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Research paper

Assessing the ecological health of some hydrosystems in central Ivory Coast using bioecological traits of aquatic macroinvertebrates

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Abstract

Global index methods based on aquatic macroinvertebrates are commonly used in bio-indication. However, these global index methods cannot be used to diagnose the real causes of degradation. This study therefore proposes to integrate recent theoretical advances linking the bioecological strategies of organisms (maximum size, life cycle, food type, feeding mode, respiration and locomotion) with disturbances to their environment. Three (03) stations were visited. Sampling was carried out from June 2016 to June 2018. A total of 59 taxa were identified, divided into 35 families, 10 orders and 5 classes. The analysis of the bioecological characteristics of aquatic macroinvertebrates in the studied hydrosystems in central Ivory Coast showed that the Raviart dam is highly disturbed by organic pollution, the Kongobo dam is moderately disturbed by organic pollution and the Allomambo dam is very slightly disturbed by organic pollution.

Keywords: *Aquatic Macroinvertebrates; Bioecological Traits; Dams; Ivory Coast.*

1. Introduction

The construction of numerous small dams in Ivory Coast has its origins in the West African drought of the 1970s to 1990s [1]. These dams were designed to ensure food self-sufficiency and food security [2]. They contribute to socio-economic progress and are home to significant biodiversity. Unfortunately, this immense wealth is in serious decline under the growing pressure of human activity. In fact, these bodies of water are receptors of pollutants of various origins (domestic or industrial waste and effluents, run-off from cultivated land) [3]. In the face of all these threats, appropriate measures must be taken to preserve the dams in central Ivory Coast. These measures require knowledge and constant monitoring of water quality. This began with measuring the concentration of pollutants in the water. However, it was not possible to assess the impact of certain environmental factors, such as sedimentation, habitat destruction and the effect of pollutants that were not measured or were present at levels below the detection limits of analytical methods [4]. For this reason, measurements have been made at the level of the organisation of living organisms. Many of the methods using aquatic organisms are based on aquatic macroinvertebrates [5]. Because of their diversity of taxonomic and functional forms, their longevity and their wide distribution in aquatic environments, these aquatic organisms are potentially excellent bioindicators of the health of hydrosystems [6]. Existing global methods, such as biotic or diversity indices, are the most widely used. However, they do not allow a diagnosis of the causes of degradation and do not integrate natural temporal and spatial variations in living communities [7].
The aim of this work is therefore to explore a new potential for bioindication by aquatic macroinvertebrates based on bioecological traits.

2. Methodology

2.1. Study area

The study area is located in central Ivory Coast. The dams studied are located in the regions of Gbêkê and Bélier, in the departments of Bouaké and Didiévi respectively. Central Côte d'Ivoire has a humid tropical climate. This climate has two seasons : a dry season from November to March and a rainy season from April to October [8]. The selected dams are Allomambo (7°46'N-4°53'W), Kongobo (7°45'N-5°28'W) and Raviart (7°24'N-4°53'W) in Figure 1.

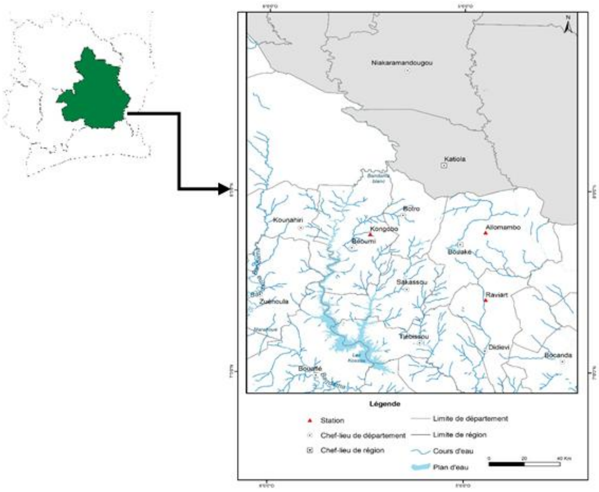

Fig. 1: Geographical Location of Study Sites and Sampling Stations from June 2016 to June 2018.

2.2. Data collection

The different sampling campaigns were carried out on a seasonal basis : two dry season campaigns (March 2017 and November 2017) and two wet season campaigns (June 2016 and rainy season (June 2016 and June 2018). Each dam was considered as a station. Stations were selected on the basis of a map of Ivory Coast showing towns and roads. Accessibility to the sampling sites at all times and the permanence of the water in the dams guided our choices. The data were collected in such a way as to provide a representative sample of the dams surveyed. Aquatic macroinvertebrate samples were collected using a Van Veen bucket and sieve. The samples were washed and fixed with 5% formaldehyde in labelled jars. In the laboratory, organisms were sorted, identified to the lowest taxonomic level using identification books ([9] ; [10] ; [11] ; [12]) and then counted.

