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RESEARCH ARTICLE

DISTRIBUTION PATTERN OF THE AQUATIC ENTOMOFAUNA ABOUT ENVIRONMENTAL FACTORS IN THE HAUT-BANDAMA WILDLIFE RESERVE AREA OF THE BANDAMA RIVER (CENTRE-NORTH, COTE D'IVOIRE)

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Abstract

The section of the Bandama River located in Haut-Bandama Wildlife Reserve was subject to several pressures induced by the anthropic activities that take place there. These activities could have impacts on the structure of biological communities such as aquatic insects which are indicators of the state of the ecological integrity of the environment. This study was conducted to evaluate the diversity and structure of the aquatic entomofauna of this part of Bandama River. Sampling was conducted from January 2018 to February 2019 at 06 sites defined according to the upstream-downstream gradient of the river. Insects were collected using a handled net and aVan Veen bucket. The inventory identified 127 species from 53 families and 10 orders. In this part of Bandama River, the order Hemiptera was the most prevalent with 30 species. The taxa *Gerisella* sp. (31% of individuals), *Dineutus* sp. (55%), and *Laccophilus* sp. (38%) wereabundant in the upstream, median and downstream sections of Bandama River respectively. Also, 33 species were common to all stations. *Thraulus* sp. And*Lispe* sp. wereonly found at station BYB, located downstream of this sectionof Bandama River. The distribution of entomofauna was influenced by pH, turbidity, dissolved oxygen, speed, depth and temperature. The entomological populations in this part of the Bandama River were well diversified and with awell balanced organisation.

Introduction:-

Aquatic insects account for nearly 95% of aquatic macroinvertebrates (MDDEFP, 2013). These animals measure more than 0.5 cm and belong to the phylum Arthropoda. They inhabit either the bottom (benthic macroinvertebrates or benthos) or the banks (pelagic and surface macroinvertebrates) of aquatic environments (Touzin, 2008). These organisms are an essential link in the trophic chain of aquatic environments since they represent a food source for many organisms such as fish, amphibians and birds (Tachet *et al*., 2000). In addition, they integrate the cumulative and synergistic effects of physical, biological and chemical disturbances in aquatic ecosystems.

The Haut-Bandama Wildlife Reserve, located in north-central Côte d'Ivoire, aims to conserve and sustainably manage savannah biodiversity, especially that of the Bandama River and its meanders. However, the section of this

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river at the level of the reserve is threatened by numerous anthropic activities, including clandestine agriculture, which contributes to the pollution of these waters with pesticides and chemical fertilizers by runoff. Artisanal fishing practiced with pesticides and especially clandestine gold panning, which leads to direct and indirect pollution of the river in various chemicals (Sulfur, Mercury, Lead ...) and the obstruction of the main river bed, by the accumulation of soil from the leaching of gold (Zamblé *et al*., 2021). This environment was favorable for the growth of plants and algae, as evidenced by their enrichment in the suspended debris. (Halle & Bruzon, 2006). These actions would be likely to have an impact on the structure of aquatic biodiversity, including the entomofauna, whose diversity and structure allowedus to assess the true impact of pollution and alteration of aquatic habitats (Allouko *et al*., 2019). However, most of the studies carried out on the Bandama River have concerned other aquatic organisms such as fish and algae. However, few data exist on macroinvertebrates and the ecological integrity of this section of the Bandama River.Thus, this study aimed to provide additional data on the composition and structure of the aquatic entomofauna of the Bandama River in the Upper Bandama Wildlife Reserve.

Materials And Methods:-

Study site

The Haut-Bandama Wildlife Reserve, established in 1973, covers 123,000 hectares. It is situated between the latitudes of 8°10'25.3" and 8°38'25.01" north and the longitudes of 5°12'14.1" and 5°37'55.3" west. It has two (2) seasons and is subject to a sub-Sudanese transitional climate. (Lauginie, 2007). The rainy season lasts from March to October and the dry season lasts from November to February. With an average flow of 700m^3/s, the Bandama River watershed covers 37500 km^2, of which 3,5 % corresponds to the Reserve's area (Bouché, 1996). The average rainfall in the region was 1230 mm, with temperatures ranging from 25 to 30°C and humidity levels ranging from 35 to 79 percent (Fabio *et al*., 2002).

