Appendix 17: Hydrobiological Study of the Bandama Basin in Yaoure Gold Project's Area of Influence

Yaoure Gold Project, Côte d'Ivoire

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Authors	**KONAN Koffi Félix** (Ecological engineering / Ichtyofauna)		
	BONY Kotchi Yves (Benthic macrofauna)		
	ADON Marie Paulette (Algal microflora)	s	
	POTGIETER Juan (Aquatic specialist)		
Proof-reader	**Dr. Genevieve Campbell**		
Project manager's validation	**Dr. Christian Kunze**	12 November 2015	

EXECUTIVE SUMMARY

Background

The present work entitled "Hydrobiological study of the Bandama basin in Yaoure gold project's area of influence" was conducted as part of the Environmental and Social Impact Assessment for Yaoure Gold Project. The objectives of this study are: to make reference to the water quality and its physical state measured *in situ*; to analyse and evaluate habitat conditions; to collect and analyse algal microflora and macro-invertebrates; to sample the ichthyofauna and consult with fishermen to collect information; to list rare or threatened species and/or species of conservation interest.

Methodology

The study took place from 1st -15th April 2015 (beginning of rainy season) using 13 sampling sites as follows: 3 on Lake Kossou (B1, B2, B11), 4 on the main course of Bandama River between the embankment of the Kossou dam and the bridge of the village Bozi (B5, B6, B7, B10), 5 on the tributaries of the Bandama River (B3, B9, B12, B13, B14) and one on a lake that originated in a previous mining pit location (B4). The groups under study were: 1) fish fauna; 2) benthic macroinvertebrates; and 3) aquatic algal microflora.

The fish were caught using gillnets of different mesh size (on important water bodies) and electrofishing devices (on small water bodies). The fishermen's catches in the area were also analysed. Benthic macroinvertebrates were sampled using a kick net and a Van Veen grab. The water intended for the study of the phytoplankton communities was sampled using the plankton net and the hydrological bottle. For periphyton, samples were collected by scraping submerged plants, stones or branches. Benthic macroinvertebrates and algae samples were preserved in pill dispensers, fixed in 70% alcohol and then transported to the laboratory for analysis and identification.

Results

1) Fish fauna

In total, 64 species of fish belonging to 35 genera, 16 families and 6 orders were recorded. Overall, 52 species of fish were observed in the main course of the Bandama River, compared to 36 in the Lake Kossou, and 14 in the tributaries and shallows areas of the study area. No species were fished in the B4 site which is an old gold mine quarry. The most diverse families in terms of number of species in the fish population are: Cichlidae, Mormyrid, Cyprinidae, Alestidae, Clariidae, Mochokidae, Claroteidae and Schilbeidae. Taking into account the species observed by the study carried out in 2007, it is altogether 70 species of fish that are confirmed in the area of the Yaoure gold project. The most heavily fished species consist of *Tilapia* spp., *Chrysichthys* spp. and *Brycinus* spp. For all 64 taxa identified to the species level in this study, two species are listed as threatened on the IUCN Red List (2014); *Tilapia busumana* (VU) and *Mormyrus subundulatus* (EN). Three other are listed as Near-Threatened: *Raiamas nigeriensis*, *Marcusenius furcidens* and *Tilapia walteri*. These five species of conservation interest represent 7.81% of the total species richness observed in this study. Furthermore, three species are

endemic to Côte d'Ivoire, *Synodontis bastiani* (LC), *Synodontis punctifer* (LC) and *Tilapia walteri* (NT), and also possess a restricted distribution.

2) Benthic macroinvertebrates

As for benthic macroinvertebrates, 2,776 individuals of 44 taxa belonging to 37 families and 10 orders were identified. They belong to four Zoological groups: insects, molluscs, worms and crustaceans. The order Basommatophora is best represented in terms of numbers with 78.23% of the individuals collected falling within this classification. Insects are the most diverse group with 7 orders, 33 families and 35 taxa (80% of the taxonomic richness). No threatened species were recorded from the area, but some individuals could not be identified to the species level, and thus their conservation status was not assessed.

3) Aquatic algal microflora

Concerning the algal microflora, a total of 287 taxa (species and varieties) divided into 91 genera, 54 families, 29 orders, 12 classes and 8 phyla were inventoried. The phyla includes Cyanobacteria (26 taxa), Euglenophyta (52 taxa), Chlorophyta (100 taxa), Pyrrhophyta (7 taxa), Bacillariophyta or diatoms (98 taxa), Rhodophyta (1 taxon), Chrysophyta (2 taxa) and the Xanthophyta (1 taxon). The Kossou dam sampling sites (B1, B2 and B11) are the most diversified with 187 taxa, followed by the Bandama river (115 taxa), its tributaries (119 taxa), and the old gold mine site (49 taxa).

The results indicated that the aquatic habitats at most of these sites tended to be characterized by a moderately disturbed state, with no Critical or Natural aquatic habitats present within and around the Project area in accordance with the IFC Performance Standard 6 (IFC, 2012). The Bandama River and streams are impacted by artisanal mining and the presence of local villages. Indeed, the local population uses the water of the Bandama River for bathing and washing dishes, as well as to conduct underwater artisanal mining activities. These activities have led to sedimentation of the river column due to extensive digging up of the riparian zone (from artisanal mining), and flow fluctuations are regulated by the Kossou hydroelectric dam. These habitats are thus classified as Modified in accordance with IFC Performace Standard 6 (IFC, 2012).

Impacts

The potential identified impacts are: Erosion; Turbidity-suspended solids; Habitat loss and fragmentation; Water pollution; Contamination of the trophic network. The proposed mitigation measures are: drainage chanels especially to minimize erosion of the bare land and mudslides toward the hydrosystem of the project area; stabilize the banks and verges either by planting shrubs, grass or other herbaceous plants; restore riparian vegetation of streams; create tailings or impoundment basins to minimize disturbance of the hydrographic network of the area; build a controlled treatment unit for the mine wastewater and apply current regulations for discharges (as back-up); collect waste oil and waste for recycling or incineration; perform a semi-annual monitoring of the hydrosystem ecological quality in the area.

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1.0 INTRODUCTION

Ratifying the majority of texts relating to the protection of the environment and the conservation of biodiversity, Côte d'Ivoire is campaigning for responsible sustainable development for current and future generations. Legislations were implemented to ensure sustainable development, and thus these must be taken into account by any development project, including mining projects.

In the ESIA process, the state zero of the biophysical and social environment, as well as the interdependence between these environments, allows understanding and definition of the potential impacts from project development.

Many studies highlight the negative impact of human activities on biodiversity (Moyle & Leidy, 1992; Kamdem Toham & Teugels, 1998; Lévêque & Paugy, 1999 Kouamélan *et al.*, 2003; Kouamélan *et al.*, 2005; Koné *et al.*. 2003; Konan *et al.*, 2006). Lévêque & Paugy (1999) highlight that continental hydrosystems are particularly affected by anthropogenic activities taking place both in the aquatic environment and on the watershed. According to Matthews & Styron (1981) and Wootton (1992), the living conditions resulting from such activities may be unfavourable to fish species. Aquatic biological communities respond quickly to disturbances of the hydrosystem thus causing alterations in the specific composition, the headcount and the trophic structure (Harmelin-Vivien, 1992; Lévêque, 1995; Lemoalle, 1999).

In this study, a hydrobiological sampling campaign took place from 1st to 15th April, 2015. The target groups were: fish fauna, benthic macroinvertebrates and aquatic algal microflora. Several species of conservation interest listed on the IUCN Red List of Threatened Species are considered to be potentially present in the area of study, since their range overlap with the study area. Therefore special emphasis was placed on their identification and description.

The specialists who took part in this study are:

1- Dr KONAN Koffi Félix (Ecological engineering / Ichtyofauna)

Jean Lorougnon Guédé University / Environment Department

Tel.: 06 21 61 60 / 57 33 76 66

Postal address: BP 150 Daloa (Côte d'Ivoire)

E-mail: konanfelix@yahoo.fr

2- Dr ADON Marie Paulette (Algal microflora)

Jean Lorougnon Guédé University / Environment Department

Tel.: 06 21 61 60 / 57 33 76 66

Postal address: BP 150 Daloa (Côte d'Ivoire)

E-mail:adonmariepaulette@yahoo.fr

3- Dr BONY Kotchi Yves (Benthic macrofauna)

Jean Lorougnon Guédé University / Environment DepartmentTel.: 47 97 54 86

Postal address: BP 150 Daloa (Côte d'Ivoire)

E-mail:bonyves@yahoo.fr

4- M. POTGIETER Juan (Aquatic Specialist)

Postal address: P.O. Box 3, Theunissen (South Africa)

E-mail:pottiejc@hotmail.com

1.1 Study area

The Bandama River covers a watershed of 97 500 km^2 along 1050 km. It rises at Sirasso North (Department of Boundiali) under the name of Lougomo at an altitude of 480 m, and flows into the lagoon in Grand Lahou (Borremans, 1986; Lévêque *et al.*, 1983). The basin of the Bandama is entirely in Côte d'Ivoire, between 3°50' and 7° West and 5° and 10°20' North. Due to its North-South orientation, the Bandama covers different climate and bio-geographical areas (Lévêque *et al.*, 1983). It is formed by the confluence of the white Bandama and the Red Bandama (i.e. Marahoué). The Marahoué, main right tributary (550 km long, drainage basin of 24 300 km²), is powered by Yani (200 km) and empties into the white Bandama, just upstream of Lake Taabo. The NZi River is the main tributary of the left bank (25 km, basin area of 35,500 km²) which rises to 400 m above the sea level in the East of Ferkessedougou and joins with the white Bandama upstream of Tiassalé. Two hydroelectric dams were built on the Bandama River, in 1972 (Kossou) and in 1978 (Taabo).

Depending on the climate and the vegetation, the Bandama River basin is subdivided into four sectors which are from North to South: Sudan sector, sub-sudan sector, mesophilic sector and rain sector. The Yaoure gold project area belongs to the mesophilic sector located between the 6th and the 8th parallel and characterised by four seasons well marked in the southern area where the rainfall is between 1200 and 1800 mm, spread over two rainy seasons, from March to June, and from September to October. The vegetation is characterized by a transition zone between forest andsavannah to the North, and forest in the South. The transition zone covers the central part of the basin.

1.2 Regional and international importance

A literature review indicates that the Bandama River is home to 123 species of fish belonging to 69 genera, 32 families and 13 orders (Daget & Iltis, 1965; Daget et al., 1973; Planquette & Lemasson, 1975; Merona, 1981; Teugels et al.,1988; Traoré, 1996 ; Lacroix & Konan, 2002; Da Costa & Konan, 2005; N'Douba, 2007; Aliko et al., 2010;

Aboua et al., 2012; Froese & Pauly, 2015). Specifically to the study area, N'Douba (2007) reported 43 species.

A set of 11 species of conservation interest according to the IUCN Red List (2014), and Froese & Pauly (2015), are potentially present in the study area. These species are classified as follows:

- Endangered (EN) : Epiplatys etzeli, Mormyrus subundulatus;
- Near Threatened (NT): Micralestes eburneensis, Citharinus eburneensis, Raiamas nigeriensis, Epiplatys chaperi, Fundulopanchax walker, Marcusenius furcidens, Clarias lamottei, Synodontis koensis;
- Vulnerable (VU): Nimbapanchax petersi.

1.3 Objectives of the study

The hydrobiological study of the Bandama basin in Yaoure gold project's area of influence aims to:

- Establish the baseline conditions of the water quality and its physical state measured *in situ*;
- Analyse and evaluate habitat conditions;
- Collect and analyse aquatic algal microflora and macro-invertebrates;
- Sample Ichthyofauna and consult with fishermen for the gathering of information; and
- Establish the list of rare or endangered species which are of conservation interest.

1.4 Desktop study

Field work carried out at 11 sampling stations in December 2006 and January 2007 (long dry season), were used to assess the potential impacts of mining activities from the company Cluff Gold on a portion of the Bandama basin located in the project's area of influence (N'Douba, 2007). Results of the study include the identification of 105 species of phytoplankton belonging to six classes (Cyanophyceae, Euglenophyceae, Conjugatophyceae, Chlorophyceae, Xanthophyceae and Bacillariophyceae) and 12 zooplankton species distributed between 4 groups of zooplankton (copepods, Cladocerans, rotifers, and Ostracods) and 8 families. For crustaceans, a species of shrimp *Caridina africana* (Atyidae) and one species of crab *Potamonautes ecorssei* (Potamidae) have been surveyed. A total of 56 benthic organisms belonging to the taxonomic groups of molluscs (7 taxa distributed among 6 families and 3 orders) and insects (49 species belonging to 21 families and 5 orders) were collected. The different fishing methods carried out helped identify 43 specimens of fish (42 species and one hydrid) distributed among 19 families.

In addition, various works were conducted on the Bandama River:

- Ichtyofauna (Daget & Iltis, 1965; Daget *et al.*, 1973; Planquette & Lemasson, 1975; Mérona, 1981; Teugels *et al.*, 1988; Traoré, 1996; Lacroix & Konan, 2002; Da Costa

&Konan, 2005; N'Douba, 2007; Aliko *et al.*, 2010; Aboua *et al.*, 2012; Froese & Pauly, 2015);

- Algal microflora (Iltis, 1982 *a* and *b*);
- Zooplankton (De Ridder & Pourriot, 1984);
- Physical and chemical characteristics (Iltis & Lévêque, 1982).

Overall, the literature reports 123 species of fish present in the Bandama basin, divided into 69 genera, 32 families and 13 orders (Daget & Iltis, 1965; Daget *et al.*, 1973; Planquette & Lemasson, 1975; Mérona, 1981; Teugels *et al.*, 1988; Traoré, 1996; Lacroix & Konan, 2002; Da Costa & Konan, 2005; N'Douba, 2007; Aliko *et al.*, 2010; Aboua *et al.*, 2012; Froese & Pauly, 2015).

1.5 Legal requirements

The applicable law, treaties and conventions, as well as institutions involved in the management of environmental issues and relevant to this project are presented below:

1.5.1 Applicable law

Côte d'Ivoire has legislation that focuses on environmental, water, mining, land use and the protection of Fauna and Flora (Ministry of the environment, urban conditions and sustainable development, 1997; Ministry of the water and forests, 1999).

The main texts in force are:

- Decrees of 5 March 1921, of 25 May 1955 regulating the public domain;
- Decree of 19 March 1921, on water conservation;
- Law No. 65-255 of 4 August 1965 on fauna protection and the exercise of hunting on the Forestry Code;
- Law No. 65-425 of 20 December 1965, Forestry Code;
- Law of 20 December 1965, on the Forestry Code;
- Act No. 88-651 of July 1988, on the protection of public health and the environment against the effects of toxic and nuclear waste and harmful substances;
- Law No. 95-553 of 18July 1996 on the Mining Code which contains provisions for the protection of the environment;
- Law No. 96-766 of 3 November 1996 amending the Environment Code; applicable decrees supplementing this code were signed (such as Decree No. 96-894 dated 8 November 1996, on the Environmental Impact Study);
- Law No. 98-755 dated 23 December 1998 on Water Code.