2.3. Data processing

Bioecological traits are variables that describe the biological and ecological potential of taxa [13]. The use of bioecological traits in aquatic macroinvertebrates to assess water quality is independent of seasonal conditions [7]. To assess water quality on the basis of bioécological, he first step is to select the bioecological traits. Thus, from the 22 bioecological traits described by [12], 06 traits comprising 39 modalities were selected for this study based on the availability of a priori predictions in the literature [13]. These are maximum size, life cycle, food type, feeding mode, respiration and locomotion mode in Table 1.

Table 1: Bioecological Traits of Selected Aquatic Macroinvertebrates and Their Corresponding Modalities (= Category) ([7])

TRAITS	CODES	MODALITES
1- Maximum size (mm)	TM1	< 2,5
	TM2	2,5 - 5
	TM3	5 - 10
	TM4	10 - 20
	TM5	20 - 40
	TM6	40 - 80
	TM7	> 80
2- Life cycle (duration)	CV1	≤ 1 year
	CV2	> 1 year
3- type of food	TN1	fine sediment + micro-organisms
	TN2	Plant debris < 1 mm
	TN3	plant debris >1 mm
	TN4	live microphytes
	TN5	macrophytes vivants
	TN6	dead animals > 1 mm
	TN7	microinvertébrés vivants
	TN8	living macroinvertebrates
	TN9	vertebrates
4- feeding mode	MA1	absorption through the integuments
	MA2	thin sediment eater
	MA3	shredder
	MA4	scraper, grazer
	MA5	filter-feeding
	MA6	burglar (algivore or sucker predator)
	MA7	predator (Cut or swallow)
	MA8	parasite
5- Respiration	RP1	integuments
	RP2	branchia
	RP3	plastron
	RP4	stigmata (aerial respiration)
	RP5	hydrostatic vesicle
6- mode of locomotion	LO1	flying
	LO2	surface swimmer
	LO3	Pelagic Swimmer (plankton, nekton)

	LO4	rampant
	LO5	digger (épibenthic)
	LO6	endobenthic (interstitial)
	LO7	temporary fixation
	LO8	permanent fixation

Fuzzy coding was then used to code the bioecological traits of the taxa. Fuzzy coding makes it possible to assign to the different taxa encountered a value that quantifies the affinity of these taxa for the different modalities of a given bio-ecological trait [14]. For each taxon, an affinity score is assigned to each of the modalities of a given trait. This affinity score can be divided into four [0-3] or six [0-5] levels and provides an estimate of the actual frequency of use of the modality by the taxon. According to [14] each affinity level can be given a verbal meaning, e.g. for a coding with four affinity levels the numerical translations (arbitrary) are 0 = 'never', 1 = 'sometimes', 2 = 'often' and 3 = 'generally'. The choice of the number of affinity levels used to code a taxon depends on the number of categories defined within the described character and the underlying biological complexity.
Taxonomic abundances are then coupled with bioecological traits to produce a frequency distribution of modalities [15]. For this purpose, a database of taxon abundances per station was constructed. The listed taxa were then coded in a second database using an affinity score according to [12]. The linkage involved multiplying the affinities of the character modalities by the abundance of each taxon per station. For each station, the sums obtained for the different trait modalities can be expressed as a frequency distribution. This frequency distribution is presented graphically.
Finally, an analysis of the frequency distribution of bioecological trait modalities was carried out to provide a diagnosis of the ecological status of the environment [12]. The analysis of the distribution of relative frequencies of bioecological trait modalities was carried out using the method of [12]. This method characterises the environment by the frequency of the highest modality for a given trait.

3. Results

3.1. Global analysis of abundance

All stations in the centre collected a total of 578 aquatic macroinvertebrates. The taxonomic composition of all the stations in the centre revealed 59 taxa belonging to 35 families, 10 orders and 5 classes (Achaetes, Gastropods, Insects, Oligochaetes and Pelecypoda). Most of these organisms were collected at the Raviart station (74%). This was followed by the Kongobo (18%) and Allomambo (8%) stations in Figure 2. Insects are the most abundant aquatic macroinvertebrates in the central zone studied. They represent 88.62% of the samples. They are followed by gastropods (9.46%). Achaetes (1%), Pelecypoda (0.20%) and Oligochaetes (0.20%) represent less than 5% in Figure 3.

