trees, banana trees, rubber trees and tall grasses. The substrate is sandy-clay.

Sampling of benthic macroinvertebrates

Sampling of benthic macroinvertebrates was carried out using a Van Veen grab during the short dry season (September 2019) and the short rainy season (November 2019). Five dredge grabs were carried out at different locations per station to collect sediment samples. The armoured dredge bucket was lowered vertically to the bottom. As soon as the jaws touch the bottom, the hook that keeps the jaws open pops out, and the jaws close, trapping the sediment. The samples were brought to the surface and overturned into a basin, then washed several times by immersion and removed using a 1 mm mesh of void sieve to eliminate as much of the substrate as possible. The rest of the refusal is put in polyethylene bags referenced and fixed with 10% formaldehyde.

Identification of benthic macroinvertebrates

The sorting of organisms was carried out in the laboratory. The contents of each polyethylene bag were overturned onto a 500 µm mesh sieve and washed several times to remove formaldehyde. A small quantity refusal of sieve was placed in a white-bottomed bin containing water to facilitate the perception of the organisms with the naked eye. The specimens separated according to their morphological appearance and by zoological group are placed in pillboxes and fixed with 5% formaldehyde. These were identified under a binocular loupe. The identification of these organisms has made to the lowest possible level or to the family for some by using the identification keys of **Belleg (1981)** and **De Moor and Day (2002)** for molluscs and of **Dejoux *et al.* (1981); Diomandé *et al.* (2000)**; **De Moor *et al.* (2003)** and **Tachet *et al.* (2003)** for Insects, Oligochaetes and Bivalves. The identified organisms were counted.

Data analysis and processing

The composition and structure were determined at each station, and the data collected were analyzed using the relative abundance (RA) of individuals and species.

RA = n/tN × 100 ; with n = number of individuals/species and tN = Total number of individuals/species in a environment.

The Shannon diversity index (H') and Equitability (E) values of benthic macroinvertebrate populations in the stations were calculated based on species abundance using Past 2.0 software. All these analyses were carried out using the following formulas respectively:

$$H' = -\sum pi \times \log_2 pi$$

With Pi = ni/N where pi = Relative abundance of species i in the sample ; ni = Population size for each species ; N = Sum of species numbers and s = Number of species.

$$E = H'/\log_2 S$$

With H'= Shannon specific diversity index and S = species richness.

Development of the Benthic Composite Index (BCI)

The Benthic Composite Index (BCI) was developed based on taxonomic richness, the number of Ephemeroptera taxa, the number of modified Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, the percentage of insects, the number of intolerant taxa, and the percentage of tolerant taxa **(MDDEFP, 2012)**. These variables were normalized. The normalization of the variables was done by dividing the value of the given station variable by the largest value of this variable obtained for all the stations in the watercourse. Thus, the values positively associated with a healthy ecosystem are normalized by dividing them by the maximum reached for rivers. As for variables negatively associated with a healthy ecosystem, the reciprocal (1-x) of the value is divided by the maximum reciprocal values (**Richard and Giroux, 2004**).

The standardized values for each variable were added per station to determine the BCI value using the formula below.

BCI = Σ (normalized values)

The BCI, for a given station, represents the sum of six normalized variables. Five quality classes (**Table 1**) were determined. The index value for a given station is interpreted using the scale presented in the grid according to **Pelletier (2002)**.

Table 1: Interpretation of the Benthic Composite Index (**Pelletier, 2002**)

Water quality	Very low	Low	Mediocre	average	Good	Excellent
Value of the Benthic Composite Index	[0-I]	[I-II]	[II-III]	[III-IV]	[IV-V]	[V-VI]

Results and Discussion

Inventory of macroinvertebrates

2765 macroinvertebrates divided into four classes (Gastropods, Bivalves, Oligochaetes, and Insects), nine orders, and 27 families were identified in the Ano-Assué River (**Table 2**). The taxonomic richness observed in the Ano-Assué river is lower than that obtained in other rivers by **Edia *et al.* (2007)**, **Camara *et al.* (2014)** and **Diarrassouba *et al.* (2022)**. These authors respectively collected 119 taxa from a set of four rivers in the Southeast, 132 taxa from the Banco River and 65 taxa from the Hana River and its tributaries. The low taxonomic richness obtained in this study would be due to the sampling period, the types of habitat surveyed and also the sampling material. Indeed, this study was carried during the two small seasons and in a river that crosses the city of Ayamé, receiving all the town's waste, which would impact the quality and abundance of the population. These two small seasons could be a period of ecological stress and hydrological imbalance, limiting the presence and diversity of benthic macroinvertebrates. However, during the great rainy season, the flow rate and speed of the current would cause substrate erosion and the expulsion of macroinvertebrates from their habitat. Furthermore, only the Van Veen grab was used in this study, whereas **Camara *et al.* (2014)** used four sampling devices (Ekman grab, trawl net, hand sieve, and landing net). In addition, these authors sampled from October 2006 to October 2008. According to **Gnohossou (2006)** and **Kouadio (2011)**, sampling with a grab causes very mobile organisms to escape.