1.5.2 International treaties and conventions

Côte d'Ivoire ratified a number of conventions and international protocols, the most important are:

- The International Convention of 1973 for the preservation against pollution by ships (MARPOL 1973); ratified by Act No. 87-776 in 1987 in Côte d'Ivoire;

- The International Convention on the intervention on the high seas in case of accident causing or consequent to pollution by hydrocarbons (e.i.f. of 6 May 1985); entered into force in Côte d'Ivoire on 7 April 1988;
- The International Convention on civil liability for damage caused by pollution by hydrocarbons. Ratified on 21 June 1973, entered into force on 15 June 1975;
- The International Convention on the establishment of an international fund for compensation for damage due to pollution by hydrocarbons (Brussels on 18 December 1971, entered into force on 16 October 1978); Côte d'Ivoire adhered on 5 October 1987;
- The Convention on the preservation of the pollution of the seas by waste dumping; entered into force on 30 August 1975; Côte d'Ivoire adhered on 9 October 1987;
- The Convention on cooperation for the protection and the development of the marine environment and coastal areas of West and Central Africa region; ratified on 23 March 1981 and entered into force in Côte d'Ivoire on 5 August 1984;
- The Protocol regarding the cooperation in combating pollution in emergency cases entered into force on 5 August 1984;
- The African Convention on nature and natural resources conservation, Algiers 1968 entered into force in Côte d'Ivoire on 16 June 1969;
- The Convention on the protection of the cultural world and the natural heritage Paris 1972 entered into force in Côte d'Ivoire on 9 April 1981;
- The Convention on international trade in fauna and flora endangered species (Washington, 1973) entered into force in Côte d'Ivoire in February 1993;
- The Basel Convention on the control of transboundary movements of hazardous wastes and their disposal (22 March 1989); Côte d'Ivoire is a member since 9 June 1994;
- The Bamako Convention on the ban of import into Africa of hazardous wastes and the control of transboundary movements and management of hazardous wastes within Africa (signed on 31 January 1991); ratified by Côte d'Ivoire on 9 June 1994;
- The Rio Convention on biological diversity (June 1992); ratified by Côte d'Ivoire on 14 November 1994;
- The Rio Convention on climate change (June 1992); ratified by Côte d'Ivoire on 14 November 1994.

1.5.3 Institutions involved in environmental management

The Stockholm Conference in 1972 is the starting point for the interest of Côte d'Ivoire in the protection of the environment. Subsequently, the management of the environment was entrusted successively to several departments: State Secretariat for the Protection of the Nature, Ministry of environment, National Commission for the environment.

Since 14 November 1991, at least one Department is responsible for the environment. Currently, it is the Ministry of the Environment, and Sustainable Development which is responsible for design and implementation of the environmental policy for the Government.

The institutions involved in the protection of the environment are divided into three types: governmental (or departments), non-governmental (NGOs) and private.

The Ministry of the Environment, and Sustainable Development is the governmental structure responsible for the formulation and coordination of national environmental policy, and the review of the environmental and social impact studies. Actions within the Ministry are entrusted to certain structures such as:

- The Branch of the Environment, the focal point of all activities relating to the environment, is responsible for the overall design of policies;
- The Environmental National Agency (ANDE), responsible for the implementation of the National Plan for Environmental Action (NPEA) for better control of environmental problems;
- The Ivorian Anti-pollution Centre (CIAPOL) is in charge of the implementation of the national network of observation of the continental, marine and lagoon water quality;
- The inspection service of classified installations which manages the facilities that generate waste.

1.6 Report structure

This report is structured as follows:

- Methodological section that presents the study sites, indicates the sampling period and presents the methodology used to collect and process data;
- Results achieved;
- Conclusion of results;
- Impact identification and assessment;
- Management and monitoring requirements; and
- Summary and conclusion.

2.0 METHODOLOGY

2.1 Field of study

This work focused on the Hydrobiological study of the Bandama basin in the Yaoure gold project's area of influence.

2.2 Data collection period and area covered by the study

This study took place at the beginning of the rainy season from 1st to 15th April 2015. The rainy season was chosen because the first study (N'Douba, 2007) carried out as part of Cluff Gold's impact assessment took place during the dry season, which allowed for a complete assessment taking into account both seasons.

The area of influence considered during this study included the Inner Exploration Licence, as well as parts of the southern shores of the Kossou Lake, the section of the Bandama River comprised between the Kossou dam and the bridge at Bozi, and its tributaries (Figure 2-1).

Within the area of influence, 13 sampling sites (Figure 2-1 and **Error! Reference source not found.**Table 2-1) were selected. The selection of the sites for the present study was based on sites sampled during the previous study. Site B8 was not sampled during the present survey. It was considered unnecessary as any impacts in the area were properly covered by the sites that were sampled. The sites selected are as follows:

- 3 on the Lake Kossou (B1, B2, B11);
- 4 on the main course of the Bandama between the embankment of the Kossou dam and the bridge of the village Bozi (B5, B6, B7, B10);
- 5 on the tributaries of the Bandama and shallows areas (B3, B9, B12, B13, B14);
- 1 on an artificial lake that originated in an old gold mine pit (B4).

The coordinates, as well as some descriptive site and habitat characteristics (physical and chemical parameters, colour of the water, canopy, composition of the substrate and other observation on site) are provided in Table 2-1 and Table 2-2 (pictures taken at the 13 sampling sites can be found in Appendix 1).

The groups of target species selected for this study are: ichtyofauna, benthic macroinvertebrates and aquatic algal microflora.

Figure 2-1: Area of influence and location of sampling sites

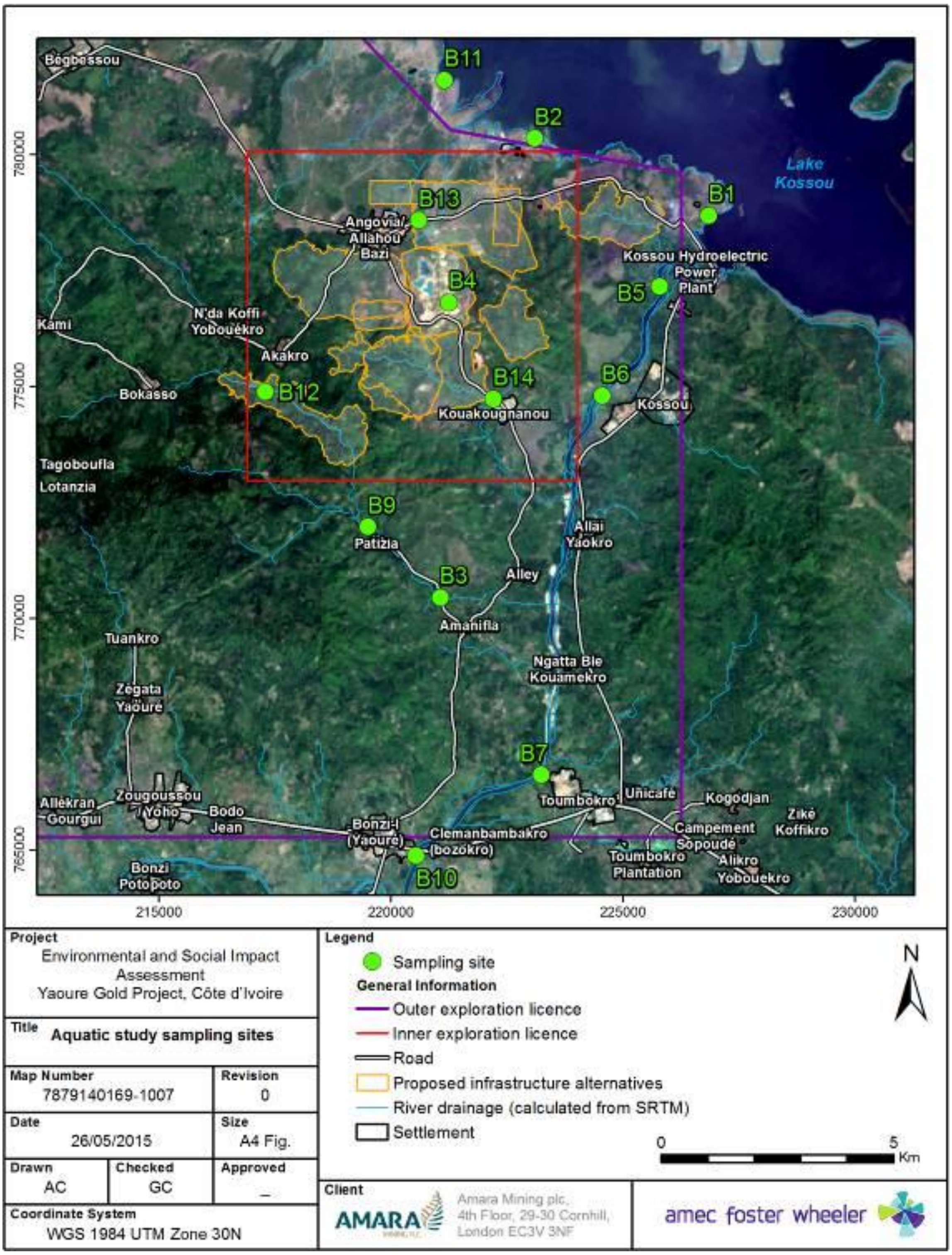


Table 2-1: Geographic coordinates and some water features of the 13 selected sampling sites (KONAN K.Félix; April 2015).

Sites	Codes	Map coordinates		Physical and chemical parameters				Water Colour	Canopy (%)
		North	East	pH	T°C	Cond. (mS/cm)	TSD (ppt)		
Kossou dam	B1	0778 680	0226 842	8.17	30.1	0.06	0.03	brown	00
Allahou Old Harbor	B2	0780 341	0223 094	7.00	33.4	0.03	0.01	brown	00
Patizia Road	B3	0770 450	0221 060	7.80	26.7	0.19	0.1	brown	20
Old Gold Mine	B4	0776 806	0221 247	8.76	31.0	0.27	0.13	light	00
High Voltage Line After Dam	B5	0777 148	0225 787	8.18	28.5	0.06	0.03	brown	15
Kossou Modern College	B6	0774 798	0224 544	7.06	28.6	0.08	0.04	brown	50
Toumbokro	B7	0766 626	0223 240	7.75	29.4	0.09	0.05	greenish	20
Palé River (Patizia)	B9	0771 969	0219 502	7.45	28.7	0.17	0.08	brown	80
Bozi	B10	0764 878	0220 529	7.89	29.6	0.04	0.01	brown	5
Angovia	B11	0781 600	0221 151	7.80	28.4	0.03	0.01	light	00
Palé River (Akakro)	B12	0774 877	0217 288	7.45	24.4	0.15	0.08	light	50
Allahou Bazi/Angovia	B13	0778 576	0220 592	6.96	31.2	0.24	0.12	light	5
Kouakougnanou	B14	0774 725	0222 202	7.30	29.2	0.32	0.14	greenish	10

T°C =temperature in degrees Celsius; Cond. = conductivity; TSD = total dissolved solid.

Table 2-2: Some features and description of the 13 selected sampling sites (Table: KONAN K. Félix; April 2015).

Sites	Codes	Substrate composition (%)						Observations
		Block	Coarse gravel	Fine gravel	Sand	Clay / silt	Plant debris	
Kossou dam	B1	0	0	10	30	60	0	Lake Kossou; close to the dam; low presence of tree trunks in the Lake; very strong fishing activity;
Allahou Old Harbor	B2	0	0	15	35	45	5	Lake Kossou; site of Allahou old harbour; remarkable presence of tree trunks in the Lake; very strong fishing activity; presence of small-scale gold panning units; presence of cattle park
Patizia Road	B3	0	10	65	15	5	5	Presence of plantation; on the roadside
Old Gold Mine	B4	0	0	0	5	85	10	Water retention originated from an old gold mine quarry; presence of water pump for pumping water from the retention; very noisy pump; presence of aquatic vegetation
High Voltage Line After Dam	B5	10	35	25	10	10	10	Bandama River after the dam; Gallery forest on surveyed shore, and savannah and cultures on opposite shore
Kossou Modern College	B6	0	0	5	60	20	15	Bandama River; Gallery forest on surveyed shore, however opposite shore cleared; presence of human activities (bathing, laundry, dishes, fishing); Strong presence of artisanal mining
Toumbokro	B7	5	35	10	40	5	5	Bandama River; Close to the village Toumbokro; low flow; Gallery forest on the shores; presence of artisanal gold mining; presence of local Whisky distillery; strong human activity (laundry, dishes, swimming)
Palé River (Patizia)	B9	0	50	30	10	5	5	Palé stream (a tributary of the Bandama) with important flow; width between 1.5 and 2.5 m; Depth of 50 cm; bridge made up with stones piled up in the bed of the stream; cocoa plantation
Bozi	B10	0	0	10	30	50	10	Bandama River (Marahoué); Important flow; Bozi bridge; village Bozi; Important camp of fishermen; Strong human presence

Sites	Codes	Substrate composition (%)						Observations
		Block	Coarse gravel	Fine gravel	Sand	Clay / silt	Plant debris	
								(bathing, laundry, dishes washing, fishing)
Angovia	B11							Lake Kossou; fisherman camp; fishing activity; presence of aquatic plants; presence of tree trunks in the Lake; presence of cattle park
Palé River (Akakro)	B12	5	10	60	10	10	5	Pale stream, towards Akakro village; Gallery forest; cocoa plantation; presence of aquatic vegetation
Allahou Bazi/Angovia	B13	0	0	10	20	50	20	Streaming shallow; strong presence of aquatic plants; road to Allahou village
Kouakougnanou	B14	0	0	5	20	65	10	Stagnant shallow; completely covered by macrophytes; on the edge of road near Kouakougnanou village

2.3 Sampling methodology

2.3.1 Ichtyofauna

Regarding the ichthyological fauna, two sampling approaches were used for sampling: experimental fishing and artisanal fishing.

For the experimental fishing, two methods were used:

- In very shallow areas, electrofishing was carried out using a Samus electro-shocker. The various sessions of electrofishing lasted between 20 and 25 minutes per site.
- In the most important streams, passive fishing was practiced using gill nets and traps. Gill nettings were carried out with 9 experimental mesh nets of 10-40 mm side, 25 m long and 1.5-2.5 m in height. These nets were placed between 4 pm and 5 pm, and were then lifted the next day between 7am and 9am.

Regarding the artisanal fishing, the data collection team ensured to check the catches of the fishermen in the study area to complete the list of species.

The identification of collected specimens were performed at species level, based on the key proposed by Paugy *et al*. (2003 a & b), Sonnenberg Busch (2009), Eschmeyer (2013), Froese Pauly (2014). The specimens were photographed on the spot. When the identification was problematic, specimens were preserved in 90% ethanol for further laboratory analysis.

When possible, the status of the inventoried species were documented (threatened species, rare, extinct, endemic, migratory species, etc.) by using the IUCN Red List (2014) and Froese & Pauly database (2014). Figure 2-2 shows a few gears used and fishing sessions performed during this study.

Figure 2-2: Fishing equipment (used for experimental and artisanal fishing): (a) Electric fishing session; (b) Preparation of nets for fishing; (c) Longline; (d) Bamboo trap; (e) Seine; (f) Fish traps *(Photo : KONAN K. Félix ; April 2015)*.