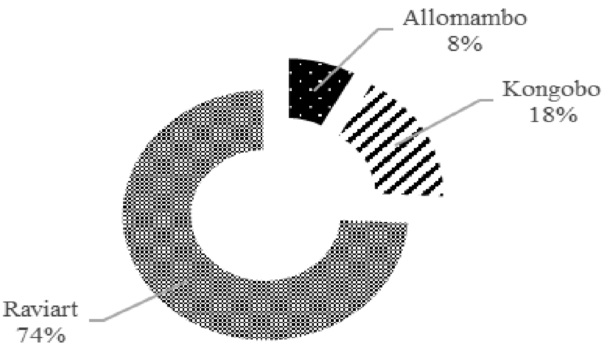

Fig. 2: Relative Abundance of Aquatic Macroinvertebrates Collected at the Different Sampling Stations in the central zone of Ivory Coast Studied.

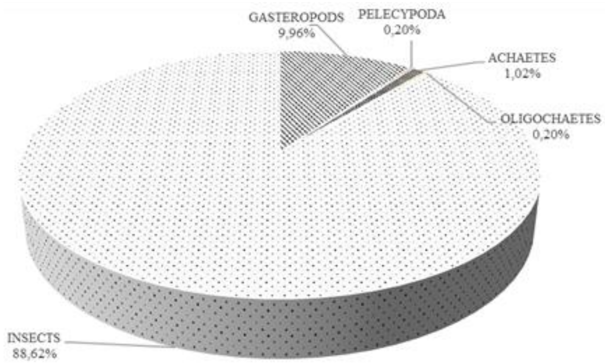

Fig. 3: Relative Abundances of Main Aquatic Macroinvertebrate Classes Collected in the central zone of Ivory Coast.

3.2. Frequency distribution of bioecological traits in aquatic macroinvertebrates in central ivory coast

At Allomambo and Raviart stations, organisms in the [10-20] mm size class (TM4) dominate. At Kongobo station, organisms in the [20-40] mm size class (TN5) dominate in Figure 4A. In terms of life history, organisms with a life cycle of less than 1 year (CV1) are relatively dominant at all stations in the centre in Figure 4B. In terms of food type (TN), organisms that consume live macrophytes (TN5) have a higher relative abundance at the Kongobo station. At the Raviart station, organisms that consume detritus smaller than 1 mm (TN2) are dominant. On the other hand, organisms that consume live macroinvertebrates (TN8) dominate at the Allomambo station in Figure 4C. In terms of feeding mode, aquatic macroinvertebrates that consume fine sediment (MA2) dominate at the Raviart stations. The Kongobo station is dominated by shredders (MA3). The Allomambo station is dominated by predators (MA7) in Figures 4D. In terms of respiration, tegumen-breathing organisms (RP1) dominate at Kongobo and Raviart stations. Gill-breathing organisms (RP2) dominate the Allomambo stations in Figure 4E. In terms of mode of locomotion, crawling organisms (LO4) clearly dominate the aquatic macroinvertebrate communities at Kongobo and Raviart stations. On the other hand, open water swimmers (LO3) are in the majority at Kongobo and Raviart in Figure 4F.