Data Collection

This study was conducted in an annual cycle of (8) eight sampling campaigns with (4) four campaigns per climate season between January 2017 and February 2019. These stations were chosen according to the longitudinal gradient (upstream-downstream) of the Bandama River, their accessibility and their proximity to anthropogenic activities. The selected stations are: upstream stations BTA and BTB, in the middle course, stations BSA and BSB and downstream, stations BYA and BYB (Figure 1).

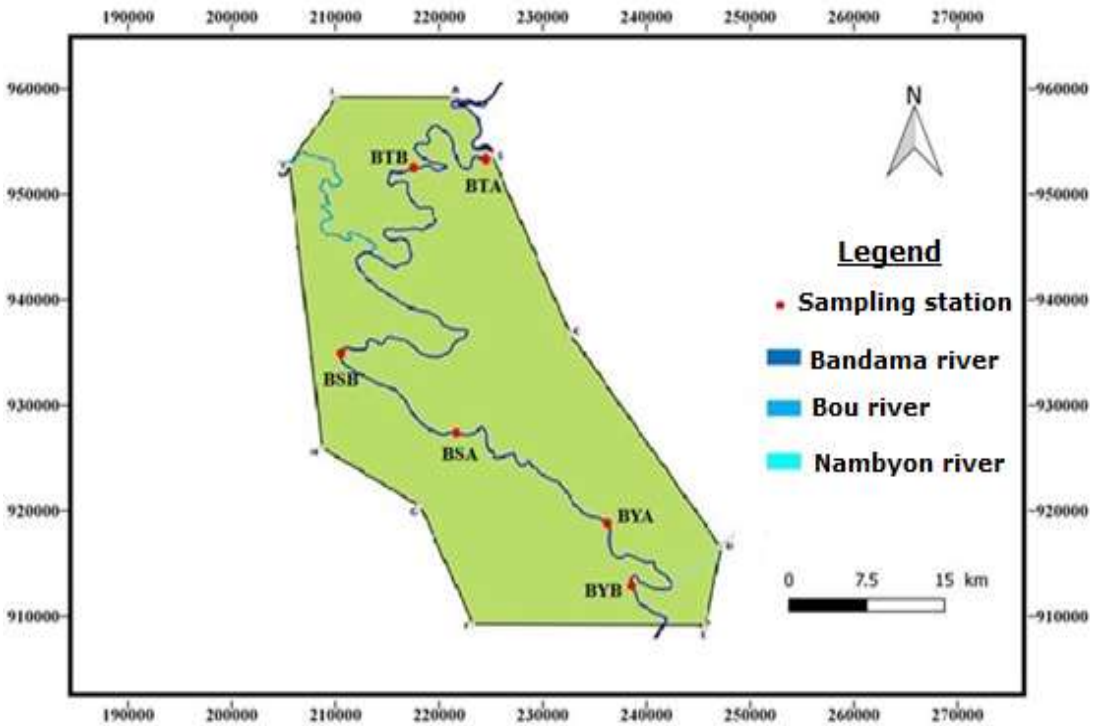

Figure 1:- Location of the (6) six sampling stations on the Bandama River in the Haut-Bandama Wildlife Reserve between January 2018 and February 2019.

Samples were collected using a turbid net over an area of 1 m^2 (2 m x 0.5 m) for 2 minutes, for pelagic macroinvertebrates and benthic macroinvertebrates of (3) three Van Veen bucket shots, i.e. an area of 0.15 m^2 (3 x 0.05 m^2). *In situ*, samples were stored in labeled 1-liter jars containing 70% alcohol. In the laboratory, the insects were sorted and separated from the macroinvertebrates under a binocular magnifying glass at 40 x magnification, and then identified using the keys and books of Déjoux *et al*. (1981) and Tachet *et al*. (2003).

The measurement of physicochemical parameters such as turbidity, dissolved oxygen level, pH, and the water temperature was done *in-situ*, between 06:00 and 09:00 in the morning at each sampling station using a multiparameter.

The maximum depth of the stations was obtained by the average of a series of elementary depth measurements. And current velocity was estimated as the average time taken for a float to travel a distance of 5 meters (Soldner *et al.*, 2004).