2.3.2 Benthic macroinvertebrates

a) Sampling and identification

Benthic macroinvertebrates were sampled at each of the 13 stations using a kick net (mesh size 250 µm) following SASS (South African Scoring System) method (Dickens & Graham, 2002). The samples were collected during 2-3 minutes sampling sessions by submerging the kick net and dragging it in the water column over a certain distance (Figure 2-2a). The net also scraped against the bottom substrate to dislodge and collect the sediment organisms. The benthic fauna was also harvested with a Van Veen grab sampler in stainless steel. At each site, three sediment samples corresponding to a total area of 0.15 m² were taken at several depths. The grab was sunk to the bottom of the water at a slow, steady pace (Figure 2-3b). The rope was retained as vertically as possible to ensure the establishment and the lifting of the grab at a right angle in relation to the bottom. As soon as the jaws of the grab touch the bottom, the rope is pulled up to close the jaws trapping sediment. Out of the water, the content of the grab was washed on a 0.5 mm mesh sieve. All samples were fixed in 70% alcohol.

In the laboratory, all the collected samples were screened, and the harvested individuals were sorted using a binocular magnifying glass, and were counted and identified to the lowest taxonomic level as possible by using the appropriate determination keys (Dejoux *et al*., 1981; Brown, 1994 ; de Moor *et al*., 2003; Tachet *et al*., 2003; Forcellini *et al*, 2011).

b) Analysis

The data analysis was carried out on the basis of:

- Total taxon richness;
- Faunal density;
- The relative abundance in diptera Chironomidae insects, being recognized as tolerant to a wide range of disturbance, and in particular sedimentary type pollution;
- Shannon's diversity index H' (1949): based on the number of species and the regularity of their frequency distribution. $H' = - \Sigma p_i \log_2 pi$ where pi is the relative abundance of the species i in the sample ($p_i = n_i/N$);
- H' fluctuates between 0 and log S. A high index of Shannon corresponds to favourable environmental conditions allowing the installation of many species. Generally, the value of H' is located between 0.5 (low diversity) and 4.5 or 5 (the most diverse communities);
- Pielou regularity or fairness index J;
    - This index is the ratio of the diversity H' to the maximum diversity that can be obtained with the same number of taxa (H'max = log2 S): J = H'/ H'max = H' / log2 S;
    - The fairness index varies between 0 and 1 (when it is close to 0, it means that a species dominates in the benthic community; when it equals to 1, all species have the same abundance). For many ecologists, a high fairness value is equivalent to a balanced community;
- EPT index (Ephemeroptera, Plecoptera and Trichoptera);

- This index is the sum of taxa in insects of the types Ephemeroptera, Plecoptera and Trichoptera, groups known to contain many polluted-sensitive taxa and which form the basis of biological methods for assessment of the aquatic environments quality. The relative abundance of Ephemeroptera, Plecoptera, and Trichoptera (EPT) was used to assess the ecological quality of the explored sites. This relative abundance is obtained by the ratio as a percentage, between the abundance of EPT and the total abundance of macroinvertebrates collected at a given sampling site. This metric was proposed by several authors (Baptista et al., 2007; Moya et al., 2007; Couceiro et al., 2012) as a powerful tool in the assessment of stream's quality. This metric increases with the quality of the explored environment.

Figure 2-3: Benthic macroinvertebrates sampling: (a) Macroinvertebrate collection session using the kick net; (b) Van Veen grab (Photo: KONAN K. Félix; April 2015)

2.3.3 Algal microflora

a) Extraction of phytoplankton and periphytic communities

The samples for the qualitative study of the phytoplankton and periphytic populations were collected using the plankton net of 20 μm mesh size, compositions of submerged plants and abrasions on submerged branches and stones on which a gelatinous or coloured coating suggests algal development at the sampling site (Figure 2-4**Error! Reference source not found.**).

For the sampling using plankton net, surface water samples were collected using a bucket of 6 litres and the microalgae collected by filtration (which is a means of concentrating organisms) and kept in a labelled box.

To collect the periphyton, a handful of plants growing in the water was torn off and then strongly pressed by rubbing between two hands in a bucket of water to loosen the epiphytic microalgae. A portion of the periphytic communities contained in the bottom of the bucket was then put into a container. Microalgae on rocks or pieces of wood, were scraped using a toothbrush and put in a box with a little quantity of water. All samples were subsequently fixed with 90% alcohol for the laboratory analyses.

Figure 2-4: ***Sampling sessions: (a) using the hydrologic bottle, and (b) using the filtration bottle (Photo: KONAN K. Félix; April 2015)***

b) Microalgae observation

Non-siliceous algae

For the observation of phytoplankton and periphytic taxa, a few drops of sample were placed between a slide and a coverslip, and observed under a microscope of Leica CME type. The observed taxa were measured and photographed using a trademark Amscope S/N C1107201525 coupled to a computer.

Siliceous algae (diatoms)

Diatoms require specific preparations in order to reveal the fine structures or ornamentation. The method of preparation of Rumeau & Coste (1988) was used. To do this, a sub-sample was homogenized and placed in a glass tube. An equal volume of nitric acid (40° Baumé) was added, and this mixture brought to a boiling point on a hot plate until complete elimination of the organic matters (Leclercq & Maquet, 1987). The resulting preparation after cooling was centrifuged five times at a minimum speed of 1 500 rpm for 15 minutes, to collect the pellet containing the frustules. It is important to mention that the second and third centrifugation were realised after adding distilled water, to eliminate nitric acid. The supernatant acid was eliminated and the recovered pellet has been re-suspended in distilled water. A few drops of this solution was deposited on a glass and dried on a hot plate to have a homogeneous distribution of diatoms (Leclercq & Maquet, 1987; Rumeau & Coste, 1988; Prygiel Coste, 2000). The lamellas were observed under the microscope (magnification 10x) to ensure a homogeneous distribution of diatoms. When the distribution was homogeneous, a drop of Naphrax (index of refraction approximately 1.7) was deposited on the slide. The placement of slides on a hot plate (of temperature 100 °C) was made to accelerate evaporation of the toluene contained in the Naphrax solution, which allows a more rapid hardening of the resin. Subsequently, all (slide and coverslip) was removed and placed on a flat surface and a slight pressure was immediately applied on the coverslip to remove air bubbles (Prygiel & Coste, 2000). Diatoms were subsequently observed, photographed and measured microscopically using oil immersion under 100 x objective.

c) Microalgae identification and counting

The identification at the specific and infraspecific level was carried out following several authors. Among them, general studies were completed by Thienemann (1950, 1955), Bourrelly (1966, 1968) and Compère (1975, 1989). Others, on the other hand, were more specialized in their themes addressed, such as those of Desikachary (1959), Anagnostidis & Komárek (1988), Compère (1974, 1986), and Komárek & Anagnostidis (1989, 1999, 2005) consulted for Cyanobacteria, Förster (1964), Philipose (1967), Compère (1977), Couté & Iltis (1981), Komárek & Fott (1983) and Uherkovich (1995) used for Chlorophyta, Von Stosch (1969) for Dinoflagellés, Carter & Denny (1982), Krammer & Lange-Bertalot (1986, 1988, 1991a,b), Cocquyt (1998), Prygiel & Coste (2000), Taylor et al. (2007) used for the determination of diatoms. The works of Marin *et al*., (2003) was used for Euglenophyta. Phytoplankton density was obtained using a Malassez cell.

d) Cross-validation of siliceous algae (diatoms) results

Additional samples were taken at sites B1, B3, B5, B9, B12 and B13 for further diatom analysis, and send to a laboratory (Ecotone) in South Africa.

Diatom laboratory procedures were carried out according to the methodology described by Taylor *et al.* (2005). Diatom samples were prepared for microscopy by using the hot hydrochloric acid and potassium permanganate method. Approximately 300 to 400 diatom valves were identified and counted to produce semi-quantitative data for analysis. Prygiel et al. (2002) found that diatom counts of 300 valves and above were necessary to make correct environmental inferences. Environmental preferences were inferred from Taylor *et al.* (2007) and various other literature sources as indicated in the discussion section to describe the environmental water quality at each site.

Two indices, namely the Specific Pollution sensitivity Index (SPI; CEMAGREF, 1982) and the Biological Diatom Index (BDI; Lenoir & Coste, 1996) were used in the diatom assessment. The SPI has been extensively tested in a broad geographical region and integrates impacts from organic material, electrolytes, pH, and nutrients. In addition, the Percentage of Pollution Tolerant Valves (% PTV; Kelly & Whitton, 1995) was used to indicate organic pollution. All calculations were computed using OMNIDIA ver. 4.2 program (Lecointe *et al*., 1993).

The limit values and associated ecological water quality classes adapted from Eloranta & Soininen (2002) were used for interpretation of the SPI and BDI scores (Table 2-3). The SPI and BDI indices are based on a score between 0 – 20, where a score of 20 indicates no pollution and a score of zero indicates an increasing level of pollution or eutrophication. The %PTV has a maximum score of 100, where a score above 0 indicates no organic pollution and a score of 100 indicates definite and severe organic pollution (Table 2-4**Error! Reference source not found.**).

Table 2-3: Class values used for the SPI and BDI indices in the evaluation of water quality (adapted from Eloranta & Soininen, 2002)

Index Score	Class
>17	**High quality**
13 to 17	**Good quality**
9 to 13	**Moderate quality**
5 to 9	**Poor quality**
<5	**Bad quality**

Table 2-4: Interpretation of the %PTV scores (adapted from Kelly, 1998)

%PTV	Interpretation
<20	Site free from organic pollution.
21 to 40	There is some evidence of organic pollution.
41 to 60	Organic pollution likely to contribute significantly to eutrophication.
>61	Site is heavily contaminated with organic pollution.

e) Trophic level calculation methods

The calculation methods are based on the review of the phytoplankton population, for which the absence of a number of organisms is as significant as their presence. Nygaard (1949) proposed several indexes, the most used one is the composite index. This index involves calculating the ratio between the number of species of four groups of typical algae of eutrophic conditions (Cyanophyceae, Chlorococcales, Centrales, Euglenophyceae) and the number of species of a typical group of oligotrophic conditions (Desmidiceae):

A = (Cyanophytes + Chlorococcales + Centrales + Euglenophyceae) / Desmidiaceae

A = composite index;

0.3 < A < 1 = Oligotrophic conditions

1 < A < 2.5 = Mesotrophic conditions

2.5 < A < 5 = Eutrophic conditions

A second index B is generally used to recognize the type of trophic level. It is based on the ratio of the number species of Chlorococcales and Desmidiaceae present in a water body.

B = (Chlorococcales) / Desmidiaceae

B < 1 = Oligotrophic conditions

B > 1 = Eutrophic conditions

The third index used, index C, involves Diatoms and the ratio of the number of Centrales species over the number of Pennales:

C = (Centrales) / Pennales

0 < C < 0.2 = Oligotrophic environment

0.2 < C < 3 = Eutrophic environment

2.3.4 Physical Chemistry

Each sampling site was geo-referenced and characterized by measuring water temperature, pH, conductivity and dissolved solids rate with a mobile multimeter (Hanna Combo pH EC). The colour of the water, the canopy and the nature of the substrate were assessed visually for each of these sites by the same observer (Gordon *et al.*, 1994; Arab *et al.*, 2004; Rios & Bailey, 2006). The canopy and the substrate composition were expressed as percentage of coverage of the site (Gordon *et al.*, 1994; Arab *et al.*, 2004; Rios & Bailey, 2006).

Photographs in the field were taken with a digital camera (*Olympus VR-350 / 16MP*).

3.0 RESULTS

3.1 Ichtyofauna

3.1.1 Ichthyological fauna diversity

Table 3-1 provides the general lists of the encountered fish species, their conservation status according to the IUCN, and their area of distribution.

A total of 64 species belonging to 35 genera, 16 families and 6 orders were observed across the 13 sampled sites.

The observed orders are composed as follows: Siluriforms (5 families, 9 genera and 17 species), Perciforms (4 families, 10 genera and 16 species), Characiforms (3 families, 5 genera and 8 species), Osteoglossiforms (2 families, 7 genera and 11 species), Cypriniforms (1 family, 3 genera and 10 species), and Clupeiforms (1 family, 1 genus and two species) (Figure 3-1).

At the level of families, the most diverse in terms of fish species richness are, in descending order, the Cichlidae (7 genera and 10 species), Mormyridae (6 genera and 10 species), Cyprinidae (3 genera and 10 species), Alestidae (3 genera and 6 species), Clariidae (2 genera and 5 species), Mochokidae (2 genera and 4 species), Claroteidae (2 genera and 4 species), Schilbeidae (2 genera and 3 species) and Clupeidae (1 genus and two species) (Figure 3-2). Seven other families (Hepsetidae, Distichodontidae, Anabantidae, Notopteridae, Channidae, Amphiliidae and Latidae) are represented by only a genus and a species each.

The most commonly observed species in the 13 sample sites as a whole are: *Auchenoglanis biscutatus, Auchenoglanis occidentalis, Barbus ablabes, Barbus macrops, Brycinus imberi, Brycinus longipinnis, Brycinus macrolepidotus, Brycinus nurse, Chromidotilapia guntheri, Chrysichthys maurus, Chrysichthys nigrodigitatus, Hemichromis fasciatus, Heterobranchus longifilis, Oreochromis niloticus, Sarotherodon galilaeus, Synodontis schall, Tilapia guineensis, Tilapia zillii* (Table 3-2**Error! Reference source not found.**). The following species were captured only in a single site : *Clarias anguilaris* (site B1), *Barbus wurtzi* (site B11), *Brienomyrus brachyistius* (site B12), *Distichodus rostratus, Hepsetus odoe, Hydrocynus forskalii, Lates niloticus, Marcusenius furcidens, Marcusenius senegalensis, Marcusenius ussheri, Mormyrops anguilloides, Mormyrus rume, Mormyrus subundulatus, Papyrocranus afer, Parailia pellucida,, Pollimyrus isidori* and *Schilbe intermedius* (site B10) (Table 3-2).

In this study, the largest number of species (44) was sampled at site B10. Only one species was recorded at site B5 and no species were captured at sites B4, B13 and B14 (Table 3-2).

Overall, 52 species of fish were observed in the main course of the Bandama river, compared to 36 recorded for the Kossou Lake, and 14 in the tributaries and shallow areas of the study area. No species were collected at site B4 which is an old gold mine pit.

The most heavily fished species consist of *Tilapia* spp., *Chrysichthys* spp. and *Brycinus* spp.

Among the species collected, only the Cichlidae *Oreochromis niloticus* and the Latidae *Lates niloticus* were recorded as invasive introduced species. These species are of high economic value and grow very rapidly in all freshwater habitats where they are introduced.

N'Douba (2007) reported 43 species, compared to the 64 species observed during this study. The six following species reported by this author were not observed in this study: *Polypterus endlicheri, Mastacembelus nigromarginatus, Malapterurus electricus, Heterotis niloticus, Epiplatys etzeli* and *Epiplatys chaperi*. Taking into account the species observed in N'Douba study (2007), it is altogether 70 species of fish that are reported in Yaoure gold project's area.