Table 2: List of aquatic macroinvertebrates recorded in the Ano-Assué River in September and November 2019

Classes	Orders	Families	Am	Co	Eg	P p	Fin AN
Gastropods	Basommatophores	Lymnaeidae	185	4	16	5	4
		Physidae	1	1	18	21	49
		Planorbidae			43	28	213
Bivalves	Eulamellibranchs	Sphaeriidae				4	
Oligochaetes	Tubifinas	Lumbriculidae				1	
		Naididae			7		
		Propapidae				2	
		Tubificidae				623	16
Insects	Ephemeroptera	Caenidae	1	1			
		Polymitarcyidae	1				
		Baetidae	3	22	55	29	20
	Lepidoptera	Pyralidae		1			
	Heteroptera	Ranatridae	3	3			1
		Belostomidae	1	3	10		
		Naucoridae	1				
		Veliidae			2		
		Nepidae		1			
	Diptera	Chironomidae	7		49	585	592
		Culicidae				26	11
		Hydrometridae					1
	Coleoptera	Hydrophylidae		7		1	5
		Dytiscidae	2	7			
	Odonata	Aeshnidae	1				
		Libellulidae	5	1	1		
		Corduliidae	12	4			
		Coenagriidae		1	34	3	2
		Calopterygidae					9
4	9	27	223	56	235	1328	923

Am = Amont ; Co = Corridor ; Eg = Eglise ; P p = Petite plage ; Fin An = Fin Ano-Assué

Relative abundance of macroinvertebrates

The relative abundance of benthic macroinvertebrates in the Ano-Assué River indicated that insects were the most abundant, representing 55.12% of the total population. They were followed by Oligochaetes and Gastropods, accounting for 23.47% and 21.27% of the total population, respectively. Bivalves represent less than 1% (0.14%) of the total population **(Table 3 and Figure 2**). These results could be explained by the fact that insects have a strong ability to colonize varied ecological niches (**Helson et Williams, 2013**; **Prommi and Payakka, 2015**). The same observation was made by **Koumba *et al.*, 2017** in watercourses in Moukalaba Doudou National Park. **Gagnon and Pedneau (2006)** indicate that the most diverse taxonomic group among aquatic macroinvertebrates is that of insects.

Table 3: Nombers and relativeabundance of macroinvertbrate classesinventoried in the Ano-Assué River in September and November 2019.

Macroinvertebrate classes	Nombers	Relative abundance
Gastropods	588	21,27
Bivalves	4	0,14
Oligochaetes	649	23,47
Insects	1524	55,12