Data analysis

- The percentage of occurrence (F) was used to see the number of times a species (i) appears in the samples by the total number of samples (Dajoz, 2000). The values taken by F distinguished the constant species (F > 50%), the accessory species (25%< F< 50%) and the accidental species (F <25%).
- Relative abundance was used to identify key insect species representing at least 4% of the total insect population collected at any sampling stations (Edia, 2008).
- The analysis of the diversity of the stands was made using the Shannon index (H') to quantify the diversity of the stands (H = - Σpi*log2pi); With: ***p*** represented***n*** the relative abundance of species i in the sample (pi = ni/N) and Piélou's equitability index (E), to evaluate the degree of equilibrium of the entomological stands. (J = H ' / $\log_2$S). with S was the number of species in samples) (Shannon &Weaver, 1963 ; Piélou,1969).
- ReDondance Analysis (RDA) was used to investigate the relationship between environmental factors (physicochemical and hydromorphological parameters) and variations in abundances of key species (Ter Braak & Smilauer, 2002).

Results:-

A. Composition and distribution of the aquatic insect population:

The taxonomic composition and occurrences of the aquatic entomofauna collected on the Bandama River in the Bandama Wildlife Reserve (Table I) showed the presence of 127 species from 54 families and 10 orders. The spatial distribution of taxonomic richness showed that the BSB station, situated in the median section of the river,was themost diversified (106 species). The BYB station, located downstream was the least diversified (67 species). Moreover, thirty-three (33) specieswere common to all the stations. *Thraulus* sp. and*Lispe* sp. were only found at the station (BYB), located downstream of the Bandama River.

The occurrence analysis showed that the upriver stations had 10 constant taxa (i.e. 6%), 57 incidental taxa (i.e. 35%) and 98 accessory taxa (59%). However, the lower and middle river stations had 10 and 17 constant taxa (7.4% and 9.3%), 51 and 36 incidental taxa (37.8% and 19.8%), and 74 and 129 accessory taxa (54.8% and 70.8%) respectively.

The species composition of the orders of insects collected on the Bandama River in the reserve according to the number of species (Figure 2) indicated that the Hemiptera with 30 species, 22% of the total species richness, was the most diversified. The Blattoptera and Hymenoptera were the least species-rich, with 1 species each representing 1%.

Table I:- Composition and occurrence of aquatic entomofauna collected in the Bandama River in the Haut-Bandama Wildlife Reserve between January 2018 and February 2019.
*= Accidental species; ** = Incidental species; *** = Constant species; - = No species

			Upstream		**Median**		**Downstream**	
Orders	**Families**	**Species**	**BTA**	**BTB**	**BSA**	**BSB**	**BYA**	**BYB**
Blattoptera		-	**	**	***	***	**	**
Coleoptera	**Dryopidae**	*Strina promontorii*	**	**	**	**	**	**
	Dytiscidae	*Canthydrus xanthinus*	-	-	*	*	-	**