The difference observed between the number of species reported for these two studies could be related to the fishing effort, the equipment and methods used, the sampling period and the surveyed areas. Indeed, our results are only concerning the beginning of the rainy season, and the zone of influence of the Yaoure Gold Project activities is only over a portion of approximately 10 km^2 of the Bandama river Basin. Only three types of capture instrument were used; gillnets, fish traps and electrical fishing. Moreover, artisanal fishing catches used gillnets, fish traps, cast nets, longline and seine fishing. As per Lévêque & Paugy (1999), each type of capture instrument has different species selectivity, and it is thus difficult to compare the results obtained by using different capture techniques. Besides, Malavoi & Souchon (1992), Kouamélan (1999), and Konan *et al.* (2006), report that the sampling period (e.g. day or night; low water season or flooding season) strongly impacts the fishing results.

The literature identifies 123 species of fish present in the Bandama River, representing 69 genera, 32 families and 13 orders (Daget & Iltis,1965; Daget *et al.,*1973; Planquette & Lemasson, 1975; Merona, 1981; Teugels *et al.,*1988; Traoré, 1996; Lacroix & Konan, 2002; Da Costa & Konan, 2005; N'Douba, 2007; Aliko *et al.,* 2010; Aboua *et al.*, 2012; Froese & Pauly, 2015), against 64 species encountered during the present survey, belonging to 35 genera, 16 families, and 6 orders.

Netherveless, this survey reports three species to add to the list of fish present in the Bandama River that were not documented in the literature previously. These are: *Tilapia busumana, Tilapia walteri* and *Pellonula vorax*. With this survey, the species richness of the Bandama is now at 127 fish species.

Table 3-1: IUCN status and distribution range of fish species reported in the Bandama River basin and those observed in this study (indicated in bold) (Daget & Iltis, 1965; Daget et al., 1973; Planquette & Lemasson, 1975 ; Mérona, 1981 ; Teugels et al., 1988; Traoré, 1996 ; Lacroix & Konan, 2002 ; Da Costa & Konan, 2005 ; N'douba, 2007 ; Aliko et al., 2010 ; Aboua et al., 2012 ; UICN, 2014 ; Froese & Pauly, 2015) (Table : KONAN K. Félix ; april 2015)

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
Characiforms	Alestidae	*Alestes baremoze*	(LC)	Low vulnerability (22%)	Africa: widely distributed
		Brycinus longipinnis	(LC)	Low vulnerability (12%)	Africa: widely distributed
		Brycinus macrolepidotus	(LC)	Moderate vulnerability (43%)	Africa: Intertropical
		Brycinus imberi	(LC)	Low vulnerability (10%)	Africa: widely distributed
		Brycinus nurse	(LC)	Low vulnerability (16%)	Africa: widely distributed
		Micralestes elongatus	Not Evaluated	Low vulnerability (10%)	Africa: widely distributed
		Micralestes occidentalis	(LC)	Low vulnerability (10%).	Africa: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Nigeria, Togo and Sierra Leone.
		Micralestes eburneensis	(NT)	Low vulnerability (10%).	Endemic to Côte d'Ivoire : endemic to the Cavally River, but might also exist in the Nipoué River
		Hydrocynus forskalii	(LC)	Moderate vulnerability (39%)	Africa: widely distributed
		Rhabdalestes septentrionalis	(LC)	Low vulnerability (10%).	Africa: from the Senegal to the Niger River in western Africa. Found in Cross and Wouri Rivers in Cameroon
		Rhexipanchax schioetzi	(LC)	Low vulnerability (11%).	West Africa: Ghana, Côte d'Ivoire, Liberia and southern Burkina Faso (Upper Volta).
	Hepsetidae	***Hepsetus odoe***	(LC)	Low vulnerability (16%).	Africa: widely distributed

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
Characiforms	Distichodontidae	***Distichodus rostratus***	(LC)	Moderate to high vulnerability (52%)	Africa: from Senegal to Chad basin, present in Nile and Cross River system
		Nannocharax ansorgii	(LC)	Low vulnerability (10%).	Africa: western and central Africa river systems
		Nannocharax fasciatus	(LC)	Low vulnerability (10%).	Africa: western and central Africa river systems
		Nannocharax occidentalis	(LC)	Low vulnerability (10%).	Africa: Niger River, Cross River and Chari-Logone
		Neolebias unifasciatus	(LC)	Low vulnerability (10%).	Africa: Widely distributed
	Citharinidae	*Citharinus eburneensis*	(NT)	Low vulnerability (16%).	Endemic of Côte d'Ivoire: known from coastal rivers. Known from the Bia, but has disappeared after the construction of Lake Ayamé.
Cypriniforms	Cyprinidae	***Barbus ablabes***	(LC)	Low vulnerability (22%)	Africa: widely distributed, present in Sudanese and coastal basins
		Barbus guildi	(DD)	Low vulnerability (13%).	Africa: known from the upper reaches of the River Hedjo (Volta basin) near the Togo and Ghanaian borders
		Barbus baudoni	(LC)	Low vulnerability (10%)	Africa: Chad, Volta, Gambia, Sassandra and Bandama basins in Côte d'Ivoire, Senegal and Niger. Reported from Benoué and Ubangi basins.
		Barbus bynni	(LC)	Moderate vulnerability (39%)	Africa: Nile system and West Africa (Chad, Niger, Senegal, Volta, Ouémé, Ogun, Sassandra, Bandama, Niouniourou, Comoé and Tano river basins).
		Barbus leonensis	(LC)	Low vulnerability (10%)	West Africa: present in large Sudanese basins, but also in Côte d'Ivoire and Sierra Leone
		Barbus macinensis	(LC)	Low vulnerability (12%)	Africa: widespread in the Sudanian region including the basins of the Chad, Niger, Senegal, Volta, Comoé, Bandama and Sassandra
		Barbus macrops	(LC)	Low vulnerability (23%)	Africa: widely distributed in West Africa. Present in DRC

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Barbus pobeguini	(LC)	Low vulnerability (10%)	West Africa: widely distributed
		Barbus punctitaeniatus	(LC)	Low vulnerability (10%)	West Africa: known from the basins of the Chad, Niger and Volta. Also reported from the coastal basins of Côte d'Ivoire and the Cross River in Cameroon
		Barbus stigmatopygus	(LC)	Low vulnerability (10%)	Africa: widely distributed in the Nilo-sudanian basins, and known from the Bandama, Comoé and Cross rivers
		Barbus sublineatus	(LC)	Low vulnerability (16%)	West Africa: known from Niger, Volta, Senegal, Gambia, Comoé, Bandama, Mono, Ouémé and Cross basins
		Barbus trispilos	(LC)	Low vulnerability (20%).	West Africa: basins of Guinea to Volta and in Nipoué (Côte d'Ivoire)
		Barbus wurtzi	(LC)	Moderate vulnerability (37%).	West Africa: widely distributed (from Konkouré to Volta)
		Clypeobarbus hypsolepis	(LC)	Low vulnerability (10%).	Africa: present in Upper Niger and known from the high basins of the Volta, Bandama, Agnébi and also in the Niger Delta in Nigeria
		Raiamas nigeriensis	(NT)	Low to moderate vulnerability (25%)	West Africa: mainly in Niger and Bénoué basins, also in Moa, Cavally, Sassandra, Bandama, Comoé (Côte d'Ivoire), Pra (Ghana), Cross (Nigeria)
		Raiamas senegalensis	(LC)	Low to moderate vulnerability (32%).	Africa: Nile, Chad, Niger, Gambie, Senegal, Volta, Sassandra, Bandama, Comoé, Tano, Pra, Ouémé, Ogun, Sanaga basins
		Labeo coubie	(LC)	Moderate vulnerability (39%).	Africa: widely distributed
		Labeo parvus	(LC)	Moderate to high vulnerability (51%).	Africa: widely distributed (from West Africa to DRC)
		Labeo senegalensis	(LC)	Moderate vulnerability (40%)	West Africa: Senegal, Volta, Niger-Benue, Chad, Gambia and Culufi rivers
Cyprinodontiforms	Poeciliidae	*Aplocheilichthys spilauchen*	(LC)	Low vulnerability (22%)	Africa: widely distributed from Senegal to Angola

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Micropanchax pfaffi	Not Evaluated	Low vulnerability (13%)	Africa: Sudan, Niger, Guinea, Côte d'Ivoire, Ghana, Burkina Faso, Chad and Cameroon. Known from Egypt and the Central African Republic
		Poropanchax normani	(LC)	Low vulnerability (12%)	Africa: widely distributed from Senegal to Angola
		Poropanchax rancureli	(LC)	Low vulnerability (15%)	West Africa: Tano (Ghana), Comoé, Banco, Boudo, Bia, Mé, Bandama, Sassandra and Cavally (Côte d'Ivoire). Recorded from Liberia
		Rhexipanchax schioetzi	(LC)	Low vulnerability (11%)	Africa: Ghana, Liberia, Burkina Faso, Côte d'Ivoire
	Nothobranchiidae	*Epiplatys olbrechtsi*	(LC)	Low vulnerability (10%)	West Africa: Liberia, Guinée, Côte d'Ivoire
		Epiplatys bifasciatus	(LC)	Low to moderate vulnerability (29%)	Africa: Senegal, Gambia, Guinea, Mali, Burkina Faso, Niger, Ghana, Togo, Benin, Nigeria, Cameroon, Chad, Central African Republic and Sudan. Reported from Côte d'Ivoire
		Epiplatys dageti	(LC)	Low vulnerability (10%)	West Africa: around Monrovia, Liberia over southern Côte d'Ivoire to southwestern Ghana
		Epiplatys etzeli	(EN)	Low vulnerability (10%)	West Africa: endemic to the area east of Abidjan around Lagoon Ono and Hébé, southern Côte d'Ivoire
		Epiplatys chaperi	(NT)	Low vulnerability (10%)	West Africa: Côte d'Ivoire, Ghana and Togo
		Epiplatys spilargyreius	(LC)	Low vulnerability (10%)	Africa: Senegal, Gambia, Guinea Bissau, Guinea, Mali, Burkina Faso, Côte d'Ivoire, Ghana, Benin, Niger, Nigeria, Chad, Cameroon, Central African Republic, DRC and Sudan
		Fundulopanchax walkeri	(NT)	Low vulnerability (10%)	West Africa: Bandama, Comoé and Bia river drainages in Côte d'Ivoire. The Bia, Tano, Ankobra and Oda river drainages in Ghana
		Nimbapanchax petersi	(VU)	Low vulnerability (10%)	West Africa: southern Côte d'Ivoire and southwestern Ghana.

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
Osteoglossiforms	Mormyridae	***Brienomyrus brachyistius***	(LC)	Low vulnerability (15%)	Africa: from Senegal to DRC.
		Marcusenius furcidens	(NT)	Low to moderate vulnerability (30%)	West Africa: endemic to Comoé, Bandama, Sassandra (Côte d'Ivoire) and also reported in Tanoe (Ghana)
		Marcusenius senegalensis	(LC)	Moderate vulnerability (36%)	West Africa: widely distributed in West Africa
		Marcusenius ussheri	(LC)	Moderate vulnerability (35%)	West Africa: from Liberia to Ghana, Benin.
		Mormyrops anguilloides	(LC)	Moderate to high vulnerability (47%)	Africa: basins of Nile, Lake Albert; from Senegal to Chad, Cameroun, coastal basins of Guinea.
		Mormyrops breviceps	(LC)	Moderate to high vulnerability (51%)	West Africa: Restricted to the Volta, rivers in Côte d'Ivoire, Ghana, Liberia and Guinea-Bissau
		Mormyrus hasselquistii	(LC)	Moderate vulnerability (44%)	Africa: Nile and Chad basins. Known from the great Sahelo-Soudanian basins in Senegal, Gambia and Volta; also in the Mono, the Gêba, the Bandama, the Comoe River, and the Ebrie and Aghien lagoons
		Mormyrus subundulatus	(EN)	Low to moderate vulnerability (29%)	West Africa: Known only from the Bandama River in Côte d'Ivoire and Tanoe River in Ghana.
		Mormyrus rume	Not Evaluated	High vulnerability (62%)	Africa: widely distributed
		Petrocephalus bovei	Not Evaluated	Low vulnerability (13%)	Africa: Chad, Niger, Volta, Gambia and Senegal basins, including the Nile. Also known from Côte d'Ivoire
		Pollimyrus isidori	Not Evaluated	Low vulnerability (12%)	Africa: basins of Gambie, Niger, Volta, Chad, Nile Côte d'Ivoire (Sassandra, Bandama, Mé).
	Notopteridae	***Papyrocranus afer***	(LC)	Moderate vulnerability (38%)	West Africa: basins of Niger, Coastal Rivers from Senegal to Ghana.
	Arapaimidae	*Heterotis niloticus*	(LC)	Moderate to high vulnerability (55%)	Africa: Native in Sahelo-Sudanese region. Introductions in Côte d'Ivoire; the Cross, Sanaga, Nyong and Ogowe rivers and Congo

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
					basin, including Ubangui and Kasaï; in Madagascar.
Perciforms	Cichlidae	***Hemichromis bimaculatus***	(LC)	Low vulnerability (20%)	Africa: widely distributed
		Hemichromis fasciatus	(LC)	Low vulnerability (14%)	Africa: widely distributed in West Africa. Also reported in Nile, Chad and Zambezi
		Chromidotilapia guntheri	(LC)	Low vulnerability (20%)	Africa: Coastal basins from Liberia to Cameroon and Equatorial Guinea ; reported in Niger and Bénoué basins
		Thysochromis ansorgii	(LC)	Low vulnerability (12%)	Africa: from coastal basins in Ivory Coast to forested coastal lowlands in Nigeria including the Ouémé in Benin. Also in the Ogooué basin in Gabon and the Kouilou-Niari in Republic of Congo
		Tilapia zillii	Not Evaluated	Low to moderate vulnerability (27%)	Africa and Eurasia: widely distributed
		Tilapia guineensis	(LC)	Low vulnerability (19%)	Africa: from Senegal to Angola
		Tilapia walteri	(NT)	Low to moderate vulnerability (27%)	West Africa: Cavally, Nipoué and St. John (Cess) Rivers in Côte d'Ivoire and in Liberia
		Tilapia mariae	(LC)	Low to moderate vulnerability (28%)	Africa: coastal lagoons and lower river courses from the Tabou River (Côte d'Ivoire) to the Kribi River (Cameroon), but absent from the area between the Pra River (Ghana) and Benin. Also recorded from the lower Ntem, Cameroon
		Tilapia busumana	(VU)	Low vulnerability (25%)	West Africa: Côte d'Ivoire and Ghana (Bia, Tanoe, Pra, Lake Bosumtwi)
		Tilapia dageti	(LC)	Low to moderate vulnerability (33%)	Africa: Upper Senegal, upper and middle Niger system, upper Comoe, Volta, Mono, Bénoué and Lake Chad
		Tilapia hybride			