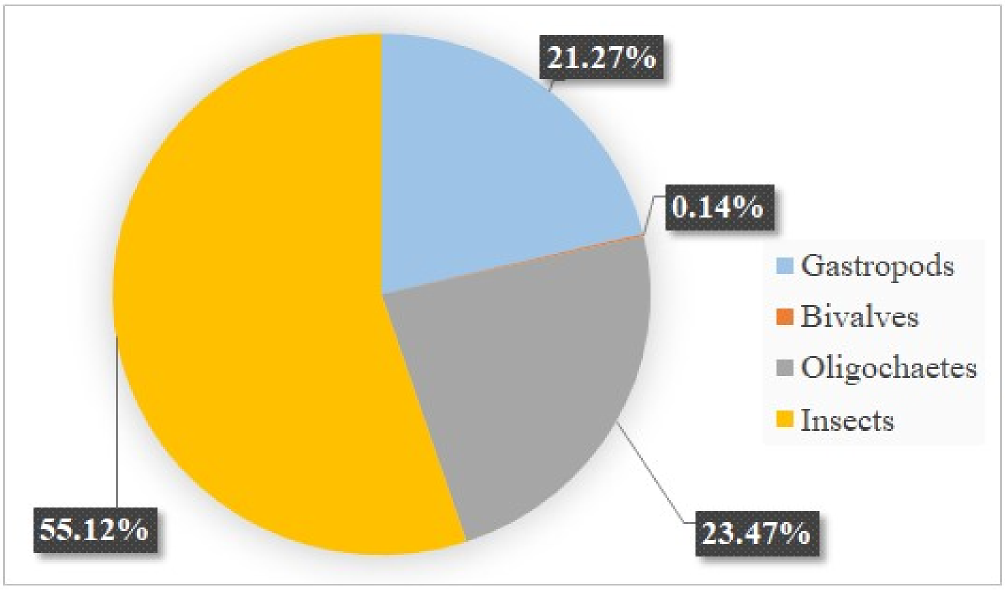

Figure 2: Relative abundance of macroinvertebrate classes inventoried in the Ano-Assué River in September and November 2019.

Relative abundance of macroinvertebrates in different seasons

Figure 3 presents the results of the relative abundance of benthic macroinvertebrate population at the five stations according to climatic seasons.

During the dry season, two classes were observed at the Amont station. They are represented by Gastropods (83.96%) and Insects (16.04%). At the Corridor station, only the Insects (100%) have been inventoried. At Eglise station, Gastropods are the most represented with a percentage of 51.53%. Next, come Insects (43.07%) and Oligochaetes (5.38%). Regarding the population of the Petite plage station, insects and oligochaetes are the most abundant with 49% and 43.32% of the population, respectively. Gastropods represent 7.13% of the population and bivalves 0.52%. As for the Fin Ano-Assué station, Insects (52.25%) and Gastropods (43.73%) dominate the population. Oligochaetes account for 3% of the total population. During the rainy season, bivalves were not observed in any stations. The Oligochaetes were only observed at the Petite plage station, where they dominate the population with a percentage of 52% of the total number. Insects have also inventoried, with a proportion of 48%. At the Amont, Corridor, Eglise and Fin Ano-Assué stations, the macroinvertebrate classes observed were gastropods and insects. They are respectively 82.6%, 17%, 9.52% and 4.71% represented by the Gastropods, and 17.39%, 83%, 90.47 and 95.28% by the Insects. The strong predominance of gastropods at the Amont station during these two seasons is thought to be linked to the abiotic characteristics of this station (**N'Drin *et al.*, 2020**). Unlike the other stations, this station is located at the foot of the hills between cocoa and coffee fields. Organic debris from these fields would constitute a shelter and a source of food for Gastropods (**Allan and Castillo, 2007**) promoting their fairly significant development in this station. Insects dominate the population of the Corridor and Fin Ano-Assué stations during both seasons. This could be explained to the presence of trees, banana plants and rubber trees at the banks of these two stations. According to **Hättenschwiler *et al.* (2005)**, the dead leaves of the plants could create hiding places and micro-habitats and also enrich aquatic environments with nutrients for insects. In addition, their sandy-clay substrate would constitute a stable habitat for aquatic insects. Furthermore, this substrate would retain the nutritive organic matter favoring their growth (**Duan *et al.*, 2008**). **Durand and Lévêque (1981)** indicated that the diversity of insect and gastropod classes in African freshwater would be due to the fact that these groups are cosmopolitan, thus colonizing more easily heterogeneous ecological niches.

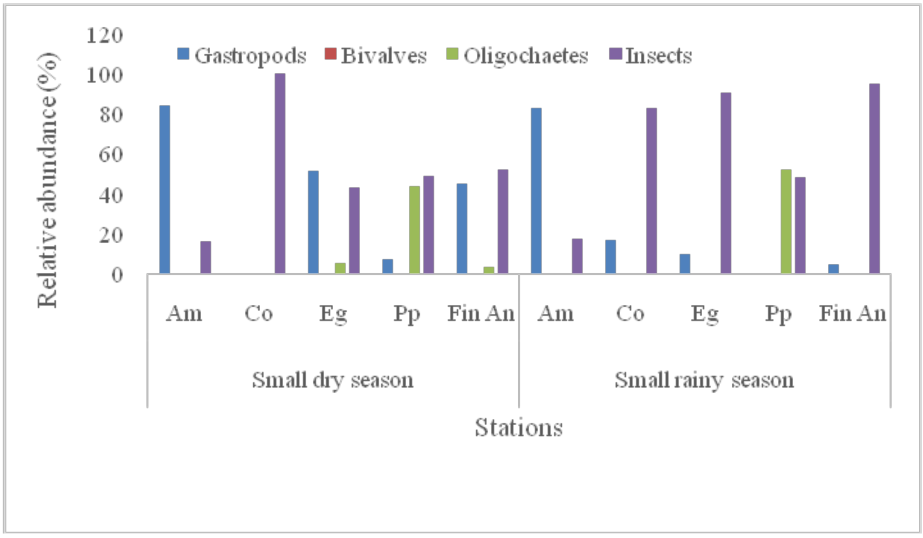

Figure 3: Relative abundance of macroinvertebrate classes inventoried at stations in September and November 2019.
Am = Amont ; Co = Corridor ; Eg = Eglise ; P p = Petite plage ; Fin An = Fin Ano-Assué