		Capelatus sp.	*	*	**	**	**	**
		Dineutus sp.	**	**	***	***	**	**
		Guignotus sp.	-	-	*	*	-	-
		Heterhydrus sp.	**	**	-	*	*	-
		Hydaticus matruelis	-	*	-	-	*	-
		Hydroglyphus sp.	**	*	-	-	-	-
		Hygrotus sp.	-	-	**	*	-	**
		Hyphydrus sp.	-	-	*	*	-	-
		Laccophilus sp.	**	**	**	***	*	**
		Yola elegantula	*	-	**	**	-	-
	Elmidae	-	*	-	-	**	-	-
		Leptelmis seydeli	**	**	-	-	*	*
		Omotonus angolensis	**	**	-	-	*	-
		Omotonus sp.	-	-	**	*	-	-
		Potamodytes sp.	*	**	-	**	*	*
		Pseudancyronyx basilewskyi	-	-	**	*	**	**
		Rhizelmis sp.	**	***	*	**	**	**
	Gyrinidae	*Orectogyrus* sp.	*	*	-	*	*	-
	Helodidae	*Helodes* sp.	-	*	**	*	**	**
	Hydraenidae	*Pterosthetops* sp.	**	**	-	**	*	-
	Hydrophilidae	*Amphiops* sp.	*	-	-	**	**	***
		Berosus sp.	*	*	-	-	-	**
		Enochrus sp.	**	***	***	**	**	*
		Grenitis sp.	*	-	**	**	-	-
		Laccobius starnuehlneri	*	-	***	**	-	-
	Limnichidae	*Limnichus* sp.	*	-	-	**	-	-
Diptera	**Ceratopogonidae**	*Bezzia* sp.	**	*	*	*	*	*
		Dasyhelea sp.	*	-	**	**	-	-
		Smittia sp.	-	-	**	**	-	-
Diptera	**Chaoboridae**	*Chaoborus cristallinus*	**	**	**	*	**	*
	Chironomidae	*Ablabesmyia* sp.	*	-	**	***	-	-
		Chironomus sp.	*	-	***	***	-	-
		Clinotanypus sp.	*	**	**	**	*	-
		Cryptochironomus sp.	*	**	-	*	*	-
		Nilodorum sp.	**	***	***	***	*	*
		Polypedilum sp.	**	**	**	***	*	*
		Stenochironomus sp.	-	-	-	-	**	*
		Stictochironomus sp.	**	*	**	***	-	**
		Tanypus sp.	**	**	**	**	**	*
		Tanytarsus sp.	*	-	**	**	-	**
	Culicidae	*Aedes* sp.	***	***	*	**	*	-
		Anopheles sp.	**	**	-	**	*	-
		Culex sp.	***	**	**	**	**	**
		Culiseta sp.	***	**	**	**	**	**
		Mansonia sp.	**	**	-	-	*	**
	Dixidae	*Dixa* sp.	**	**	**	**	*	-
	Dolichopodidae	*Leptoconops*sp.	-	-	*	*	-	-
	Muscidae	*Limnophora* sp.	-	-	*	*	**	*
		Lispe sp.	-	-	-	-	-	**
	Phoridae	*Megaselia scarlaris*	-	-	*	*	-	-
	Rhagionidae	*Atherisc* sp.	*	-	-	**	-	-
	Simuliidae	*Simulium* sp.	**	*	-	-	-	-
	Tabanidae	*Tabanus* sp.	*	-	**	**	-	-

Ephemeroptera	**Baetidae**	*Afrobeatodes* sp.	*	-	-	**	-	-
		Bifurcatum sp.	**	**	**	**	*	**
		Claeon sp.	*	-	-	**	-	-
		Dicercomyzon sp.	-	-	-	-	**	***
	Caenidae	*Caenis* sp.	**	**	**	**	**	*
	Heptageniidae	*Afronurus* sp.	*	*	**	***	**	**
		Notonurus sp.	**	**	**	**	**	***
	Leptophlebiidae	*Adenophlebia* sp.	-	*	-	-	*	*
	Leptophlebiidae	*Adenophlebiodes* sp.	**	**	**	**	*	*
		Thraulus sp.	-	-	-	-	-	**
	Polymitarcidae	*Povilla adusta*	-	-	*	*	-	-
	Tricorythidae	*Tricorythus* sp.	*	*	**	**	*	*
Hemiptera	**Anthocoridae**	*Anthocoris nemoralis*	-	-	-	-	**	*
	Aphididae	*Melanaphis* sp.	-	-	**	*	-	-
	Belostomatidae	*Appasus* sp.	**	*	*	**	-	**
		Diplonychus sp.	**	**	**	**	**	***
	Cicadellidae	*Cicadella viridis*	**	**	**	**	*	-
	Corixidae	*Micronecta scutellaris*	-	-	*	*	-	-
		Micronecta sp.	**	**	*	*	*	-
		Stenocorixaprotrudea	*	-	**	***	**	**
	Cydnidae	*Sehirus cinctus*	*	-	**	**	-	-
	Gerridae	*Eurymetra* sp.	**	**	**	**	**	**
		Gerisella sp.	**	**	-	**	***	**
		-	**	**	-	*	*	-
		Limnogonus chopardi	*	-	-	*	**	***
	Hydrometridae	*Hydrometra* sp.	-	**	-	-	*	-
	Mesoveliidae	*Mesovelia vittigera*	*	-	**	**	-	-
	Naucoridae	*Laccocoris* sp.	*	*	-	**	*	**
		Macrocoris flavicolis	**	***	-	*	*	-
		Naucoris sp.	-	*	-	-	*	-
	Nepidae	*Laccotrephes ater*	-	-	**	*	*	*
		*Laccotrephes*sp.	**	*	**	**	-	**
		Nepa sp.	-	-	**	*	-	-
		Ranatra sp.	*	-	-	**	-	-
	Notonectidae	*Anisops sarclea*	*	-	**	**	*	**
		Anisops sp.	***	***	***	***	**	**
	Pentatomidae	*Dolycoris* sp.	**	**	**	**	**	**
		Eysarcoris sp.	-	-	-	-	**	**
	Pleidae	*Plea pullula*	**	**	**	***	**	**
	Veliidae	*Microvelia* sp.	*	-	-	**	-	-
		Rhagovelia reitteri	**	**	**	**	**	**
		-	**	**	**	**	*	-
Hymenoptera	**Formicidae**	*Solenopsis* sp.	**	**	***	**	*	-
Lepidoptera	**Crambidae**	-	**	*	**	**	-	-
		Hygraula sp.	*	-	**	**	-	-
	Noctuidae	*Agrotis ipsilon*	-	-	-	-	**	**
Odonates	**Coenagrionidae**	*Ceriagrion* sp.	**	**	**	**	*	**
		Pseudagrion sp.	**	**	**	***	*	*
	Gomphidae	*Gomphidia* sp.	-	-	**	*	-	-
		Ictinogomphus sp.	**	*	**	**	-	*
		Lestinogomphus angustus	-	-	**	*	-	*
		Microgomphus sp.	**	*	**	**	-	-
		Neurogomphus sp.	**	**	**	***	**	***