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Tylochromis jentinki	(LC)	Low vulnerability (22%)	West Africa: coastal rivers from Gambia to the Tanoe River in Ghana
		Sarotherodon galilaeus	Not Evaluated	Low to moderate vulnerability (28%)	Africa and Eurasia: widely distributed
		Sarotherodon melanotheron	Not Evaluated	Low vulnerability (16%)	Africa and Eurasia: widely distributed
		Oreochromis niloticus	Not Evaluated	Low to moderate vulnerability (34%)	Africa and Eurasia: widely distributed
	Channidae	*Parachanna obscura*	Not Evaluated	Moderate vulnerability (43%)	Afrique: Nile and from Senegal to Chad system.
	Anabantidae	***Ctenopoma petherici***	(LC)	Low to moderate vulnerability (34%)	Africa: Widely distributed (from Senegal to DRC)
		Ctenopoma kingsleyae	(LC)	Moderate vulnerability (35%)	Africa: Widely distributed (from Senegal to DRC)
Perciforms	Gobiidae	*Awaous lateristriga* ≠	Not Evaluated	Moderate vulnerability (36%)	Eastern Atlantic: St. Louis, Senegal to the Cunene River, Angola and from the islands of Gulf of Guinea. Reported from the East Coast drainage of Africa
		Nematogobius maindroni ≠	Not Evaluated	Low vulnerability (20%)	Eastern Atlantic: Senegal to Gulf of Guinea and offshore islands. Reported as far as Angola
		Parasicydium bandama	(LC)	Low vulnerability (13%)	Africa: Known from the type locality, Bandama River in Côte d'Ivoire. Known from the Lokunje in Cameroon and the Kouilou basin in Congo
		Periophthalmus barbarus	(LC)	Low to moderate vulnerability (25%)	Africa: Senegal to Angola
	Carangidae	*Caranx hippos* ≠	Not Evaluated	High vulnerability (58%)	Eastern Atlantic: Portugal to Angola, including the western Mediterranean. Western Atlantic: Nova Scotia, Canada and northern Gulf of Mexico to Uruguay, including the Greater Antilles

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Trachinotus teraia ≠	Not Evaluated	Moderate vulnerability (37%)	Eastern Atlantic: Senegal to Gabon, including Cape Verde.
	Eleotridae	*Eleotris vittata* ≠	Not Evaluated	Low to moderate vulnerability (31%)	Eastern Atlantic: Senegal to Angola and the islands of the Gulf of Guinea.
		Kribia nana	(LC)	Low vulnerability (10%)	Africa: Nile River, Lake Chad, and Congo River systems. Also known from the Niger basin and from Guinea to the Cross River in Nigeria
	Gerreidae	*Eucinostomus melanopterus* ≠	Not Evaluated	Low vulnerability (24%)	Eastern Atlantic: Mauritania to Angola. Western Atlantic: Bermuda and Florida, USA to Brazil; not found in the Bahamas.
	Polynemidae	*Polydactylus quadrifilis* ≠	Not Evaluated	High to very high vulnerability (69%)	Eastern Atlantic: Senegal to Congo. Reported from Mauritania
	Latidae	***Lates niloticus***	(LC)	Moderate to high vulnerability (47%)	Africa: Widely distributed
Siluriforms	Claroteidae	***Auchenoglanis occidentalis***	(LC)	Moderate vulnerability (38%)	Africa: present in most rivers of West Africa, Lake Chad, the entire Congo River system, the Nile, East African lakes, and the rivers Omo and Giuba
		Auchenoglanis biscutatus	(LC)	Moderate to high vulnerability (48%)	Africa: present in the Senegal, Gambia, Niger and Chad basins and in the Nile and Lake Turkana
		Chrysichthys maurus	(LC)	Moderate to high vulnerability (46%)	West Africa: Rivers of Côte d'Ivoire, Guinea, Bissau Guinea, Sierra Leone, Liberia Senegal, Ghana
		Chrysichthys nigrodigitatus	(LC)	Low to moderate vulnerability (32%)	Africa: from Senegal to Angola. Mauritania, lower Congo
	Clariidae	***Clarias anguilaris***	(LC)	Moderate to high vulnerability (54%)	Africa: from Senegal to Angola. Mauritania, lower Congo. Reported in the Nile
		Clarias ebriensis	(LC)	Low to moderate vulnerability (26%)	West Africa: from Côte d'Ivoire to Nigeria.
		Clarias laeviceps	Not Evaluated	Low to moderate vulnerability (26%)	West Africa: from St. Paul (Liberia) to Volta (Ghana); from Fouta Dialon (Guinea) to Sierra Leone.

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Clarias buettikoferi	(LC)	Low vulnerability (16%)	Africa: Upper Gambia up to the Agnebi river in Côte d'Ivoire. Reported from Ghana.
		Clarias gariepinus	(LC)	Very high vulnerability (79%)	Africa and Eurasia: Widely distributed.
		Clarias lamottei	(NT)	Low vulnerability (15%)	Endemic to Côte d'Ivoire: Nzi River, tributary of the Bandama
		Heterobranchus isopterus	(LC)	Moderate to high vulnerability (50%)	West Africa: Coastal basins of Guinée (Konkouré) to Nigeria (Cross River).
		Heterobranchus longifilis	(LC)	High to very high vulnerability (69%)	Africa: Nile, Niger, Senegal, Congo, Zambezi, Gambia, Benue, Volta. Coastal basins from Guinéa to Nigeria. Lakes Tanganyika, Edward et Tchad.
	Mochokidae	***Chiloglanis occidentalis***	(LC)	Low vulnerability (10%)	West Africa : Widely distributed
		Synodontis koensis	(NT)	Low vulnerability (15%)	Endemic of Côte d'Ivoire : Nzo basin
		Synodontis punctifer	(LC)	Low vulnerability (24%)	Endemic to Côte d'Ivoire : rivières Nzo, Sassandra and Bandama
		Synodontis bastiani	(LC)	Low vulnerability (25%)	Endemic to Côte d'Ivoire : Sassandra, Bandama, Comoé and Agnébi
		Synodontis schall	(LC)	High vulnerability (65%)	West Africa : Widely distributed
		Synodontis velifer	(LC)	Low vulnerability (23%)	West Africa: Sassandra and Bandama basins in Côte d'Ivoire; Volta basins. Reported from Pra, Ghana
	Schilbeidae	***Schilbe intermedius***	(LC)	High vulnerability (63%)	West Africa : Widely distributed
		Schilbe mandibularis	(LC)	Moderate to high vulnerability (52%)	West Africa : Widely distributed

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
		Schilbe mystus	(LC)	Low to moderate vulnerability (33%)	West Africa : Widely distributed
		Parailia pellucida	(LC)	Low vulnerability (22%)	Africa: From upper course of Nile to West Africa.
	Amphiliidae	***Amphilius atesuensis***	(LC)	Low to moderate vulnerability (35%)	West Africa : Libéria, Togo, Guinea, Mali
	Malapteruridae	*Malapterurus electricus*	(LC)	High to very high vulnerability (74%)	Africa: Nile system, Lake Turkana, Lake Chad and Senegal basins, Niger system, and in smaller southward flowing basins in west Africa (rivers Bandama through Volta)
Clupeiforms	Clupeidae	***Pellonula leonensis*** ≠	Not Evaluated	Low vulnerability (11%)	Africa: lagoons, lakes, rivers from Senegal to Cameroon.
		Pellonula vorax ≠	(LC)	Low vulnerability (14%)	Africa: From Liberia to Angola including Congo
		Laeviscutella dekimpei	(LC)	Low vulnerability (10%)	Africa: Casamance River in Senegal to Democratic Republic of the Congo
Polypteriforms	Polypteridae	*Polypterus endlicheri*	Not Evaluated	Moderate to high vulnerability (48%)	Africa: Nile River, Chad basin, Niger River, Volta River, Bandama River, upper Comoé River and Ouémé River
Synbranchiforms	Mastacembelidae	*Mastacembelus nigromarginatus*	(LC)	Low to moderate vulnerability (32%)	West Africa: wide distribution (from Cavally to Volta)
Elopiforms	Elopidae	*Elops lacerta* ≠	(LC)	Moderate vulnerability (42%)	Eastern Atlantic: coastal waters from Mauritania to Angola or Namibia. Sometimes entering freshwater, like in Cross River and Kouilou-Niari.
Syngnathiforms	Syngnathidae	*Enneacampus kaupi*	(LC)	Low vulnerability (20%)	Africa: Liberia to the Congo River estuary, DRC. Records of a specimen from marine waters off Punta Durnford are questionable.
		Microphis brachyurus	Not Evaluated	Low to moderate vulnerability (27%)	Africa, Eurasia, Oceania and América: Widely distributed
Mugiliforms	Mugilidae	*Liza falcipinnis* ≠	Not Evaluated	Moderate to high vulnerability (48%)	Africa: Mauritania to the Congo River and Angola

Order	Family	Species	Conservation status[1]	Vulnerability[2]	Distribution area[3]
Lepidosireniforms	Protopteridae	*Protopterus annectens*	(LC)	Moderate vulnerability (42%)	West Africa : Widely distributed

*(Daget & Iltis,1965; Daget *et al.*,1973; Planquette & Lemasson,1975; Merona,1981 ; Teugels *et al.*,1988; Traoré, 1996 ; Lacroix & Konan, 2002 ; Da Costa & Konan, 2005 ; N'Douba, 2007 ; Aliko *et al.,* 2010 ; Aboua *et al.*, 2012 ; Froese & Pauly, 2015) *(Table : KONAN K. Félix ; April 2015).*

ᵻ (species with estuarine / marine affinities)

[1]*Conservation Status: LC=Least Concern; DD=Data deficient; NT=Near Threatened; VU=Vulnerable; EN=Endangered*

[2]*Vulnerability: Intrinsic vulnerability reflects the inherent ability of the fish fauna to withstand fishing mortality (Cheung et al., 2005; Froese & Pauly, 2015).*

[3]*Distribution: based on FishBase (Froese & Pauly, 2015).*

Figure 3-1: Number of fish taxa encountered according to their order in the Bandama basin of the Yaoure Gold Project

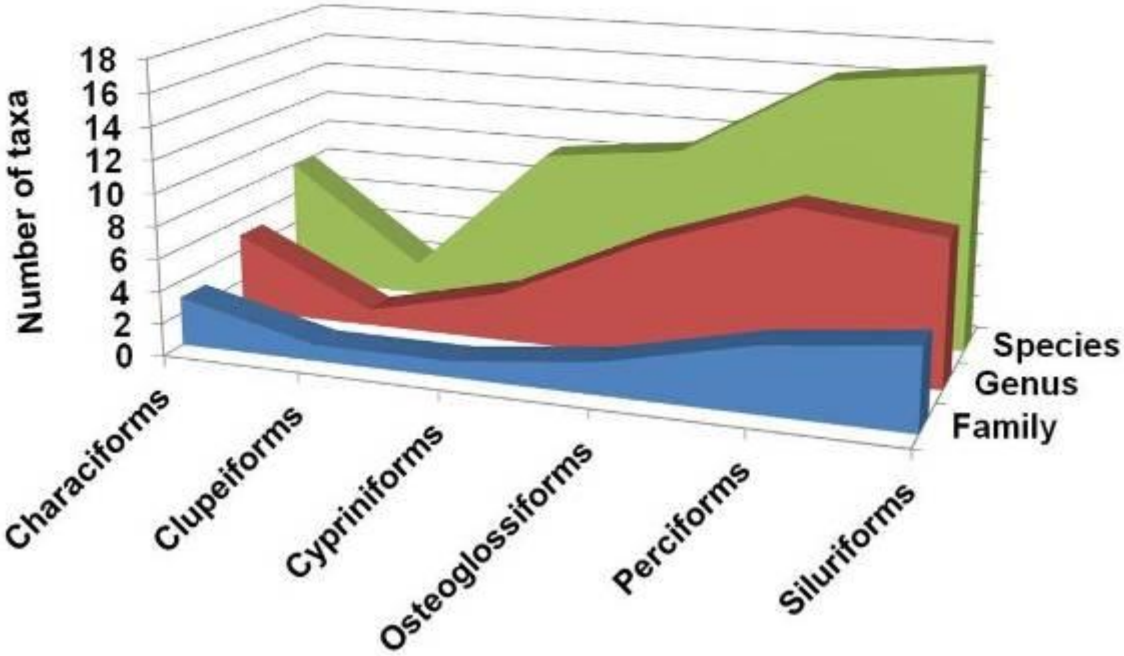


Figure 3-2: Number of fish taxa encountered according to their family in the Bandama basin of the Yaoure Gold Project

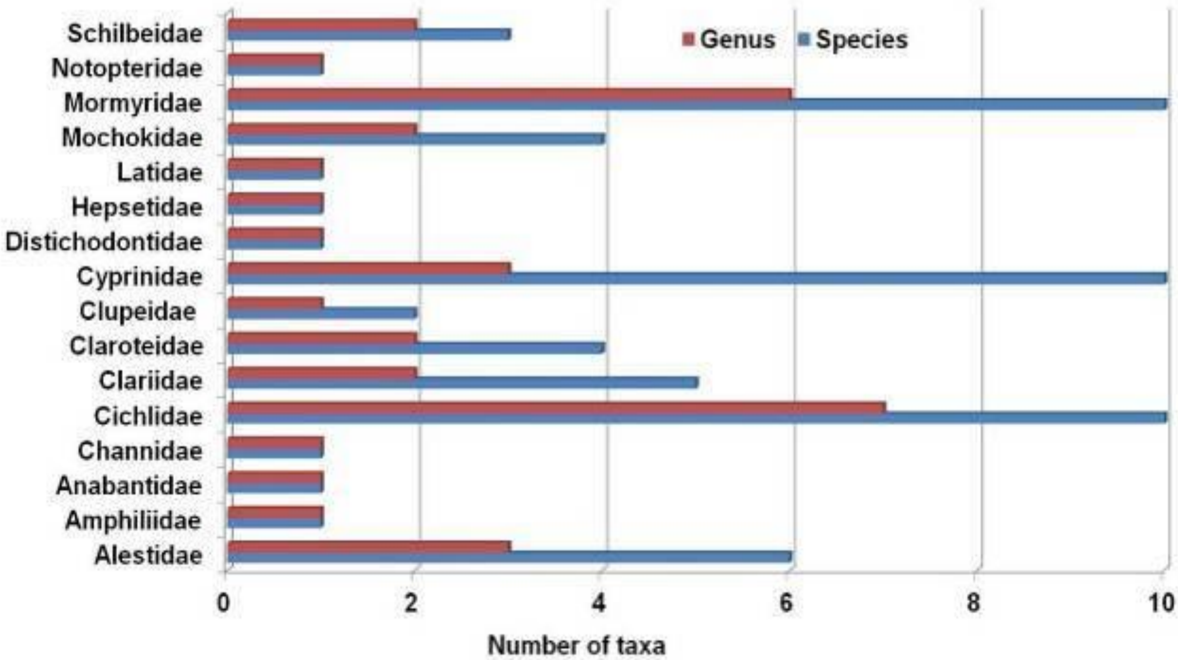


Table 3-2: Comparison of the spatial distribution of fish species encountered in the Bandama River basin's area of influence in this study and in N'Douba 2007(Froese & Pauly, 2015; IUCN, 2014) (Table: KONAN K. Félix; April 2015).

