IJIRR

International Journal of Information Research and Review
Vol. 06, Issue, 01, pp.6055-6060, January, 2019

RESEARCH ARTICLE

IMPACT OF HUMAN ACTIVITIES ON FISH COMMUNITIES IN THE AQUATIC SYSTEMS OF THE IVORIAN COASTAL ZONE AND ESTABLISHMENT OF A BIOTIC INTEGRITY INDEX (IIB)

Gooré Bi Gouli, N'Zi Konan Gervais and *Kouamé Toto

University Félix Houphouët- Boigny, Laboratory of Hydrobiology, 22 po. Box 584 Abidjan 22

ARTICLE INFO

Article History:
Received 17th October, 2018
Received in revised form
29th November, 2018
Accepted 20th December, 2018
Published online 30th January, 2019

Keywords:
Biotic Integrity Index
Coastal basins
Côte d'Ivoire- fish.

ABSTRACT

The main objective of this study is the establishment of a Biotic Integrity Index (IIB) based on fish by considering 5 coastal basins of Côte d'Ivoire. Samplings were made between 1999 and 2001, in 109 stations using an electrofisher Smith Root model 12 POW Back pack Electrofisher and in 56 stations using 15 mesh vacuum nets of 8, 10, 12, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80 and 90 mm. The results indicated that the ichthyological populating of all the basins was composed of 57 species and 01 hybrid. Stomach analysis revealed four trophic guilds distributed among omnivores, piscivores, phytophages, and insectivores. On the basis of fish populations and trophic guilds, six metrics have been selected for the calculation of IIB. This is the Shannon-Weaver Diversity Index, percentages of omnivorous species and species of the family Cyprinidae and piscivorous species, total biomass by species and total number of species. The average value of the IIB calculated for all five basins is 2.48. The maximum and minimum values are respectively 4.33 and 1. Five integrity classes ranging from 0 to 4 have been identified. Classes are unequally distributed. Class 3 is the best distributed in the coastal zone. The study area is moderately disturbed. Three types of human activities were identified for a sample of 72 sites. This is agriculture, the layout and use of various chemicals. The combination of these 3 types of activities is responsible for the major disturbances of the aquatic system.

INTRODUCTION

Disturbances produced by human activities (industrial and agricultural, etc.) have caused and still cause considerable pressure on river ecosystems, which result in a degradation of the quality of water and habitats on which aquatic life depends (Tramer and Rogers, 1973; Klein 1979; Allan and Flecker, 1993). In Côte d'Ivoire, according to a United Nations report, deforestation is more recent in the south-west, but is much larger than in other parts of the Ivorian territory (Abé and Kaba, 1997). According to Karr and Dudley (1981), the first factors of stress of aquatic communities and especially fish are the degradation activities led by humans, particularly the creation of agricultural plantations. The state of the resident biological communities, at a given moment, reflects the usual or extreme events that occurred in the past until that moment. The assessment of the impact of human activities on the biodiversity of the coastal zone is therefore essential. For Piavaux (1992), a simple physico-chemical analysis is not enough, since it can only reflect the environmental conditions at the time of sampling. For this reason, for several authors (eg Cairns and Dickson, 1971; Gammon, 1980; Oberdoff and Hugues, 1992), organization-level measures of taxonomic groups are essential.

***Corresponding author*: Kouamé Toto,**
University Félix Houphouët- Boigny, Laboratory of Hydrobiology, 22 po. Box 584 Abidjan 22

From all these taxonomic groups, fish are ubiquitous in most aquatic places; they occupy several trophic levels which allows a vertical integration of the changes and disturbances that occur in the food chain; they move (for some) between the sites which allows an integration both temporal and spatial; they are easy to identify and biological and ecological knowledges are extensive. Fish are a great interest to the public and decision-makers because of their socio-economic value. Fish therefore have the attributes of a good environmental indicator (Hendricks *et al,* 1980; Berkman *et al* 1986; Karr *et al,* 1986; Harris, 1995).

The Biotic Integrity Index (IIB) based on fish (Karr, 1981; Karr *et al.*, 1986) is a synthetic measure that contains several characteristics of fish communities. Given the encouraging results obtained by this index for its first applications in Africa (Hay *et al*., 1996), the Laboratory of Hydrobiology of the University of Cocody (Abidjan), in collaboration with the partners of the Catholic University of Leuven, the Royal Museum of the Central Africa (RMCA) and the Research Institute for Nature and Forests (Belgium) decided to develop it as a method for measuring the water quality of several coastal basins in Côte d'Ivoire. This work aims to (1) assess the impact of the above developments on fish communities in coastal basins and (2) develop a biotic integrity index (IIB) for water quality assessment.