		Paragomphus genei	*	-	-	*	-	-
		Paragomphus sp.	**	**	**	**	***	***
		Phyllogomphus aethiops	*	-	**	**	**	**
	Libellulidae	*Olpogastra* sp.	*	-	-	*	-	-
		Orthetrum caffrum	*	-	**	**	-	-
		Palpopleura lucia lucia	**	*	*	*	-	-
		Parazyxomma flavicans	**	*	**	*	-	*
		Trithemis dorsalis	**	***	**	**	**	***
	Macromiidae	*Phyllomacromia picta*	-	*	-	-	**	*
		Phyllomacromia sp.	**	**	-	-	*	-
Orthoptera	**Acrididae**	-	**	**	**	**	**	**
	Gryllidae	*Acheta* sp.	*	-	**	***	-	-
	Tettigoniidae	-	*	**	-	-	**	**
Trichoptera	**Hydropsychidae**	*Polymorphanysus* sp.	-	-	*	*	-	-
	Leptoceridae	-	-	-	**	*	-	-
		Leptocerus sp.	**	**	*	*	**	*
		Oecetis modesta	**	**	-	-	*	-
	Polycentropodidae	*Dipseudopsis capensis*	*	-	**	**	-	-
Total : 10	**53**	**127**	**95**	**73**	**85**	**106**	**75**	**67**