Species	Conservation status	Lake Kossou			Bandama River				Tributaries of Bandama					Former gold mine	This study	N'Douba (2007)
		B1	B2	B11	B5	B6	B7	B10	B3	B9	B12	B13	B14	B4		
Amphilius atesuensis	Least Concern (LC)	-	-	-	-	-	-	-	1	1	1	-	-	-	1	1
Auchenoglanis biscutatus	Least Concern (LC)	1	1	1	-	-	-	1	-	-	-	-	-	-	1	-
Auchenoglanis occidentalis	Least Concern (LC)	1	1	-	-	1	-	1	-	-	-	-	-	-	1	1
Barbus ablabes	Least Concern (LC)	-	1	1	-	-	-	-	1	1	1	-	-	-	1	1
Barbus macrops	Least Concern (LC)	1	1	-	-	-	-	-	1	-	1	-	-	-	1	1
Barbus pobeguini	Least Concern (LC)	-	-	1	-	-	-	-	-	-	1	-	-	-	1	-
Barbus punctitaeniatus	Least Concern (LC)	-	1	1	-	-	-	-	1	-	1	-	-	-	1	-
Barbus sublineatus	Least Concern (LC)	-	-	1	-	-	-	-	1	-	-	-	-	-	1	-
Barbus trispilos	Least Concern (LC)	-	-	-	-	-	-	-	1	1	1	-	-	-	1	1
Barbus wurtzi	Least Concern (LC)	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
Brienomyrus brachyistius	Least Concern (LC)	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Brycinus imberi	Least Concern (LC)	1	-	1	-	1	-	1	-	-	-	-	-	-	1	1
Brycinus longipinnis	Least Concern (LC)	1	1	1	-	1	-	1	-	-	-	-	-	-	1	1
Brycinus macrolepidotus	Least Concern (LC)	1	1	1	-	1	-	1	-	-	-	-	-	-	1	1
Brycinus nurse	Least Concern (LC)	-	1	1	-	1	-	1	-	-	-	-	-	-	1	-
Chiloglanis occidentalis	Least Concern (LC)	-	-	-	-	-	-	-	1	1	1	-	-	-	1	-
Chromidotilapia guntheri	Least Concern (LC)	-	1	1	-	1	-	1	-	-	-	-	-	-	1	1
Chrysichthys maurus	Least Concern (LC)	1	1	-	-	1	-	1	-	-	-	-	-	-	1	1
Chrysichthys nigrodigitatus	Least Concern (LC)	1	1	-	-	1	-	1	-	-	-	-	-	-	1	1
Clarias anguilaris	Least Concern (LC)	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Clarias gariepinus	Least Concern (LC)	1	-	-	-	-	-	1	-	-	-	-	-	-	1	-

Species	**Conservation status**	**Lake Kossou**			**Bandama River**				**Tributaries of Bandama**					**Former gold mine**	**This study**	**N'Douba (2007)**
		B1	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B3**	**B9**	**B12**	**B13**	**B14**	**B4**		
Clarias laeviceps	Not Evaluated	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-
Ctenopoma petherici	Least Concern (LC)	-	-	-	-	-	-	1	-	1	-	-	-	-	1	1
Distichodus rostratus	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Epiplatys chaperi	Near Threatened (NT)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Epiplatys etzeli	Endangered (EN)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Hemichromis bimaculatus	Least Concern (LC)	-	1	1	-	-	-	-	1	-	-	-	-	-	1	1
Hemichromis fasciatus	Least Concern (LC)	1	1	1	-	1	-	1	1	1	-	-	-	-	1	1
Hepsetus odoe	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Heterobranchus isopterus	Least Concern (LC)	-	-	-	-	-	-	-	1	-	1	-	-	-	1	1
Heterobranchus longifilis	Least Concern (LC)	-	-	-	-	-	-	1	1	1	1	-	-	-	1	-
Heterotis niloticus	Least Concern (LC)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Hydrocynus forskalii	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Labeo coubie	Least Concern (LC)	-	-	1	-	1	-	1	-	-	-	-	-	-	1	1
Labeo parvus	Least Concern (LC)	-	-	-	-	1	-	1	-	-	-	-	-	-	1	1
Lates niloticus	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Malapterurus electricus	Least Concern (LC)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Marcusenius furcidens	Near Threatened (NT)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Marcusenius senegalensis	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Marcusenius ussheri	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Mastacembelus nigromarginatus	Least Concern (LC)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Micralestes occidentalis	Least Concern (LC)	-	-	1	-	-	-	1	-	-	-	-	-	-	1	-
Mormyrops anguilloides	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Mormyrops breviceps	Least Concern (LC)	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-

Species	Conservation status	Lake Kossou			Bandama River				Tributaries of Bandama					Former gold mine	This study	N'Douba (2007)
		B1	B2	B11	B5	B6	B7	B10	B3	B9	B12	B13	B14	B4		
Mormyrus rume	Not Evaluated	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Mormyrus subundulatus	Endangered (EN)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Oreochromis niloticus	Not Evaluated	1	1	1	-	1	-	1	-	-	-	-	-	-	1	1
Papyrocranus afer	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
Parailia pellucida	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Pellonula leonensis	Not Evaluated	1	1	1	-	-	-	-	-	-	-	-	-	-	1	1
Pellonula vorax	Least Concern (LC)	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-
Petrocephalus bovei	Not Evaluated	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1
Pollimyrus isidori	Not Evaluated	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Polypterus endlicheri	Not Evaluated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Raiamas nigeriensis	Near Threatened (NT)	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-
Raiamas senegalensis	Least Concern (LC)	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-
Sarotherodon galilaeus	Not Evaluated	1	1	1	-	-	-	1	-	-	-	-	-	-	1	1
Schilbe intermedius	Least Concern (LC)	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Schilbe mandibularis	Least Concern (LC)	-	-	-	1	-	1	1	-	-	-	-	-	-	1	1
Synodontis bastiani	Least Concern (LC)	-	1	-	-	1	-	1	-	-	-	-	-	-	1	1
Synodontis punctifer	Least Concern (LC)	-	1	-	-	-	-	1	-	-	-	-	-	-	1	1
Synodontis schall	Least Concern (LC)	-	-	-	-	6	-	1	-	-	-	-	-	-	1	1
Thysochromis ansorgii	Least Concern (LC)	-	1	1	-	1	-	-	-	-	-	-	-	-	1	-
Tilapia busumana	Vulnerable (VU)	1	1	-	-	1	-	-	-	-	-	-	-	-	1	-
Tilapia guineensis	Least Concern (LC)	1	1	1	-	1	-	1	-	-	-	-	-	-	1	1
Tilapia hybride	Not listed	1	1	1	-	-	-	-	-	-	-	-	-	-	1	1
Tilapia mariae	Least Concern (LC)	-	1	1	-	-	-	-	-	-	-	-	-	-	1	-

Species	**Conservation status**	**Lake Kossou**			**Bandama River**				**Tributaries of Bandama**					**Former gold mine**	**This study**	**N'Douba (2007)**
		B1	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B3**	**B9**	**B12**	**B13**	**B14**	**B4**		
Tilapia walteri	Near Threatened (NT)	-	1	1	-	-	-	-	-	-	-	-	-	-	1	-
Tilapia zillii	Not Evaluated	1	-	1	-	1	-	1	-	-	-	-	-	-	1	1
Tylochromis jentinki	Least Concern (LC)	1	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Total by site		**20**	**26**	**24**	**1**	**25**	**3**	**44**	**11**	**7**	**10**	**0**	**0**	**0**	**64**	**43**
Total by sector		**36**			**52**				**14**					**0**		

3.1.2 Conservation Status of the various fish species encountered

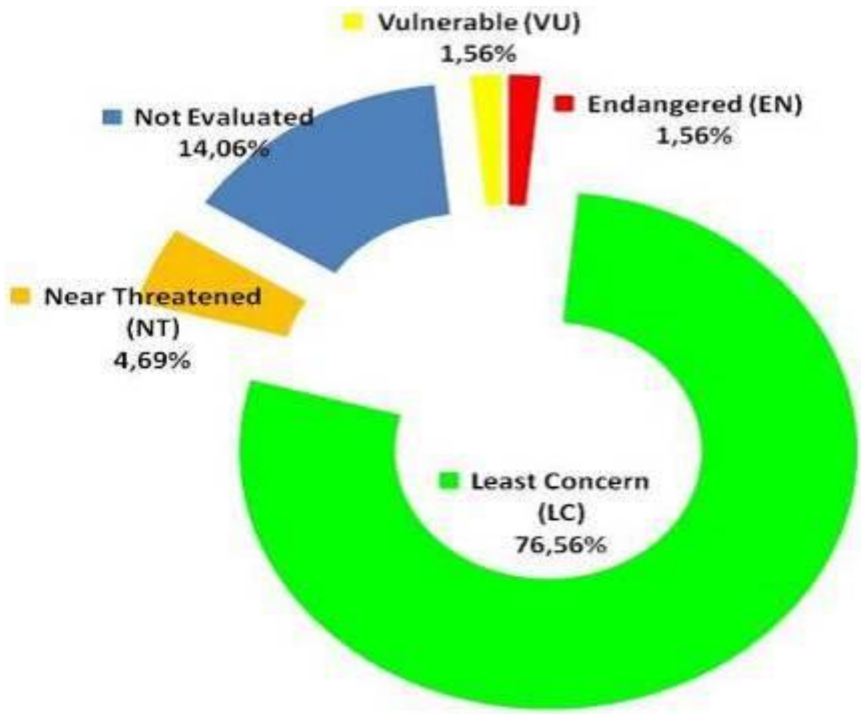
The fish species observed during this survey can be divided into five groups (Not Evaluated, Least Concern (LC), Vulnerable (VU), Endangered (EN) and Near Threatened (NT)) as per the International Union for Conservation Nature (IUCN) classification based on their conservation status (Table 3-1**Error! Reference source not found.**).

From the 64 taxa identified up to species level during this survey, one (i.e. 1.56%) species (*Tilapia hybrid*) does not have a status in the IUCN database, and 9 species (i.e. 14.06 %) have not been subject to any evaluation yet by the IUCN (Figure 3-3). The 49 species described by the IUCN as least concern (LC) represent 76.56 % of the observed total species richness. The five species appearing on the red list of the IUCN and bearing an importance for conservation are the following (Table 3-1 and Table 3-2):

- 1 Vulnerable species (VU): *Tilapia busumana* (Cichlidae) (B1, B2 & B6);
- 1 Endangered species (EN): *Mormyrus subundulatus* (Mormyridae) (B10);
- 3 Near Threatened species (NT): *Raiamas nigeriensis* (Cyprinidae) (B6 & B10), *Marcusenius furcidens* (Mormyridae) (B10) and *Tilapia walteri* (Cichlidae) (B2 & B11).

These five species represent 7.81 % of the total observed species richness observed during this survey, and 9.25 % of the number of taxa whose conservation status has been assessed by the IUCN.

Figure 3-3: Distribution of the species encountered based on their conservation status within the Basin of Bandama in the Yaoure Gold Project area.



3.1.3 Vulnerability of the fish fauna

Cheung *et al.* (2005) present an expert system that integrates life history and ecological characteristics of fishes to estimate their intrinsic vulnerability to fishing. It is a good predictor of rate of population decline. This intrinsic vulnerability that reflects the inherent ability of the fish fauna to withstand mortality allowed the division of the observed species from the portion of Bandama Basin into seven groups surveyed (Table 3-1**Error! Reference source not found.**):

- 40.63 % of the species have a low vulnerability;
- 20.31 % of the species have a low to moderate vulnerability;
- 14.06 % of the species have a moderate vulnerability;
- 14.06 % of the species have moderate to high vulnerability;
- 4.69 % of the species have a high vulnerability;
- 3.13 % of the species have a high to very high vulnerability;
- 1.56 % of the species have a very high vulnerability.

The total number of species having a moderate to high and very high vulnerability represents 23.44% of the species encountered during this survey.

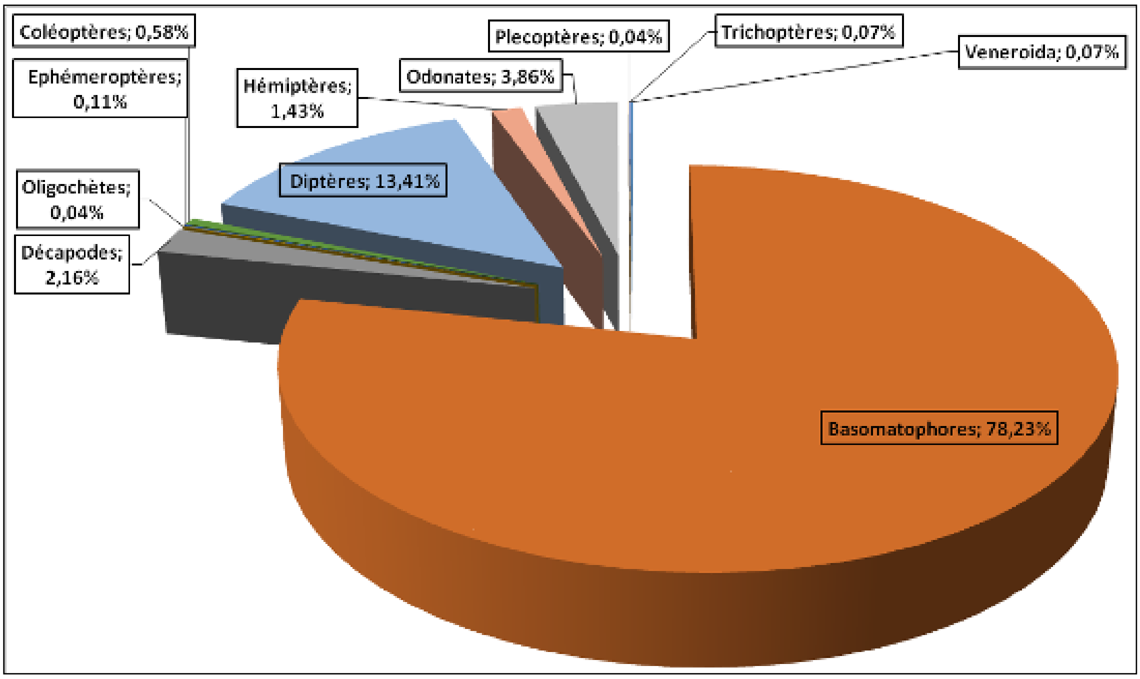
3.1.4 Endemic and restricted range species

Of the 64 fish species observed during this survey, four (i.e. 6.25 %) have a very wide distribution at the African and Euro-Asian levels (Table 3-1**Error! Reference source not found.**) (Paugy *et al.*, 2003 *a* & *b*; Sonnenberg & Busch, 2009; Eschmeyer, 2014; Froese & Pauly, 2014). Species that have an African level distribution total 35, i.e. 54.69%. Those having a distribution limited to the West African sub-region total 22, i.e. 34.38 %. In contrast, three species have a very restricted distribution, namely: *Synodontis bastiani, Synodontis punctifer* and *Tilapia walteri*. The endemic species to Côte d'Ivoire are restricted to the water bodies of the Sassandra, Bandama, Comoé and Agnébi rivers as far as *Synodontis bastiani* is concerned. With regard to *Synodontis punctifer*, its range is limited to the Nzo, Sassandra and Bandama hydrosystems. Concerning *Tilapia walteri,* it is present only in the Cavally and Nipoué rivers. However, Konan *et al.* (2014) have noticed the presence of the *Tilapia walteri* in the Aghien lagoon fisheries, in the region of Abidjan, which suggest that the distribution range of the *Tilapia walteri* is wider than previously thought and extends towards the East and North-East of the Cavally river.