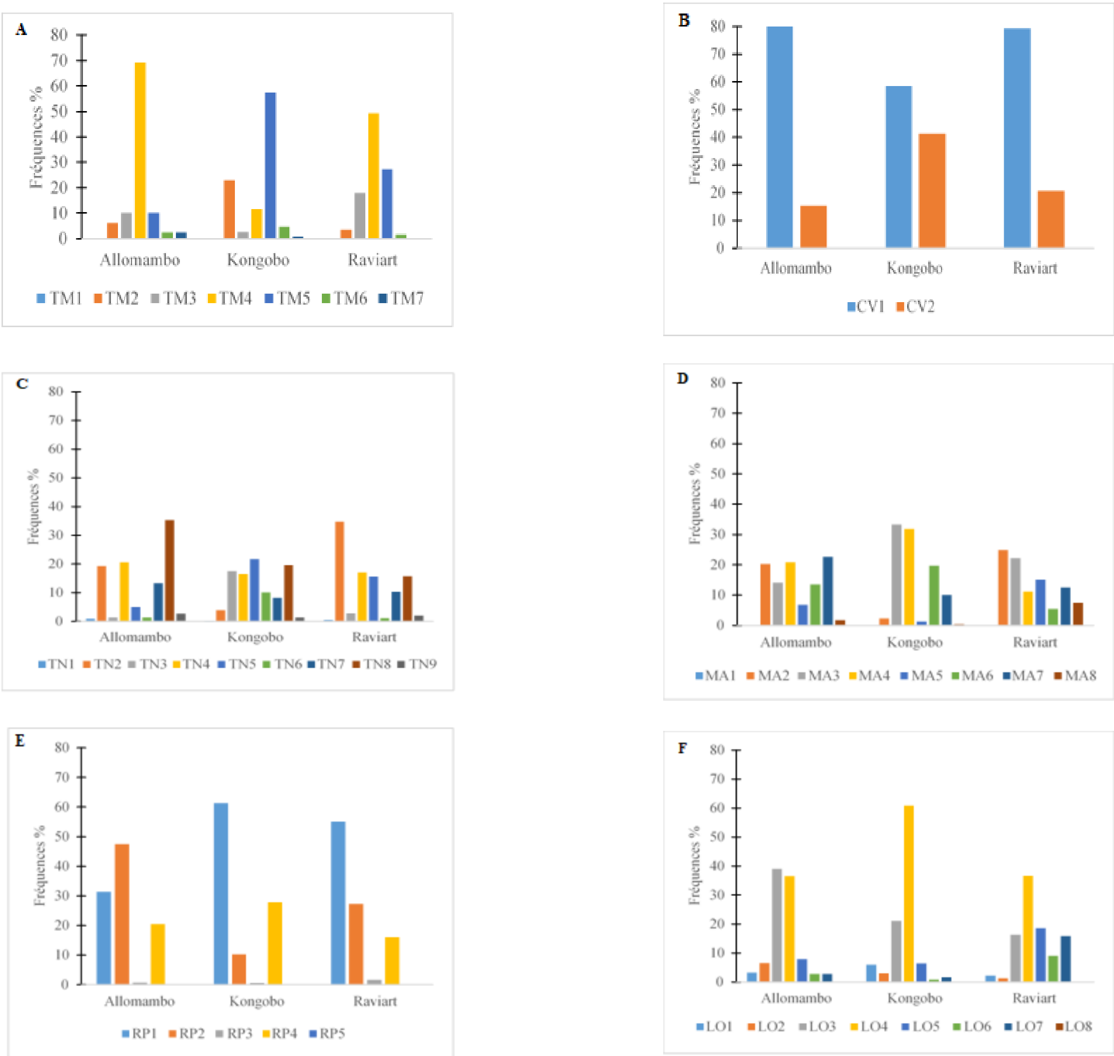

Fig. 4: Frequency Distribution of Modalities for the Six (6) Bioecological Traits of Aquatic Macroinvertebrates at Stations in Central Côte d'Ivoire: A= Maximum Size (TM); B= Life Cycle (CV); C= Type of Food (TN); D= Mode of Feeding (MA); E= Respiration (RP); F= Mode of Locomotion (LO); See Table 1: Bioecological Traits of Selected Aquatic Macroinvertebrates and Their Corresponding Modalities (= Category)

4. Discussion

The aim of the study of the aquatic macroinvertebrate population of a number of dams in the Centre is to determine the quality of their water on the basis of bio-ecological characteristics. Organisms between [10-20] mm (TM4) dominate at the Allomambo and Raviart stations, while those in the [20-40] mm TN5 size class dominate at the Kongobo station. In addition, the aquatic macroinvertebrates collected at all dams consisted mainly of small organisms (maximum size <40 mm). According to [13], large organisms range in size from 40 mm to 80 mm or more. The small size of aquatic macroinvertebrates in all the dams is attributed to strong anthropogenic pressure. [16] made the same observation in the urban reservoirs of Yamoussoukro. He stressed that the aquatic macroinvertebrates collected were mainly small organisms due to the high anthropogenic pressure that these urban lakes are subjected to. The analysis of characteristics related to mobility revealed a dominance of crawling organisms (LO4) at the Kongobo and Raviart stations. This mode of movement facilitates the search for shelter and recolonization [17]. These organisms could therefore have refugia away from disturbed areas [13].
However, at the Allomambo station, the majority of organisms move in open water (LO3). This type of movement would require dissolved oxygen. In his study of Lake Kodjoboué (South-East of the Ivory Coast), [13] showed that dissolved oxygen is significantly associated with the LO3 modality (swimming in open water). The dominance of tegumen-breathing organisms (RP1) at the Kongobo and Raviart stations effectively confirms that these reservoirs are strongly affected by organic pollution. Furthermore, the preponderance of organisms with tegumentary respiration would indicate a strong disturbance [13]. Similar observations were made by [18], who associated tegumentary respiration with high organic pollution. In addition, organisms with gill respiration (RP2) dominate in the Allomambo station. This finding confirms that the Allomambo dam is well oxygenated. In fact, gill-breathing organisms are generally more abundant in flowing or well-oxygenated standing water [19]. In addition, many gill-breathing species are known to be sensitive to organic pollution [20]. At all sites the organisms are short-lived (life cycle <1 year) (CV1). The results obtained at Allomambo, Raviart and Kongobo are characteristic of resilience. In fact, short life cycles are also an advantage for recolonization of refugia in disturbed environments, thus promoting greater resilience to pollution [21]. Food type (TN) and feeding mode (MA) are two inseparable variables [22]. The importance of the fine sediment feeders (MA2) in the Raviart station is due to the fact that all this dam would be very exposed to inputs of wastewater and runoff rich in