MATERIALS AND METHODS

Study area: The Ivorian coastal zone is delimited by latitude 4 ° and 5 ° 30 North and longitudes 2 ° 25 and 7 ° 30 West. It covers an area of 45.160 km^2. The different coastal ecosystems of the South are mangroves (marshes and swamps), lagoons and estuaries, the lower reaches of rivers, marine ecosystems, forests and artificialized ecosystems. The forest's cover consists of swamp forest (15%), mangrove forest (2%), evergreen moist forest (20%), sparse forest (40%), industrial plantations (15%) and agricultural areas (8%) (Abé and Kaba, 1997).

The collected fish were identified using the keys of Paugy *et al.* (2003 a & b) then measured, weighed and dissected. For reasons of standardization, only specimens collected using electric fishing were used to establish the biotic integrity index of the basins of the coastal zone.

***Habitat Characterization*:** The geographical position of each station is determined (longitude, latitude, altitude) at the fishing location using a GPS 12 of Garmin. Substrate (gravel, sand, mud, dead wood, dead leaves, or a mixture of two or more of these components) was identified from the water bottom sample.

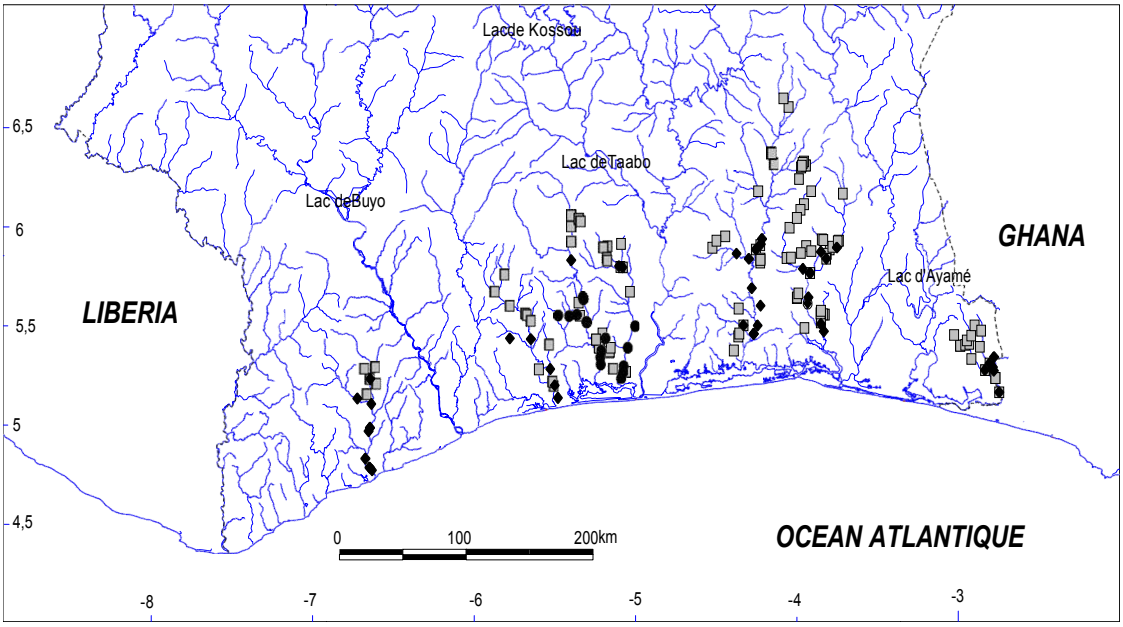

Figure 1. Distribution of sampling sites in coastal basins = Electric fishing; = Gillnet fishing

Table 1. List of candidate metrics for the final calculation of the IIB for 5 Côte d'Ivoire's coastal basins from catches made from December 1999 to March 2001

Candidates Metrics	*Abbreviation*
Total number of species	MNSTOT
Number of tolerant species	MNSTOL
Number of benthic species	MNSBEN
Number of Mormyridae species	MNSMOR
Number of Cichlidae species	MNSCIC
Number of Cyprinidae species	MNSCYP
Number of Siluriformes and Benthiformes species	MNSSILBEN
Number of species Characiformes and Cyprinodontiformes	MNSCHACYP
Percentage of intolerant species	MPSINT
Shannon-Weaver Diversity Index	MSWI
Percentage of phytophagous-planktivorous individuals	MPIPP
Percentage of omnivorous individuals	MPIOMN
Percentage of piscivorous individuals	MPIPIS
Percentage of invertive individuals	MPIINV
Percentage of hybrid individuals	MPSHYB
Percentage of migratory species	MPIMG
Number of tolerant individuals	MTOL
Total biomass	MBIOM
Total number of individuals	MNIND