3.2 Benthic Macroinvertebrates

The list of macroinvertebrates taxa surveyed in the basin of the Bandama River within the area of influence is presented in Table 3-3. From 13 sampling stations, 2,776 individuals from 44 taxa belonging to 37 families and 10 orders were identified. The macroinvertebrates collected belong to four zoological groups namely the insects, molluscs, worms and crustaceans. The Basomatophora order is the most represented in terms of number, with 78.23% of the individuals collected (Figure 3-4). Insects are the best represented group with seven orders, 33 families and 35 taxa (80% of the species richness). In terms of this group, the Odonata and Diptera orders are the most diversified with eight taxa belonging to six families. They are followed by the Hemyptera order with seven taxa divided into six families, followed by the Coleoptera order with six taxa of five different families. The Ephemeroptera order is composed of three taxa divided into three families and the Trichoptera represented by two families and two taxa. The Plecoptera are represented by a single taxon. Molluscs are represented by six taxa belonging to five families and two orders. Within this group, the Planorbidae are presenting two taxa and the other families such as Donacidae, Ampullariidae, Viviparidae and Thiaridae have a single taxon. The crustaceans from the Decapods order are represented by two taxa from the families Varinudae and Atyidae.

Figure 3-4: Relative proportions of the macroinvertebrates orders collected in the basin of the Bandama river within the Yaoure Gold Project's area of influence.



The Table 3-3 presents the summary of the statistics obtained for the different sampling stations. The station B2 shows the greatest taxonomic richness (15 taxa) followed by the stations B4 and B11 (13 taxa), and B14 (11 taxa). This is followed by the stations B1, B13, B12, B6, B3 and B9, with respectively 9, 8, 7, 7, 5 and 4 taxa, and finally stations B7, B5 and B10 presenting 2, 1 and 1 taxon. The highest individual abundance has been obtained at station B11 (1,054 individuals), stations B2 and B14 are also characterized by a high abundance (632 and 417 individuals). The lowest abundances were encountered at stations B5, B7 and B10 (1, 2 and 1 individual).

Moreover, the relative abundance of Chironomidae, a family recognised as tolerant to a wide range of disturbances, and particularly to pollution of the sedimentary type, was very high at sampling stations B1 and B4, and relatively less represented at the other stations.

The spatial variations of the Ephemeroptera, Plecoptera, and Trichoptera (EPT) indexes displayed in Table 3-4**Error! Reference source not found.** are showing very low values at all the stations (from 8,33 to 0), which indicates the weak representation or absence of polluo-sensitive taxa.This could be the sign of relatively bad water quality in the prospected area (Mary & Archaimbault, 2011).

The Shannon Index shows a very low specific diversity at the different sampling stations. The lowest diversity was recorded at stations B5 and B10 with a single taxon. This may be a result of the lack of habitat availability at these sites due to steep river banks and limited access.The equitability values indicate that stations B3, B7 and B9, located outside the operation perimeter of the Project have a balanced population in contrast to stations B11, B12, B14 and B2.

The macroinvertebrates taxa identified in the framework of this survey, namely: *Lanistes varicus, Bellamya unicolor, Melanoides tuberculata, Atyoida serrata, Abedus lutarium, Ceriagrion* and *Trithemis sp.* are listed as least concern (LC) by the IUCN. Some specimen could not be identified to species level and could potentially be threatened species. Further studies would be needed to assess their status with certainty. The other taxa present no particular conservation status, however it has to be noted the presence of a species belonging to the genus *Microvelia* which is less common.

Table 3-3: Spatial distribution of the aquatic macroinvertebrates species encountered in the Bandama River Basin within the Yaoure Gold Project area of influence (BONY K. Yves; April 2015).

Class	Order	Family	Taxa	IUCN Status[1]	B1	B2	B3	B4	B5	B6	B7	B9	B11	B12	B13	B14	Total
Bivalves	Veneroida	Donacidae	Iphigenia truncata	NA	-	-	-	-	-	-	-	-	2	-	-	-	**2**
Gasteropods	Basomatophora	Ampullariidae	Lanistes varicus	LC	1	1	-	-	3	12	-	-	6	-	-	2	**25**
		Viviparidae	Bellamya unicolor	LC	-	6	-	-	-	-	1	-	17	-	-	-	**24**
		Planorbidae	Bulinus sp	NA	-	4	-	5	-	-	1	-	-	-	6	336	**352**
			Biomphalaria sp	NA	-	-	5	6	-	-	-	-	-	-	-	-	**11**
		Thiaridae	Melanoides tuberculata	LC	20	513	3	33	-	152	-	12	951	3	67	4	**1758**
Crustaceans	Decapods	Varunidae	Varuna litterata	NA	-	-	-	-	-	-	-	-	1	-	-	-	**1**
		Atyidae	Atyoida serrata	LC	-	-	2	-	-	-	-	2	-	52	-	3	**59**
Worms	Oligochaeta	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	**1**
Insects	Ephemeroptera	Caenidae	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**1**
		Leptophlebiidae	Adenophlebiodes sp	NA	-	-	1	-	-	-	-	-	-	-	-	-	**1**
		Baetidae	Centroptilum sp	NA	-	-	-	-	-	-	-	1	-	-	-	-	**1**
	Coleoptera	Gyrinidae	Aulanogyrus sp	NA	-	-	-	1	-	-	-	-	-	-	-	-	**1**
		Hydrophilidae	Hydrobiinae	NA	-	8	-	-	-	-	-	-	1	-	1	-	**10**
		Dytiscidae	Hydaticus sp	NA	-	-	-	-	-	-	-	-	1	-	-	1	**2**
		Elmidae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	**1**
			Leptelmis sp	NA	-	1	-	-	-	-	-	-	-	-	-	-	**1**
		Naucoridae	Ilyocoris cimicoides	NA	-	-	-	-	-	-	-	-	1	-	-	-	**1**
	Diptera	Culicidae	Culex sp	NA	-	-	-	142	-	-	-	-	-	-	-	45	**187**
		Ceratopogonidae	-	-	-	1	-	2	-	-	-	-	-	-	-	-	**3**
		Chironomidae	Chironomini sp	NA	76	43	-	1	-	3	-	2	25	-	6	1	**157**
			Chironomus sp	NA	4	7	-	-	-	-	-	-	-	-	-	-	**11**
		Psychodidae	-	-	-	-	-	-	-	-	-	-	2	-	-	-	**2**
		Syrphidae	-	-	-	-	-	-	-	-	-	-	-	-	-	1	**1**

Class	Order	Family	Taxa	IUCN Status[1]	B1	B2	B3	B4	B5	B6	B7	B9	B11	B12	B13	B14	Total
		Tanypodinae	Ablabesmya sp	NA	7	-	1	1	-	-	-	-	-	-	-	-	**9**
		Chironomidae	Procladius sp	NA	-	-	-	-	-	2	-	-	-	-	-	-	**2**
	Hemiptera	Ranatridae	Ranatra sp	NA	-	-	-	1	-	-	-	-	-	-	-	-	**1**
		Belostomatidae	Diplonychus sp	NA	-	4	-	2	-	4	-	-	6	-	2	9	**27**
			Abedus lutarium	LC	-	-	-	-	-	-	-	-	1	-	-	-	**1**
		Corixidae	Stenocorixa protrusa	NA	-	-	-	-	-	-	-	-	-	-	1	-	**1**
		Gerridae	Eurymetra sp	NA	-	-	-	3	-	-	-	-	-	-	-	-	**3**
		Mesoveliidae	Mesovelia sp	NA	-	1	-	-	-	-	-	-	-	-	-	-	**1**
		Veliidae	Microvelia sp	NA	-	6	-	1	-	-	-	-	-	-	-	-	**7**
	Odonata	Calopterygidae	Phaon iridipennis	LC	-	-	-	-	-	-	-	-	-	1	-	-	**1**
		Aeshmidae	-	-	1	-	-	-	-	-	-	-	-	-	-	-	**1**
		Coenagrionidae	Ceriagrion sp	LC	1	33	-	-	-	-	-	-	40	-	-	-	**74**
		Corduliidae	Phyllomacromia sp	NA	-	-	-	-	-	-	-	-	-	-	5	13	**18**
		Gomphidae	Ichinogomphus sp	NA	1	1	-	-	-	1	-	-	-	-	-	-	**3**
			Paragomphus hagenis	NA	-	-	-	-	-	4	-	-	-	-	-	-	**4**
		Libellulidae	Trithemis sp	LC	-	3	-	-	-	-	-	-	-	-	-	-	**3**
			Urothemis sp	NA	-	-	-	-	-	-	-	-	-	-	1	2	**3**
	Plecoptera	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	**1**
	Trichoptera	Ecnomidae	Ecnomus sp	NA	-	-	-	-	-	-	-	-	-	1	-	-	**1**
		Hydropsychidae			-	-	-	-	-	-	-	-	-	1	-	-	**1**
Overall total					**112**	**632**	**12**	**199**	**3**	**178**	**2**	**17**	**1054**	**60**	**89**	**417**	
Number of taxa					**9**	**15**	**5**	**13**	**1**	**7**	**2**	**4**	**1**	**13**	**7**	**8**	**2,775**

[1] *IUCN Status: Least concern (LC); Not assessed (NA).*

Table 3-4: Summary statistics of the data collected on aquatic macroinvertebrates at the different sampling stations of the Bandama river basin within the influence area of the Yaoure Gold Project (BONY K. Yves; April 2015).

	B1	B2	B3	B4	B5	B6	B7	B9	B10	B11	B12	B13	B14
Taxa	9	15	5	13	1	7	2	4	1	13	7	8	11
Individuals	112	632	12	199	3	178	2	17	1	1054	60	89	417
Chironomides (%)	77,7	8,1	8,3	73,4	0	2	0	12	0	2,6	0	6,7	11,3
Shannon_H	1,1	0,8	1,4	1,1	0	0,6	0,7	0,9	0	0,5	0,6	1,0	0,8
Equitability_J	0,5	0,3	0,9	0,4	0	0,3	1	0,7	0	0,2	0,3	0,5	0,3
EPT Index	0	0	8,33	0,5	0	0	0	5,88	0	0	5	0	0

3.3 Algal Microflora

3.3.1 Taxonomic composition

A total of 287 taxa (species and varieties) distributed into 91 genera, 54 families, 29 orders, 12 classes and 8 phyla have been identified (Table 3-5**Error! Reference source not found.**). The phyla include Cyanobacteria (26 taxa), Euglenophyta (52 taxa), Chlorophyta (100 taxa), Pyrrhophyta (7 taxa), Bacillariophyta or diatoms (98 taxa), Rhodophyta (1 taxon), Chrysophyta (2 taxa) and Xanthophyta (1 taxon). Chlorophyta, and diatoms are the most diversified, followed by Euglenoidea and Cyanobacteria. Amongst Chlorophyta, the Zygnematale order (56 taxa) is the most diversified. At this order level, the most represented genus are in order of importance, the *Staurastrum* (24 taxa), *Cosmarium* (16 taxa) and *Euastrum* (6) taxa. The phyla of Euglenoidea is made of only the Euglenales order. This order is mainly represented by the taxa from the genus *Trachelomonas* (20 taxa), *Euglena* (9 taxa), *Phacus* (10 taxa) and *Lepocinclis* (9 taxa). From the 98 taxa of the Bacillariophyta reported, 36 taxa belong to the Naviculales order, 15 taxa to the Cymbellales, 13 to the Bacillariales and 11 taxa to the Achnanthales. The most represented genus are *Nitzschia* (12 taxa), *Gomphonema* (10 taxa), Navicula (10 taxa) and *Pinnularia* with 8 taxa. The species number of Cyanobacteria is low compared to the first three groups. In this phylum, the genus *Oscillatoria* (5 taxa), *Chroococcus*, *Microcystis* and *Lyngbya* (with 3 taxa each) comprise the greatest number of taxa. The Xanthophyta, Rhodophyta, Chrysophyta and the Pyrrhophyta are very poorly represented. The phylum of Xanthophyta is primarily composed of the genus *Centritractus* with 1 taxon. The genera *Karenia* (1 taxon), *Peridinium* (2 taxa) and *Protoperidinium* with 5 taxa are the most diversified within the Pyrrhophyta. The Chrysophyta and Rhodophyta are represented by the genera *Dinobryon*, *Mallomonas* and *Audouinella* with respectively one taxon each.

Amongst the Chlorophyceae, there are 41 Chlorococcales, and among Zygnematophyceae there are 55 Desmidiales. It can be seen that this is characterized by a high number of Cyanophyceae, Chlorophyceae and diatoms, while the Desmidiales are in relatively few in number for these tropical waters.

The distribution of Desmidiales is rather curious as we encounter 1 *Actinotaenium*, 3 *Closterium*, 16 *Cosmarium*, 1 *Desmidium*, 6 *Euastrum*, 24 *Staurastrum*, 1 *Teilingia* and 1 *Mougeotia*. The absence of the genus Micrasterias, amongst others, is quite surprising. It is probable that these astonishing proportions and the deficiency of the Desmidiales genus might be caused by the sampling, with many collections having been done in flowing waters and less in stagnant waters. Our sampling period was also too limited in time to draw conclusions on the possible disappearence of these taxa. Additional observations should be performed to clarify this point and complete our inventory. Therefore, this survey represents a first inventory but does not allow the ability to draw bio-geographical conclusions.

Table 3-5: Spatial distribution of the algal micro-flora species encountered within the Basin of the Bandama River inside the Yaoure Gold Project area of Influence (ADON Marie Paulette; April 2015).