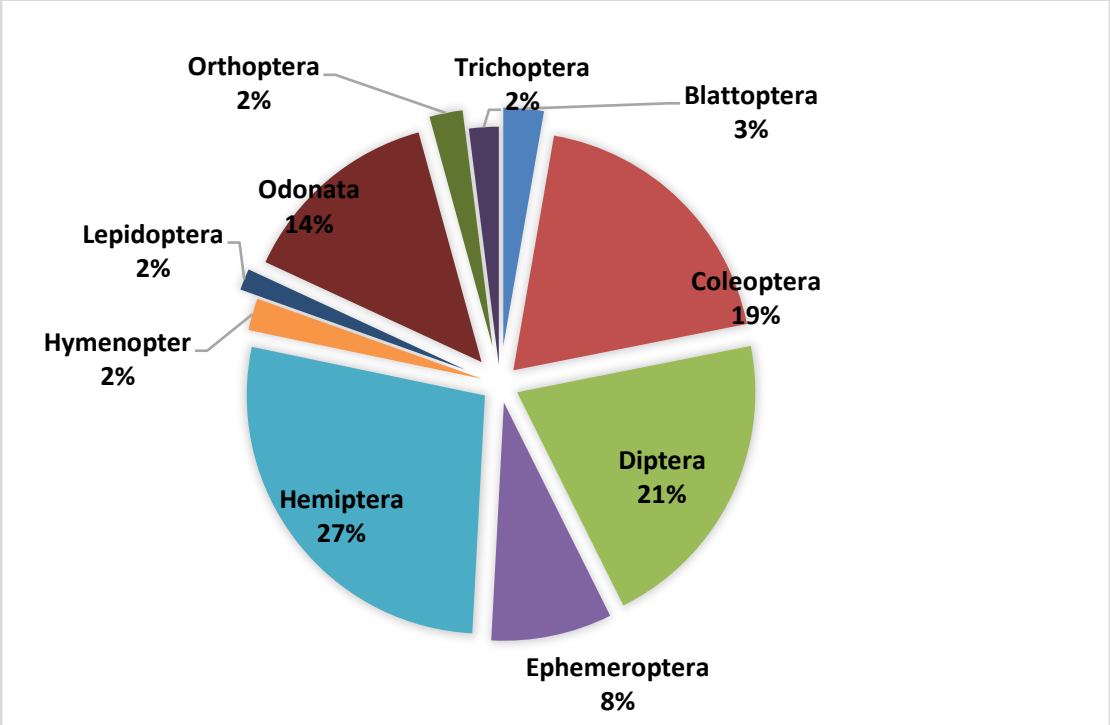

Figure 2:- Specific composition of aquatic insect orders observed on the Bandama River in the reserve based on the number of species between January 2018 and February 2019.

Occurrence frequencies of taxa :

The analysis of frequencies of occurrence shows that, overall, the structure of the populations shows that the different zones of this section of the Bandama River are dominated by accessory taxa (Table 1). Accessory taxa constitute 59.39% of the taxa encountered upstream, 70.87% of the taxa in the middle course and 54.81% of the taxa recorded upstream. However, accidental taxa represent 34.54% of the taxa upstream, 19.78% in the middle course and 37.78% downstream. Finally, 32 taxa (24.24% of taxa) were recorded consistently in the different sections of the river. Thus, at the upstream level, 10 constant taxa were collected: *Aedes* sp., *Culex* sp., *Culiseta* sp., *Anisops* sp.,

Rhizelmis sp., *Enochrus* sp., *Nilodorum* sp., *Macrocorisflavicolis*, *Anisops* sp. et *Trithemisdorsalis*. 17 constant taxa were noted in the middle short: *Dineutus* sp., *Enochrus* sp., *Laccobiusstarnuehlneri*, *Chironomus* sp., *Nilodorum* sp., *Anisops* sp., *Solenopsis* sp., *Laccophilus* sp., *Ablabesmyia* sp., *Polypedilum* sp., *Stictochironomus* sp., *Afronurus* sp., *Stenocorixa protrusa*, *Plea pullula*,*Pseudagrion* sp., *Neurogomphus* sp. and*Acheta* sp. Finally, 10 constant taxa were encountered downstream of the river. These are *Gerisella* sp.,*Paragomphus* sp., *Amphiops* sp., *Dicercomyzon* sp., *Notonurus* sp., *Diplonychus* sp., *Limnogonuschopardi*, *Neurogomphus* sp., *Paragomphus* sp.and *Trithemis dorsalis*.

Structure of population :

The relative abundances of the (13) thirteen main insect species collected on the Bandama River in the reserve according to the sampling stations (Figure 3) indicated that in the upper reaches of the river, *Gerisella* sp. was abundant and accounts for 31% of the total insects. In the median stream, *Dineutus* sp. was the most abundant with 55%. Downstream, *Laccophilus* sp. predominated with 38%.