Choice of fish sampling sites: From east to west, 07 basins were visited, five of which (Niouniourou, Mé, Agnébi, Gô, and Boubo) were used to calculate the IIB and two (Tanoé and San- Pedro) were used to validate the integrity index obtained. Samplings were made between 1999 and 2001, in 109 stations using an electrofisher Smith Root model 12 POW Back pack Electrofisher and in 56 stations using 15 mesh vacuum nets of 8, 10, 12, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80 and 90 mm. These stations were chosen according to their accessibility.

Human activities on the shore of the sampling site were observed and described. The degree of disturbance associated with these activities is assessed after observation in four stages of degradation that range from "highly disturbed", "few disturbed", "disturbed" and "undisturbed". At each level of degradation, a score is assigned. It varies from "1" (very disturbed) to "5" (undisturbed). The exposure rate to sunshine was appreciated in terms of closing or opening the canopy. It varies from 100% (fully covered site) to 0% (totally open site).

***Choice of metrics*:** For the calculation of the IIB of the 5 coastal basins, 19 metrics or biological parameters (Table 1) were identified and grouped into 3 categories according to Karr and Dudley (1981) and widely adopted by Faush *et al.* (1984), Oberdorff and Porcher (1994), Kamdem Toham and Teugels (1999), Belpaire *et al.* (2000), Kestemon *et al.* (2000) and Breine *et al.* (2004). These are categories as «the composition and species richness», «trophic composition» and «fish condition». The metrics were subjected to three types of analysis: (1) presence at all basins, (2) discriminating character at the site level, (3) correlation with certain environmental factors, in order to define the most discriminating metrics for the assessment of water quality. Principal Component Analysis, Canonical Correspondence Analysis, and Pearson Correlation were used to make decisions.

RESULTS

Population and trophic guilds: Table 2 presents the species recorded in the 5 coastal basins of Côte d'Ivoire for the sampling period from December 1999 to March 2001 and the corresponding guilds.

Table 2. Guilds of fish caught in 5 coastal basins of Côte d'Ivoire (a: value of intolerance, b: benthic and siluriform, c: foreign species, d: piscivorous species, e: omnivorous species, f: invertivory species; g: phytophagous and zooplankton-eating species, h: tolerant species, i: migratory species, j: Characiformes and Cyprinodontiformes species, k: Mormyridae species, l: Cichlidae species, m: Cyprinidae species, n: hybrid species, 1 = for identification at the guild and 0 = for not assigning the guild to the species)