organic matter. On the other hand, in the Kongobo station, the dominance of shredders (MA3) would be linked to the availability of live macrophytes (TN5) and live macroinvertebrates (TN8). Studies in Guinean rivers have suggested that the density of shredders is controlled by the availability of organic matter [23]. At the Allomambo station, predators (MA7) dominate due to the importance of macrophytes in this dam. In fact, the density and diversity of predators are under the combined action of the plant cover, the moderate current and the coarse substrate, or that of the macrophytes at the edge of a slow current and a loose substrate [23]. According to [19], these types of stations have modalities characteristic of a habitat type where adversity is very high (or, in comparison, productivity is very low). The very high presence of predators and grazers indicates that the waters are acceptable, as these organisms are abundant in healthy streams [13] (Kra, 2020). In fact, the density and diversity of predators are under the combined action of the plant cover, the moderate current and the coarse substrate, or that of the macrophytes at the edge of a slow current and a loose substrate [23]. According to [19], these types of stations have modalities characteristic of a habitat type where adversity is very high (or, in comparison, productivity is very low). The very high presence of predators and grazers indicates that the waters are acceptable, as these organisms are abundant in healthy streams [13]. In short, the Raviart station is strongly affected by organic pollution, the Kongobo station is moderately affected by organic pollution and the Allomambo station is very weakly affected by organic pollution. The Raviart and Kongobo dams are characteristically resilient, with small organisms, short life cycles and tegumentary respiration. The corresponding taxa are mainly snails and bivalves [13]. In addition, the Allomambo station would also be characteristically resilient, with organisms of small size, short life cycle and gill respiration. The corresponding taxa are mainly Ephemeroptera [13] (Kra, 2020). The aquatic macroinvertebrates collected in the reservoirs studied at the centre comprise 59 taxa, 35 families, 10 orders and 5 classes (Achaetes, Oligochaetes, Pelecypoda, Gastropods and Insects). The number of taxa obtained is higher than the 55 taxa collected by [24] in the two Korhogo dam lakes. This difference is due to the sampling period. The collection of aquatic macroinvertebrates in the two Korhogo dam lakes was carried out from January to March 2020, which corresponds to the dry season. However, the present study was carried out during both seasons (dry and rainy). The faunal composition of the aquatic macroinvertebrates present in our study corresponds in general to that of African freshwaters [9] and in particular to that of West Africa ([25]; [26]; [27]). The taxonomic composition showed that insects represented 88.62% of the taxonomic richness obtained at the central Ivory Coast. This dominance of insects is due to the fact that they represent almost 95% of the organisms present in aquatic environments [28]. In addition, the short life cycle of insects, with several generations per year, gives them an exceptional capacity to adapt [29]. Some authors ([30]; [31]) have also noted the high proportion of insects in the waterways of tropical Africa.

5. Conclusion

This study assessed the water quality of a number of dams in central and northern Côte d'Ivoire using aquatic macroinvertebrates. The bio-ecological characteristics showed that organic pollution was average at the Kongobo station, very low at the Allomambo station and very high at the Raviart stations. In addition, the Raviart and Kongobo dams were found to be resilient, with small organisms, short life cycles and tegumental respiration. In addition, the Allomambo station would also be characteristic of resilience, with small organisms with short life cycles, but with gill-breathing organisms. The composition of the population showed 59 taxa, 35 families, 10 orders and 5 classes, with a dominance of the insect class.

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