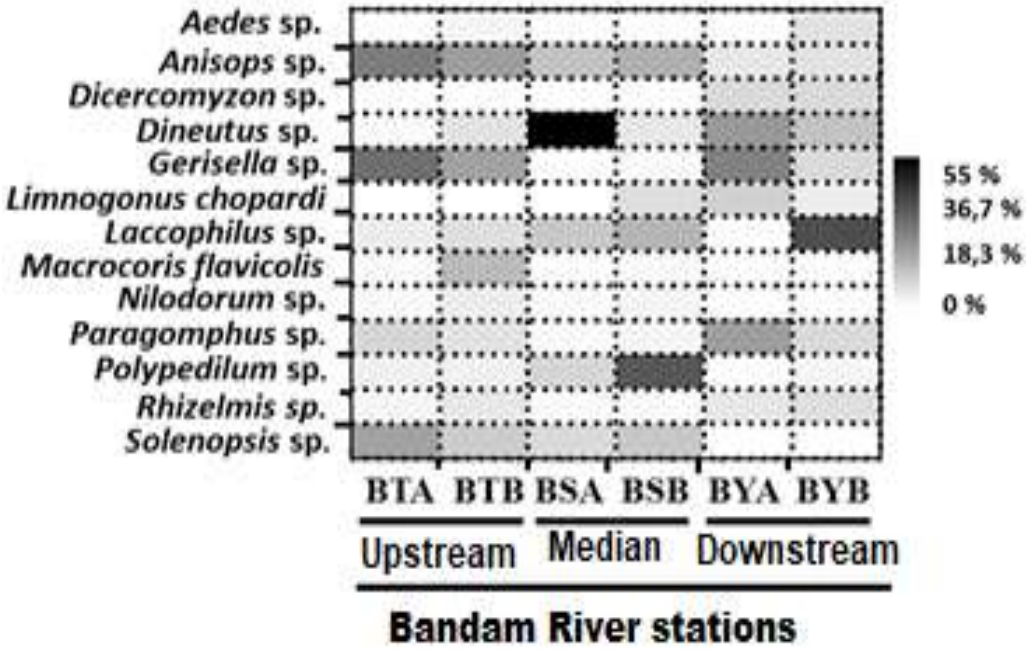

Figure 3:- Relative abundances of the (13) top insect species collected on the Bandama River in the reserve between January 2018 and February 2019.

Entomofauna diversity analysis :

The analysis of the diversity index in the different stations showed that the abundance of the stands varied from 86 (station BYA) to 333 individuals (station BSA). At the level of Shannon index, all the values were higher than 2.5 bits.The values fluctuated between 3.67 bits (station BYA) and 4.25 bits (station BSA). The equitability index values were all higher than 0.5 and fluctuated between 0.94 and 0.98.

Table II:- Recap of calculated diversity index.

	Samples sites					
Diversity Index	**BSA**	**BSB**	**BTA**	**BTB**	**BYA**	**BYB**
Taxa_S	95	73	85	106	75	67
Individuals	333	313	166	191	86	150
Shannon_H'	4.25	4.22	3.89	4.0	3.67	3.89
Equitability_J	0.94	0.95	0.94	0.96	0.98	0.96

A Redundancy Analysis (RDA) (Figure 4), indicated from axis I and II express 47.35 and 22.55% of the information respectively, for a total of 69.90% of the variability. The projection of the main insect species on the vector axes of environmental parameters indicated that *Gerisella*sp.,*Rhizelmis* sp., *Limnogonuschopardi*,*Paragomphus* sp. and*Dicercomyzon* sp. were associated with high values of temperature and dissolved oxygen in the positive part of

axis I, while *Nilodorum*sp.,*Anisops* sp. and*Solenopsis* sp. were influenced by high values of depth and pH in the negative part of this axis. On axis II, *Aedes* sp. and*Macrocorisflavicolis*were positively influenced by high values of turbidity and velocity. In contrast, *Laccophilus*sp.,*Polypedilum* sp. and*Dineutus* sp. were opposed to high values of turbidity and velocity.