SPECIES	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Barbus trispilos	2	0	0	0	1	0	0	0	0	0	0	0	1	0
B. ablabes	2	0	0	0	1	0	1	1	0	0	0	0	1	0
B. punctitaeniatus	3	0	0	0	0	1	0	0	0	0	0	0	1	0
B. macrops	2	0	0	0	1	0	0	0	0	0	0	0	1	0
B. boboi	4	0	0	0	1	0	0	0	0	0	0	0	1	0
B. sublineatus	4	0	0	0	1	0	0	0	0	0	0	0	1	0
Labeo parvus	3	1	0	0	0	0	1	0	0	0	0	0	1	0
Raiamas nigeriensis	4	0	0	1	0	0	0	0	0	0	0	0	1	0
Brycinus longipinnis	2	0	0	0	1	0	0	0	0	1	0	0	0	0
B. macrolepidotus	2	0	0	0	1	0	1	1	0	1	0	0	0	0
B. imberi	3	0	0	0	0	1	0	0	0	1	0	0	0	0
Micralestes elongatus	3	0	0	0	0	1	0	0	0	1	0	0	0	0
M. occidentalis	3	0	0	0	1	0	0	0	0	1	0	0	0	0
Synodontis bastiani	4	1	0	0	0	1	0	0	0	0	0	0	0	0
S. schall	4	1	0	0	0	1	0	0	0	0	0	0	0	0
Thysochromis ansorgii	3	0	0	0	1	0	1	0	0	0	0	1	0	0
Tilapia zillii	3	0	0	0	0	0	1	0	0	0	0	1	0	0
T. mariae	3	0	0	0	0	0	1	0	0	0	0	1	0	0
T.hybride(*T. guineensis* X *T.zillii*)		0	0	0	0	0	0	0	0	0	0	1	0	1
T. guineensis	3	0	0	0	0	0	1	0	0	0	0	1	0	0
Chromidotilapia guntheri	3	0	0	0	0	0	1	0	0	0	0	1	0	0
Oreochromis niloticus	3	0	1	0	0	0	1	0	0	0	0	1	0	0
Hemichromis fasciatus	1	0	0	1	0	0	0	1	0	0	0	1	0	0
H. bimaculatus	2	0	0	0	1	0	0	1	0	0	0	1	0	0
Sarotherodon melanotheron	4	0	0	0	0	0	1	0	0	0	0	1	0	0
Chrysichthys nigrodigitatus	3	1	0	0	0	0	0	0	0	0	0	0	0	0
C. maurus	3	1	0	0	1	0	0	0	0	0	0	0	0	0
Nannocharax fasciatus	3	0	0	0	0	1	0	0	0	0	0	0	0	0
Neolebias unifasciatus	4	0	0	0	0	1	1	0	0	0	0	0	0	0
Parachanna obscura	1	0	0	1	0	0	0	1	0	0	0	0	0	0
Hepsetus odoe	2	0	0	1	0	0	0	1	1	0	0	0	0	0
Ctenopoma petherici	3	0	0	0	0	1	1	0	0	0	0	0	0	0
Heterobranchus longifilis	1	0	0	1	0	0	0	1	0	0	0	0	0	0
H. isopterus	1	0	0	1	0	0	0	1	0	0	0	0	0	0
Clarias ebriensis	1	1	0	1	0	0	0	1	0	0	0	0	0	0
C. anguillaris	1	1	0	1	0	0	0	1	0	0	0	0	0	0
C. gariepinus	1	1	0	0	0	0	0	1	0	0	0	0	0	0
C. buettikoferi	1	1	0	1	0	0	0	1	0	0	0	0	0	0
Schilbe mandibularis	4	1	0	0	0	1	0	0	0	0	0	0	0	0
S. intermedius	4	1	0	0	0	0	0	0	0	0	0	0	0	0
Polypterus endlicheri	1	0	0	0	1	0	0	1	0	0	0	0	0	0
Petrocephalus bovei	3	0	0	0	0	1	0	0	0	0	1	0	0	0
Pollimyrus isidori	3	0	0	0	0	1	0	0	0	0	1	0	0	0
Marcusenius ussheri	4	1	0	0	0	1	0	0	0	0	1	0	0	0
M. senegalensis	4	0	0	0	0	1	0	0	0	0	1	0	0	0
Awaous lateristriga	5	0	0	0	0	1	0	0	0	0	0	0	0	0
Amphillius atesuensis	4	0	0	0	0	1	0	0	0	0	0	0	0	0
Mastacembelus nigromarginatus	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Malapterurus electricus	4	0	0	1	0	0	0	0	0	0	0	0	0	0
Poropanchax rancurelli	4	0	0	0	0	1	0	0	0	1	0	0	0	0
Rhexipanchax schioetzi	4	0	0	0	0	1	0	0	0	1	0	0	0	0
Applocheilichthys spilauchen	4	0	0	0	0	1	0	0	0	1	0	0	0	0
Fundulopanchax walkeri	4	0	0	0	0	1	0	0	0	1	0	0	0	0
Epiplatys etzeli	4	0	0	0	0	1	0	0	0	1	0	0	0	0
E. chaperi chaperi	4	0	0	0	0	1	0	0	0	1	0	0	0	0
E. chaperi scheljuzhkoi	4	0	0	0	0	1	0	0	0	1	0	0	0	0
E. dageti	4	0	0	0	0	1	0	0	0	1	0	0	0	0
Kribia nana	4	0	0	0	0	1	0	0	1	0	0	0	0	0

A total of 14 guilds are identified: intolerant species, benthic and siluriform species, foreign species, piscivorous species, omnivorous species, invertivorous species, phytophagous species, tolerant species and migratory species. Quantitatively, 40% of the studied species are invertivorous. Non-native and migratory species are the least numerous with 4% registered fish. The piscivores represent 16%, the omnivores 21%, the invertivores 40% and the phyto-zooplanctonophages 20% fish collected. The 12 benthic species represent 21% of the total population. As for the reaction to degradation of the medium, 22% of the species are tolerant and 78% are intolerant.