Shannon diversity and Equitability indices by seasons

Among all stations, the Corridor station recorded the highest values for Shannon indices during both short seasons (2.9 in the dry season and 2.45 in the rainy season) and for Equitability (0.87 in the dry season and 0.77 in the rainy season) (**Table 4**). Next, come those of the station Eglise where the values of the Shannon index are 2.77 in dry season and 2.14 in rainy season, while those of the Equitability index are respectively 0.8 and 0.76. At the Amont station, the highest Shannon index value was recorded during the rainy season, while at the Petite Plage and Fin Anno-Assué stations, the highest Shannon index values were observed during the dry season. Regarding the Equitability Index, the highest values were recorded during the rainy season at the Amont and Petite Plage stations, while at the Fin Ano-Assué station, the highest value was observed during the dry season. The highest Shannon and Equitability diversity indices values for all river stations were recorded at Corridor station. These high values reflect a good organization of its population and a good stability of this station, offering ecological conditions more conducive to the installation of rich and diverse fauna. However, the Amont, Petite plage and Fin Ano-Assué stations, whose index values are low, indicate that their populations would be less diverse and therefore would translate poor organization. These low values could be explained by the releases of domestic effluents and household waste at the level of Petite plage and Fin Ano-Assué as well as agricultural effluents at the Amont station. All these releases would constitute an important source of pollution (**Kouamé *et al.*, 2009**). Hence, an imbalance in macroinvertebrate communities, favoring the proliferation of certain pollution-resistant taxa to the detriment of other taxa.

Table 4: Shannon (H') and Equitability (E) indices of macroinvertebrates inventoried in the Ano-Assué River in September and November 2019

	Small dry season		Small rainy season	
Stations	H'	E	H'	E
Amont	1,07	0,34	1,19	0,36
Corridor	**2,90**	**0,87**	**2,45**	**0,77**
Eglise	2,77	0,8	2,14	0,76
Petite plage	1,96	0,51	1,18	0,59
Fin Ano-Assué	1,76	0,49	1,2	0,35

Benthic Composite Index (BCI) by seasons

The values of the normalized variables used for the calculation of the BCI were recorded in **Table 5**. The modified EPT and intolerant taxa are absent in all stations during the dry season, while they were observed at the Amont station during the rainy season.

Table 6 shows that during the dry season, the highest BCI value (3.71) was recorded at Corridor station, while the lowest (1.94) was recorded at Amont station. Index values reflect average water quality at Corridor station, and low at Amont station. The Eglise, Petite Plage and Fin Ano-assué stations, whose index values are strictly superior to two and inferior to three, have mediocre water quality. Analysis of water quality at the different stations during the rainy season shows that at the Amont station, the index of 5.02 indicates excellent water quality. The Corridor and Petite Plage stations, with indices of 3.33 and 0.69, respectively, reflect average and very low water quality. The Eglise and Fin Ano-assué stations, whose index values are also strictly superior to two and inferior to three, have mediocre water quality. Overall, the water quality of the Ano-Assué River is not very good. However, some stations have posted good quality water such as the Corridor station whose water quality does not change, it is average over the two seasons. The average water quality would be due to the low presence of tolerant taxa at this station. Indeed, at the Corridor station, no taxon predominates over the others. Therefore, this station would offer a favorable environment for the installation and development of several taxa of benthic macroinvertebrates (**Fotsing, 2018**). As for the Amont station, water quality is excellent during the rainy season. These results would be due to environmental conditions favoring the colonization of the environment by sensitive taxa, leading to a relative decrease in the abundance of tolerant taxa (**Galić *et al.*, 2019**). Indeed, during this season, the volume of water increases. Water runoff would promote the oxygenation of the environment and would lead certain tolerant taxa towards downstream stations. However, during the dry season, this water degrades. It goes from excellent quality to low quality. This would be linked to the high percentage of tolerant taxa following the decrease in water level due to evaporation, which leads to an increase in pollutant concentration and a decrease in dissolved oxygen (**Everaert *et al.*, 2014**). The values of the Benthic Composite Indices for the Eglise, Petite Plage, and Fin Ano-assué stations revealed poor water quality. These results could be explained by effluent discharges, which would promote the proliferation of pollution-resistant taxa such as Tubificidae and Chironomidae, characteristic of aquatic environments disturbed by human activities (**Azrina *et al.*, 2005**). Indeed, the Eglise and Petite Plage stations are located in the middle of the urban agglomeration and are connected to the draining pipes for domestic effluents and household waste. As for the Fin Annô-Assué station, located downstream, it becomes the receptacle for polluted water drained from upstream and also by certain agricultural activities which consists of the use of herbicides and insecticides. According to **Ben Moussa *et al.* (2014)**, the dumping of organic waste would intensify the loading of organic matter into the environment, which would promote the proliferation of Tubificidae.