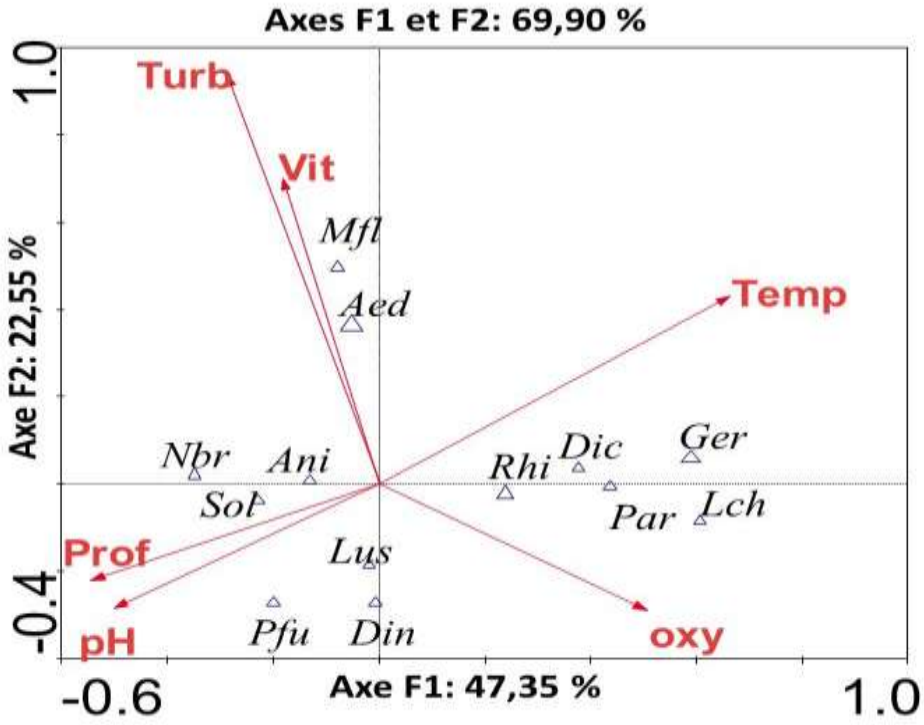

Figure 3:- Redundancy Analysis (RDA) of the (13) top insect species collected on the Bandama Riverand environmental variables between January 2018 and February 2019.

Temp = Temperature, **Prof** = depth, **Vit** = Speed ; **Trub** = Turbidity ; **Oyg =** Dissolved oxygen, **pH** = Hydrogen potential. **Ger** = *Gerisella* sp.**Rhi** = *Rhizelmis*, **Par** = *Paragomphus* sp. **Lch**= *Limnogonus chopardi*, **Dic**= *Dicercomyzon* sp., **Nbr** = *Nilodorum* sp.,**Din** = *Dineutus* sp, **Ani** = *Anisops* sp, **Aed** = *Aedes* sp, **Mfl** = *Macrocoris flavicolis*, **Sol**= *Solenopsis* sp, **Pfu** = *Polypedilum* sp., **Lus** = *Laccophilus* sp.

Discussion:-

The specific composition of the entomofauna (127 species of 53 families and 10 orders) collected on the Bandama River in the reserve was higher than that obtained by Kouamé (2014), on the Bandama River at the Taabo reservoir, where this author inventoried 53 species of 41 families and 09 orders. This specific difference could be due on the one hand to the study area and the types of tools used on the other hand. Indeed, Kouamé's work was carried out in an anthropized environment and only with the help of a net. The preponderance of Hemiptera on the Bandama River has already been observed by Kouamé (2014) at the Taabo River. For Lee *et al*. (2006), their abundance would be related to their ubiquity. Furthermore, the high diversity of Hemiptera in the reserve could be due to the presence of aquatic plants and prey such as fry. In addition, the high diversity of Hemiptera in an aquatic environment would indicated a moderate degradation of that biotope. The analysis of the diversity of the populations showed that in all studies stations, the values of the Shannon and equitability index were all higher than 2.5 bits and 0.5 respectively. This result indicated that the entomological populations in this part of the Bandama River were well diversified and with a well balanced organization (Dajoz, 2000).

Redundancy analysis showed that pH, turbidity, dissolved oxygen, velocity, depth, and temperature influenced insect distribution. This result highlights the influence of the impact of anthropogenic activities in the watershed of this section of the Bandama River. Bond & Downes (2003), related macroinvertebrate diversity to fluctuations in environmental factors caused by an anthropogenic disturbance in a wetland in the central Himalayan mountains of India.

Conclusion:-

Given the impacts of anthropogenic activities on the distribution of biological communities, the present work made it possible to show the composition and structure of the aquatic entomofauna of the Bandama River in the Haut-Bandama Wildlife Reserve. The inventory highlighted 127 species from 54 families and 10 orders were inventoried. The order of Hemiptera was the most diversified with 30 species. *Gerisella* sp. (31%) was abundantupstream, *Dineutus* sp. (55%) in the median course and *Laccophilus* sp. (38%) in downstream. Also, 33 species were common to all stations. *Thraulus* sp. and*Lispe* sp. were only found at station BYB, located in downstream of the river section. The entomological populations in this part of the Bandama River were well diversified and with a well balanced organization. The pH, turbidity, dissolved oxygen, velocity, depth and temperature strongly influenced the distribution of insects in this section of the Bandama River.Finally, a monitoring and follow-up plan for ecological integrity is needed in this ecosystem.

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