Metrics retained: Out of nineteen candidates of metrics for the assessment of the quality of coastal basins (Table 3), the study of the dispersion of stations on the basis of these parameters shows a grouping of stations around axis 1 under the strong influence of 6 metrics such as the Shannon-Weaver Diversity Index (Mswi), the percentage of omnivorous individuals (Mpiomn), the percentage of Characiformes and Cypriniformes species (Mnschacyp), biomass (Mbiom), the number total species (Mnstot) and the percentage of piscivorous species (Mpipis).

(Table 4). All the metrics are significantly well correlated (r > 0.5) with the IIB except Mpipis. Table 5 presents the integrity classes assigned to the IIB values. Thus, for values below 1.50, the class "1" is assigned. Class "2" is indicated for values between 1.5 and 2.5. For IIB values between 2.5 and 3.5, class "3" is used. Class "4" is assigned for values between 3.5 and 4.5. Class "5" is used for values above 4.5. In total, the classes obtained range from "0" to "4" for all the basins. The class "0" has been assigned for values less than 1. With the exception of class "5", all other integrity classes are observed in the coastal zone studied. At the Go River, only classes "2" and "3" are assigned. Other integrity classes ranging from "1" to "4" are unequally distributed between basins (Figure 2).

Relationship Between Human Activities and Integrity Classes: In all the basins surveyed, the ordination of correlations by the canonical correspondence analysis (CCA) of experimental fishery data and human activities as environmental variables indicates that the factorial axis 1 (eigenvalue $\lambda 1 = 0.208$) and axis 2 (eigenvalue $\lambda 2 = 0.063$) express 59.9% of the cumulative variance for integrity class data.

Table 3. Contribution of metrics to different axes from the principal component analysis based on stations and metrics

	Axis 1*	Axis 2*	Axis 3	Axis 4	Axis 5
MNSTOT	0.8992872	-0.1227147	-0.1619148	-0.0759921	-0.2898611
MBIOM	0.5279292	0.2735534	-0.2510474	0.7270448	0.1374585
MSWI	0.7113506	0.2291883	-0.0465099	-0.3248602	0.5724844
MNSCHACYP	0.6160466	-0.6253548	-0.107321	-0.2945608	-0.0604297
MPIOMN	0.9012261	0.1047457	0.1217166	0.1254235	-0.1826706
MPIPIS	0.1509273	0.6953738	0.5966445	0.0014977	-0.0496666
MPIPP	-0.24510039	0.4909484	-0.7628692	-0.1093253	-0.0601959
Prp. Tot	3.56166662	1.04574	-0.6113012	0.0492277	0.067119

The metrics colored in bold are strongly correlated with the axis 1 and axis 2

Table 4. Pearson correlation between metrics, between IIB and metrics (Significant for $p < 0.05$)

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
MNSTOT	0.899287	-0.12271	-0.16191	-0.07599	-0.28986
MBIOM	0.527929	0.273553	-0.25105	0.727045	0.137458
MSWI	0.711351	0.229188	-0.04651	-0.32486	0.572484
MNSCHACYP	0.616047	-0.62535	-0.10732	-0.29456	-0.06043
MPIOMN	0.901226	0.104746	0.121717	0.125423	-0.18267
MPIPIS	0.150927	0.695374	0.596644	0.001498	-0.04967
MPIPP	-0.2451	0.490948	-0.76287	-0.10933	-0.0602
Prp. Tot	3.561667	1.04574	-0.6113	0.049228	0.067119

Table 5. Biotic Integrity Index Values and Corresponding Integrity Classes

Biotic Integrity Index	Integrity class	Appreciation
0	Class 0	Dead water
1 - 1.49	Class 1	Very bad water
1.5 - 2.49	Class 2	Bad water
2.5 – 3.49	Class 3	Medium water or Moderate Moderate Good water
3.5 – 4.49	Class 4	Good water
4.5 – 5	Class 5	Very good water

The metrics colored in bold are strongly correlated with the axis 1 and axis 2

Average Biotic Integrity Index of the Coastal Zone: For all sites, the overall average of the IIB is 2.48. The values per station oscillate between a maximum value of 4.3 and a minimum value of 0. At the value of 0 no fish were harvested in the basin. The Pearson test performed between the metrics and the biotic integrity index on the one hand and the metrics between them on the other hand, shows a positive correlation between the metrics and between the metrics and the IIB

The ordination of the correlations (Figure 3) highlighting the rates of occurrence of the different human activities recorded on the sites and the corresponding integrity classes, releases along the factorial axis 1, two (2) groups of classes of integrity. Group I consists of classes 0, 1, 2 and 3. They are positively correlated with axis 1 and closely associated with human activities predominantly dominated by PC7; PC10; PC6; PC8 and Aa11. Group II consists of class 4. It is negatively correlated to the factorial axis 1 and is not associated with any variable of the place.