Table 5: Variables normalized per stations by seasons

	Small dry season					Small rainy season				
Stations	Am	Co	Eg	P p	Fin An	Am	Co	Eg	P p	Fin An
TR	0,64	0,71	0,78	1	0,85	0,9	0,81	0,63	0,36	1
NET	1	1	1	1	1	1	0,66	0,33	0	0,33
NEPTm	0	0	0	0	0	1	0	0	0	0
% In	0,16	1	0,43	0,49	0,52	0,18	0,86	0,94	0,51	1
NiT	0	0	0	0	0	1	0	0	0	0
% TT	0,14	1	0,67	0,1	0,38	0,94	1	0,46	0,02	0,12

Am = Amont ; Co = Corridor ; Eg = Eglise ; Pp = Petite plage ; Fin An = Fin Ano-Assué ; TR = Taxonomic Richness ; NET = number of Ephemeroptera taxa ; NPTEm = number of modified EPT taxa; % In = percentage of insects ; NiT = number of intolerant taxa ; % TT = percentage of tolerant taxa

Table 6: Relative abundance of tolerant taxa, Benthic Composite Index (BCI) values, and water quality at stations during the two seasons

	Small dry season					Small rainy season				
Stations	Am	Co	Eg	P p	Fin An	Am	Co	Eg	P p	Fin An
% TT	86,25	7,4	37,69	90,09	60,71	11,95	6,89	57,14	98,07	88,48
BCI	1,94	3,71	2,88	2,59	2,75	5,02	3,33	2,36	0,69	2,45
Water quality	Lo	Av	Me	Me	Me	Ex	Av	Me	Vl	Me

Conclusion

This study characterized benthic macroinvertebrate communities and assessed water quality at all stations along the Ano-Assué River using these bioindicators. Four classes of benthic macroinvertebrates were identified, with a marked abundance of insects, particularly Diptera (Chironomidae) and Oligochaeta (Tubificidae) at the Petite Plage and Fin Ano-Assué stations. Furthermore, the Eglise, Petite Plage, and Fin Ano-Assué stations, located in the middle of the urban area and subject to intense anthropogenic pressure, proved to be the most polluted stations on the Ano-Assué River.

Acknowledgments

The authors would like to express their sincere thanks to the Ayamé municipality for authorising the collection of samples, as well as to the guide Aka Simon for his assistance at the various stations. They also thank the Biology and Health Laboratory and the Hydrobiology and Water Ecotechnology Teaching and Research Unit, both attached to the Biosciences Faculty of Félix Houphouët-Boigny University, for their valuable support.

Conflict of Interest

The authors declare that there are no conflicts interests regarding the publication of this paper.

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ARTICLE INFO
Article History:
Received 1st June, 2026
Received in revised form 10th July, 2026
Accepted 20th July, 2026
Published online 31st July, 2026

Access this Article in Online	
	Website: www.ijarbs.com
Quick Response Code	Subject: Aquatic Biology
DOI:10.22192/ijarbs.2026.13.07.005	

How to cite this article:
Kouadio Akissi Natahalie, Aboua Bénié Rose Danielle, Aimé Louis Stevens, Yéo Nahouaha Mathias & Adja Akré Maurice. (2026). Benthic macroinvertebrates as an indicator of the biotic quality of an anthropized watercourse in Ayamé (Southeast, Côte d'Ivoire). Int. J. Adv. Res. Biol. Sci. 13(7): 53-64.
DOI: http://dx.doi.org/10.22192/ijarbs.2026.13.07.005