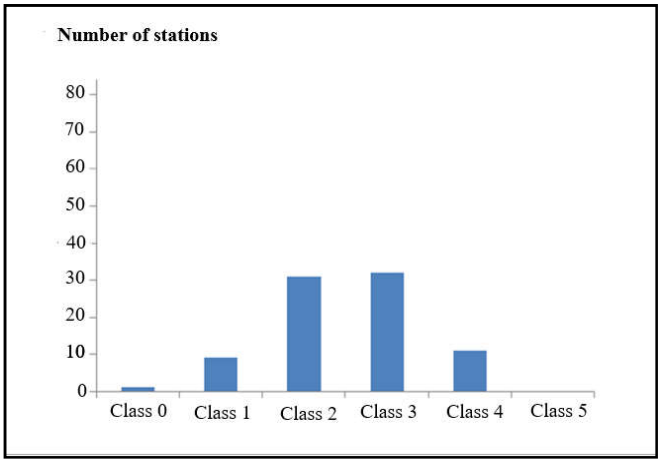

Figure 2. Distribution of biotic integrity classes at the Ivorian coastal zone sampled from December 1999 to March 2001

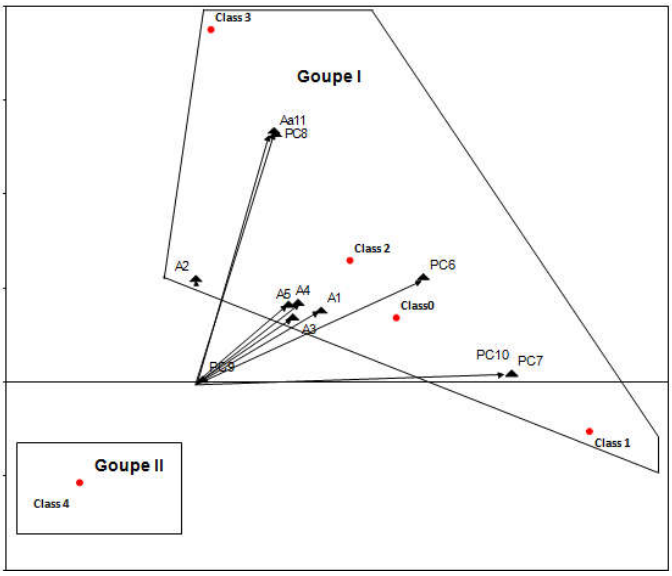

Figure 3. Canonical Correspondence Analysis (CCA) applied to human activities and different integrity classes. A1: plantation of cocoa trees; A2: Coffee plantation; A3: Oil palm plantation; A4: Food crops; A5: Banana plantation; PC6: Use of detergents on the site; PC7: Chemicals; PC8: Presence of bridge; PC9: Agglomeration; PC10: Dam used as a fishery; A11: No activity

DISCUSSION

Guilds and metrics: The trophic guilds were inspired by the bibliography (Traoré, 1996; Lauzanne, 1988; Lévêque *et al.*, 1988 and Moreau *et al.*, 1988) and the analysis of the stomach contents of some fish. The result indicates globally a predominance of invertivorous species. If we consider that insects are particularly present in areas rich in vegetation, it is probably correct to say that the study area is not / or is / little degraded. Six metrics belonging to the three biological categories defined by Karr (1981) [(specific richness and its composition (1), trophic composition (2) and condition of fish and their abundance (3)] were retained. Ultimately, the choice of metrics remained in accordance with IIB principles defined by Karr (1981) for categories. This result is consistent with those obtained by David and Wesley (2005). However, the metrics have been modified so that in the first category there is the presence of the Shannon-Weaver Diversity Index. In this same category " specific richness and composition ", we note the presence of the metric relative to Cyprinodontiformes on the one hand and Cyprinidae on the other hand. This result is consistent with that obtained by KamdemToham and Teugels (1999). These modifications also concern the trophic composition category where all the original metrics have not been selected. With regard to the fish condition category, a new metric concerning " total biomass " was selected. This metric was used for the first time by Belpaire *et al.* (2000) and Breine *et al.* (2004). It expresses the overweight of individuals and reflects not only the availability of food resources but also a good physical and chemical quality of the environment necessary for the development of the individual.

Spatial Distribution of Integrity Classes: The average value of the biotic integrity index of the coastal zone is 2.48. The maximum and minimum values are respectively 4.33 and 1. The calculated integrity classes vary from 0 to 4. According to Karr (1991) each of the classes corresponds to a stream status: Death (0), Very bad (1), bad (2), moderate (3), good (4). Class 5 which is the highest value of the IIB, has not been observed in the coastal zone. It corresponds according to (Karr (1991) to a station comparable to the best situation without disturbance of human origin where all the expected species of this type of habitat are present including, the most intolerant species with all size classes and where we observe trophic equilibria. The fact that this class is not represented in any of the rivers shows that no environment of the studied sites is intact.This result is due to the fact that the coastal zone undergoes deforestation which is getting in magnitude. According to a United Nations report, south-west France, which until 1979 was the best preserved, has been subject to deforestation, which remains much greater than that of other parts of Ivorian territory (Abé and Kaba, 1997). The best represented class 3 in this zone corresponds to a place of moderate quality where the water corresponds, in terms of characteristics, to an average value close to the acceptable. It is a station that reflects the accumulation of environmental deterioration and whose fish population includes many intolerant forms with a medium number of species. The trophic structure is slightly unbalanced with a high frequency of omnivores as well as that of other forms of tolerant species. This result is explained by the fact that the coastal zone remains a moderately degraded region. Class 0, which means that the body of water is dead, was observed at only one station in the Mé basin. It has not been taken into account because it is considered to be the result of insufficient sampling. However, if this should be admitted as a correct value, this could be explained by the effect of drought and / or fishing for toxic products.

Human activities and integrity class: Three types of activities have been identified in the Ivorian coastal zone. These are agricultural activities, development work and the use of plant protection products. The canonical analysis applied to human activities indicates that all classes are associated with agricultural activities. This observation seems to indicate that even if the establishment of plantations and agro-industrial blocks contribute to degradation, it is not the only factor. Indeed, classes 1 and 2 are associated with the use of chemicals of 16.6 and 4.6% respectively. These rates drop to 3.5% for class 3 and vanish for class 4. This last class is associated with more than 50% to agricultural activities and only 16.6% to development type activities. These observations suggest that the degradation of the aquatic system in the coastal zone is accelerated and aggravated by the use of chemicals in water bodies. This observation is confirmed by the fact that the average integrity class for the entire coastal

zone is 3, which means that degradation is moderate despite the presence of more than 73% of agricultural plantations.

Conclusion

The Biotic Integrity Index (IIB) based on fish by considering five coastal basins of Côte d'Ivoire (Agnébi, Mé, Boubo, Niouniourou, and Gô) has made it possible to highlight an ichthyological populating of 57 species and 01 hybrid. The populating and Trophic Guilds that result have permitted to identify a total of 14 guilds. Six metrics out of 19 metrics candidate for the assessment of the quality of the coastal basins strongly influence the stations prospected. For all sites, the overall average of the IIB is 2.48. The relationship between human activities and Integrity classes revealed that classes 0, 1, 2 and 3 are closely associated with anthropogenic activities except class 4, which is not associated with any environmental variable. The Biotic Integrity Index established in this study has provided biological and ecological knowledges of great interest to the public and policymakers around the world who advocate for social development and biodiversity conservation of ecosystems.

REFERENCES

Abé J and Kaba N. Côte d'Ivoire : Profil environnemental de la zone côtière. Grd Écosystème marin du Golfe. *Rapport ONUDIFEM,* 1997 : 151p.

Allan JD and Flecker SA. Biodiversity conservation in running waters: identifying the major factors that threaten destrcution of riverine species and ecosystems. *BioSci,* 1993; 43: 32- 43.

Belpaire C, Smolder R, Auweele IV, Erken D, Breine J, Gerlinde VT and Ollevier F. An index of Biotic Integrity characterizing fish populations and the ecological quality of Flandrian water bodies. *Hydrobio.,* 2000; 434: 17-33.

Berkman HE, Rabeni FC and Boyle PT. Biomonitors of stream quality in agricultural areas: fish versus invertebrates. *Environ. Manage,* 1986; 10: 413-419.

Breine J, Simoens I, Goethals P, Quataert P, Erken D, Van Liefferinghe C, and Belpaire C. A fish-based index of biotic integrity for upstream brooks in Flanders (Belgium). *Hydrobio.,* 2004; 522: 133-148.

Cairns JR and Dickson S. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. *Jour. Water Poll.Control Fed,* 1971; 43: 755-772.

David J and Wesley JB. Effectiveness of stream restoration following highway reconstruction projects on two freshwater streams in Kentucky, 2005.

Fausch KD, Karr RJ and Yant RP. Regional application of an index of biotic integrity based on stream fish communities. *Trans. Am. fish. Soc*, 1984; 113-: 39-55.

Gammon JR. The use of community parameters derived from electrofishing catches of river fish as indicators of environmental quality: 1980: p. 335-363. *In Seminar on Water quality Management Trade-Offs*. US, Environmental Protection Agency, Washington, D.C. EPA-905/9-90-005.

Harris JH. The use of fish in ecological assessment. *Aust. J. Ecol.*, 1995; 20: 65-80

Hay CJ, Van Zyl JB and Steyn JG. A quantitative assessment of the biotic integrity of the Okavango River, Namibia, based on fish. Water SA, 1996; 22: 263-284.

Hendricks ML, hocutt HC and Stauffer RJJr. Monitoring of fish in lotic habitats: 1980: P. 205-231. In C.H. Hocuttet J.R. Stauffer, Jr. éd, *Biolo. Monitor. of fish.* Lexington Books, Toronto.

KamdemToham A and. Teugels GG. First data on an Index of Biotic Integrity (IBI) based on fish assemblages for the assessment of the deforestation in a tropical West Africa River. *Hydrobio.*, 1999; 397:29-38.

Karr J. Assessing of biotic Integrity using fish communities. *Fisher.*, 1981; 6: 21-27.

Karr JR, and Dudley RD. Ecological perspective on water quality goals. *Environ. Management. Springer New York,* 1981; 5 (1) 55-68 p.

Karr JR, Fausch KD, Angermeier PL, Yant PR and Schlosser IJ. Assessing biological integrity in running waters – a method and its rationale. *Illinois Nat. Hist. Survey*, special publication, 5 Urbana, 1986: 28 p.

Karr JR. Biological integrity a long-neglected aspect of water resource management. *Ecol. Appl.,* 1991; 1: 66 - 84.

Kestémont P, Didier J, Depiereux E and Micha JC. Selecting ichthyological metrics to assess river basin ecological quality. *Archiv für Hydrobio. - Supplement* (Monogr. Stud.), 2000; 121: 321-348.

Klein RD. Urbanization and stream quality impairment. *Water Resour. Bull*., 1979; 15: 948- 963.

Lauzanne L. Les habitudes alimentaires des poissons d'eau douce africains. In: *Biologie et écologie des poissons d'eau douce africains* (Lévêque C., Bruton M. N. & Ssentongo G. W., eds). *Travaux et Documents ORSTOM* Paris, 1988; 216: 221-242.

Lévêque C, Bruton NM. And Ssentongo VG (eds). Biology and Ecology of African Freshwater Fishes. *Editions de l'ORSTOM*, Paris: 1988: 510 p.

Moreau J, Arrignon J and Jubb AR. Les introductions d'espèces étrangères dans les eaux continentales africaines. Intérêt et limite, *In* : Biologie et Ecologie des poissons d'eau douce africains (Lévêque C., Bruton MN & Ssentongo WG, eds): 1988**:** pp.395-435. Paris ORSTOM

Oberdorff T and Hughes MR**.** Modification of an index of biotic integrity based on fish assemblages to characterize rivers of the Seine Basin, France. *Hydrobio.,* 1992; 228 : 117-130.

Oberdorff T and Porchet PJ. An index of biotic integrity to assess biological impacts of Salmonid farm affluents on receiving waters. *Aquacul.,* 1994; 119: 219-235.

Paugy D, Lévêque C and Teugels GG (eds). Faune des poissons d'eaux douces et saumatres de l'Afrique de l'Ouest. Tome 1. IRD (Paris), MNHN (Paris), MRAC (Tervuren): 2003a: 457 p.

Paugy D, Lévêque C and Teugels GG (eds). Faune des poissons d'eaux douces et saumatres de l'Afrique de l'Ouest. Tome 2. IRD (Paris), MNHN (Paris), MRAC (Tervuren), 815 p.

Piavaux A., 1992. La protection de la qualité écologique des eaux. Tribu de l'eau, 2003b; 45, 555, 1, 5-7p.

Tramer EJ and Rogers MP. Diversity and longittudinal zonation in fish populations of two streams entering a metropolitan area. *Am. Midl. Nat*., 1973; 90: 366-374.

Traoré K. État des connaissances sur les pêcheries continentales ivoiriennes. (Rapport de consultation Avril 1996). Projet F.A.O. TCP/ IVC/ 4553 :1996: 135 p.

****