	Sampling sites												
	Kossou lake			Bandama river				Old mining pit	Bandama river's tributaries				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
CYANOBACTERIA													
CYANOPHYCEAE													
CHROOCOCCALES													
Synechococcaceae													
Aphanothece sp.		X						X					
Chroococcaceae													
Chroococcus limneticus Lemmerm.			X	X									
Chroococcus turgidus (Kütz.) Nägeli	X							X					
Chroococcus sp.			X										
Microcystaceae													
Microcystis aeruginosa (Kütz.) Kütz.	X	X											
Microcystis densa G.S.West	X				X								
Microcystis novacekii (Komárek) Compère		X	X										
Merismopediaceae													
Merismopedia glauca (Ehrenb.) Kütz.			X										
Merismopedia punctata Meyen			X				X						
HORMOGONALES													
Pseudanabaenaceae													
Pseudanabaena cf. *limnetica* (Lemmerm.) Komárek	X	X						X		X			
Spirulina gigantea Schmidle			X		X								
Spirulina sp.												**X**	X
Phormidiaceae													
Anabaenopsis sp.	X	X	X				X	X					

	Sampling sites												
	Kossou lake			Bandama river				Old mining pit	Bandama river's tributaries				
TAXA	B1	B2	B11	B5	B6	B7	B10	B4	B3	B9	B12	B13	B14
Anabaena sp.	X							X		X			
Anabaena sp.1										X			
Lyngbya sp.	X							X					
Lyngbya sp.1	X				X			X					
Lyngbya sp.2	X											X	
Oscillatoria tenuis Agardh ex Gomont				X			X	X					
Oscillatoria princeps Vaucher ex Gomont								X					X
Oscillatoria pseudocurviceps Welsh								X					
Oscillatoria salina Biswas	X			X				X			X		
Oscillatoria cf. *nitida* Schkorbatov												X	
Phormidium numarium Playfair	X		X					X		X		X	
Phormidium calcicola Gardner								X					
Heteroleibleinia rigidula (Kützing ex Hansgirg) L.Hoffmann							X				X		
EUGLENOPHYTA													
EUGLENOPHYCEAE													
EUGLENALES													
Euglenaceae													
Euglena proxima P.A.Dangeard													X
Euglena polymorpha Dang.			X										
Euglena sp.			X										
Euglena sp.1			X										X
Euglena sp.2	X		X										
Euglena sp.3				X									
Euglena sp.4					X								X
Euglena sp.5			X	X				X			X		

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Euglena sp.6			X										
Lepocinclis oxyuris (Schmarda) Marin & Melkonian f. *oxyuris*				X									
Lepocinclis oxyuris f. *charkowiensis* Huber-Pestalozzi													X
Lepocinclis acuminata Deflandre	X	X											
Lepocinclis ovum (Ehrenberg) Lemmermann		X	X					X		X		**X**	X
Lepocinclis acuta Prescott			X										
Lepocinclis texta (Duj.) Lemmerm.			X										
Lepocinclis acus (O.F.Müll.) Marin & Melkonian			X		X								
Lepocinclis sp.		X	X										X
Lepocinclis sp.1			X										
Phacus limnophila (Lemmermann) Linton & Karnkowska													X
Phacus incrassatus(Deflandre) Pochmann			X										
Phacus longicauda var. *insecta* Huber-Pestalozzi	X		X								X		**X**
Phacus Stokesii Lemmermann		X	X										
Phacus tortus (Lemmerm.) Skvortsov													X
Phacus platalea Drezep.													X
Phacus indicus Skvortzov													X
Phacus sp.			X										
Phacus sp.1													X
Phacus sp.2													X
Trachelomonas volvocinopsis	X	X	X	X	X		X	X		X		X	
Trachelomonas volvocina Ehrenb.	X	X	X	X	X		X	X	X	X			X
Trachelomonas volvocina var. *derephora* Conrad				X			X						
Trachelomonas hispida (Perty) Stein	X	X	X				X	X		X			
Trachelomonas hispida var. *coronata* Lemmerm.	X				X					X			

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Trachelomonas hispida var. *duplex* Deflandre	X							X					
Trachelomonas oblonga Lemmerm.	X	X			X								
Trachelomonas oblonga var. *attenuata* Playfair							X						
Trachelomonas planctonica var. *oblonga* Drezep.	X		X				X						
Trachelomonas planctonica var. *longicollis* Skvortzov	X		X										
Trachelomonas mangini G.Deflandre			X				X						
Trachelomonas intermedia P.A.Dangeard		X	X	X	X			X					
Trachelomonas scabra Playfair	X												
Trachelomona klebsiis Deflandre	X												
Trachelomonas armata f. *inevoluta* G.Deflandre							X						
Trachelomonas raciborskii Wolosz. var. *nova*			X										
Trachelomonas armata var. *steinii* Lemmermann			X										
Trachelomonas botanica Playfair	X												
Trachelomonas sp.	X												
Strombomonas verrucosa (Daday) Deflandre var. *zmiewika* (Svirenko) Deflandre		X											
Strombomonas acuminata var. *deflandreana* Conrad												X	X
Strombomonas sp.													X
Strombomonas sp.1												X	X
Strombomonas sp.2												X	
CHLOROPHYTA													
CHLOROPHYCEAE													
CHLOROCOCCALES													
Hydrodictyaceae													
Pediastrum duplex var. *gracillimum* W.West & G.S.West			X										
Pediastrum biradiatum var. *longicornutum* Gutw.		X											

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Pediastrum sp.													
Pediastrum sp.1				X	X								
Pediastrum sp.2			X										
Pediastrum sp.3	X						X						
Oocystaceae													
Oocystis solitaria Wittrock in Wittrock & Nordstedt	X		X					X					
Golenkiniaceae													
Golenkinia radiata Chodat	X			X				X					
Golenkiniopsis minutissima (M.O.P.Iyengar & M.S.Balakrishnan) Philipose	X			X				X					
Micractiniaceae													
Dictyosphaerium pulchellum H.C.Wood	X												
Dictyosphaerium granulatum Hindák				X									
Radiococcaceae													
Thorakochloris sp.	X		X										
Oocystaceae													
Fusola viridis J.Snow		X								X			
Chlorellaceae													
Monoraphidium arcuatum (Korshikov) Hindák				X									
Ankistrodesmus fusiformis Corda		X	X										
Ankistrodesmus falcatus (Corda) Ralfs	X	X									X	X	
Ankistrodesmus spiralis (W.B.Turner) Lemmermann			X										
Coelastraceae													
Coelastrum microporum Nägeli								X					
Coelastrum astroideum De Notaris	X	X	X		X								
Scenedesmaceae													

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Crucigeniella crucifera (Wolle) Komárek	X		X		X					X			
Scenedesmus opoliensis P.G.Richt.			X										
Scenedesmus obtusus Meyen f. *alternans* (Reinsch) Compère	X							X					
Scenedesmus disciformis (Chodat) Fott & Komárek	X											X	
Scenedesmus acutiformis Schröd.			X					X					
Scenedesmus dimorphus (Turpin) Kützing	X		X		X			X					
Scenedesmus acuminatus (Lagerheim) Chodat	X						X	X					
Scenedesmus bernardii G.M.Sm.		X	X		X								
Scenedesmus quadricauda (Turpin) Bréb.	X	X	X	X	X		X						
Scenedesmus bicaudatus Dedusenko	X	X	X										
Scenedesmus sp.		X											
Scenedesmus sp.1			X										
Scenedesmus sp.2										X			
Chlorococcaceae													
Goniochloris mutica (A.Braun) Fott	X			X						X			
Tetraëdriella gigas (Wittrock) Hansgirg	X			X									
Tetraedron minimum (A.Braun) Hansgirg			X									X	
Tetraedron trigonum (Nägeli) Hansg. f. *crassum* (Reinsch) DeToni						X							
Tetraedron muticum (A.Braun) Hansgirg			X										
Tetraedron tumidulum (Reinsch) Hansg.				X									
Tetraedron regulare Kütz.			X										
Tetraedron sp.								X					
ZYGNEMATOPHYCEAE													
ZYGNEMATALES													
Desmidiaceae													

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Closterium erhenbergii Meneghini ex Ralfs											X		
Closterium sp.1											X		
Closterium sp.2											X		
Staurastrum volans W.West & G.S.West					X								
Staurastrum tetracerum Ralfs ex Ralfs	X	X	X	X				X					
Staurastrum forficulatum P. Lundell	X		X		X								
Staurastrum forficulatum var. *minus* (F.E.Fritsch & M.R.Rich) R.L.Grönblad & A.M.Scott P	X		X										
Staurastrum asperatum var. *minus* Behre	X		X	X									
Staurodesmus cuspidatus (Brébisson) Teiling			X				X						
Staurastrum leptocladum var. *cornutum* Wille	X	X	X	X	X		X						
Staurastrum polymorphum Brébisson in Ralfs	X	X					X						
Staurastrum gracile var. *elongatum* A.M.Scott & Prescott	X												
Staurastrum sp.	X	X	X	X			X				X		
Staurastrum sp.1	X	X			X								
Staurastrum sp.2		X	X	X				X					
Staurastrum sp.3	X	X	X		X		X			X			
Staurastrum sp.4			X										
Staurastrum sp.5	X		X										
Staurastrum sp.6	X		X										
Staurastrum sp.7		X											
Staurastrum sp.8	X												
Staurastrum sp.9	X												
Staurastrum sp.10										X			
Staurastrum sp.11										X			

	Sampling sites												
	Kossou lake			Bandama river				Old mining pit	Bandama river's tributaries				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Staurastrum sp.12			X										
Staurastrum sp.13			X										
Staurastrum sp.14	X												
Arthrodesmus convergens Ehrenberg ex Ralfs			X										
Arthrodesmus constrictus G.M.Smith	X												
Euastrum rectangulare Fritsch & M.F.Rich	X	X					X			X			
Euastrum binale Ehrenberg ex Ralfs	X	X	X	X						X			
Euastrum platycerum Reinsch			X										
Euastrum praemorsum (Nordstedt) Schmidle				X									
Euastrum elegans Ralfs			X	X									
Euastrum germanicum (Schmidle) Kreiger			X										
Actinotaenium cucurbitinum (Bisset) Teiling	X		X										
Cosmarium moniliforme Ralfs	X		X	X	X		X						
Cosmarium aversiforme Krieger & Gerloff	X	X	X		X			X					
Cosmarium contractum O.Kirchner	X	X											
Cosmarium spinuliferum West & G.S.West				X									
Cosmarium quadrum Lundell	X	X	X	X	X								
Cosmarium retusiforme var. *africanum* (F.E.Fritsch) Compère		X	X										
Cosmarium portianum Archer			X		X			X					
Cosmarium pseudoconnatum Nordstedt			X										
Cosmarium granatum var. *concavum* Lagerheim			X	X	X			X					
Cosmarium subtumidum Nordstedt	X		X		X								
Cosmarium impressulum Elfving			X										
Cosmarium binum Nordstedt in Wittrock			X										
Cosmarium pachydermum f. *parvum* Croasdale								X					

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Cosmarium asphaerosporum Wittrock in Wittrock				X									
Cosmarium sp.1	X			X	X		X						
Cosmarium sp.2			X	X									
Teilingia granulata (J.Roy & Bisset) Bourrelly		X	X	X									
Mougeotia sp.	X	X	X	X	X		X	X		X			
Desmidium swartzii Ca. A. Agardh Ex Ralfs								X					
Peniaceae													
Gonatozygon monotaenium De Bary	X				X			X			X		
VOLVOCALES													
Volvococcaceae													
Pandorina morum (O.F.Müller) Bory de Saint-Vincent Seattle	X						X						
Eudorina elegans Ehrenberg					X	X							
OEDOGONIOPHYCEAE													
OEDOGONIALES													
Oedogonium sp.			X		X		X			X			
Bulbochaete sp.		X											
PYRROPHYTA													
DINOPHYCEAE													
GYMNODINIALES													
Gymnodiniaceae													
Karenia sp.	X							X					
PERIDINIALES													
Peridiniaceae													
Peridinium cinctum (O.F.Müll.) Ehrenb.	X	X	X	X			X	X		X	X		
Peridinium sp.		X	X	X	X		X	X			X		

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Protoperidiniaceae													
Protoperidinium conicoides (Paulsen) Balech	X		X		X		X	X		X		X	
Protoperidinium quinquecorne (Abé) Balech	X	X	X	X			X	X					
Protoperidinium sp.	X		X	X	X		X						
Protoperidinium sp.1				X	X		X			X			
BACILLARIOPHYTA													
COSCINODISCOPHYCEAE													
THALASSIOSIRALES													
Thalassiosiraceae													
Conticribra sp.										X			
Stephanodiscaceae													
Cyclotella sp.												X	
BIDDULPHIALES													
Biddulphiaceae													
Terpsinoe musica Ehrenberg										X	X		
AULACOSEIRALES													
Aulacoseiraceae													
Aulacoseira sp.	X	X	X	X	X		X			X	X		X
MELOSIRALES													
Melosiraceae													
Melosira varians C.Agardh		X	X	X	X			X					
BACILLARIOPHYCEAE													
CYMBELLALES													
Cymbellaceae													
Cymbella tumida (Brebisson) Van Heurck									X				

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Cymbella turgidula Grunow									X				
Encyonema mesianum (Cholnoky) D.G. Mann	X												
Encyonema silesiacum (Bleisch) D.G.Mann	X		X										
Encyonema ventricosum (Agardh) Grunow											X		
Gomphonemataceae													
Gomphonema affine Kützing	X	X			X					X	X		
Gomphonema parvulum Kützing			X										
Gomphonema lagenula Kützing	X												
Gomphonema gracile Ehrenberg	X								X				
Gomphonema insigne Gregory										X			
Gomphonema minutum(Agardh)				X						X			
Gomphonema parvulius Lange-Bertalot & Reichardt	X												
Gomphonema parvulum (Kützing)	X										X		
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot									X	X			
Gomphonema venusta Passy. Kociolek & Lowe										X	X		
COCCONEIDALES													
Achnanthidiaceae													
Planothidium frequentissimum (Lange-Bertalot)											X		
Planothidium rostratum (Oestrup) Lange-Bertalot											X		
EUNOTIALES													
Eunotiaceae													
Eunotia minor (Kützing) Grunow in Van Heurck	X								X	X	X		
Eunotia sp.	X										X		
Actinella brasiliensis Grunow in Van Heurck										X			
SURIRELLALES													

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Surirellaceae													
Surirella brebissonii Krammer & Lange-Bertalot var. *brebissonii*				X									
FRAGILARIOPHYCEAE													
FRAGILARIALES													
Fragilariaceae													
Asterionella formosa Hassall	X	X	X				X			X			
Fragilaria capucina Desmazieres var. *capucina*	X												
Fragilaria capucina Desm. ssp. *rumpens* (Kütz.) Lange-Bert. ex Bukht.	X												
Ulnaria ulna (Nitzsch) Compère	X	X	X		X		X	X	X	X	X		
ACHNANTHALES													
Achnanthes oblongella Oestrup				X					X	X	X	X	
Achnanthes standeri Cholnoky	X												
Achnanthes subaffinis Cholnoky				X					X		X	X	
Achnanthidium affine (Grun) Czarnecki										X			
Achnanthidium exiguum (Grunow) Czarnecki											X		
Achnanthidium minutissimum (Kützing) Czarnecki	X			X					X	X	X	X	
Achnanthidium saprophilum (Kobayasi & Mayama) Round & Bukhtiyarova										X			
Cocconeidaceae													
Cocconeis engelbrechtii Cholnoky				X					X	X	X		
Cocconeis placentula Ehrenberg var. *placentula*									X	X	X		
Cocconeis placentula var. *euglypta*										X	X		
Cocconeis sp.											X		
THALASSIOPHYSALES													
Amphora veneta Kützing	X												
NAVICULALES													

	Sampling sites												
	Kossou lake			Bandama river				Old mining pit	Bandama river's tributaries				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Brachysiraceae													
Brachysira neoexilis Lange-Bertalot	X												
Pleurosigmataceae													
Gyrosigma kuetzingii (Grunow) Cleve		X	X				X		X			X	
Pinnulariaceae													
Pinnularia biceps W.Gregory f. *peterseni* R.Ross			X										
Pinnularia interrupta W.Sm.			X										
Pinnularia brauniana (Grunow ex A.Schmidt) Cleve				X									
Pinnularia divergens W.Smith		X											
Pinnularia amabilis K.Krammer		X											
Pinnularia gibba (Ehrenb.) Ehrenb.		X											
Pinnularia subbrevistriata (Krammer)				X					X				
Pinnularia sp.	X		X	X	X		X	X			X		
Naviculaceae													
Caloneis bacillum (Grunow) Cleve									X				
Sellaphora pupula (Kütz.) Mereschk.			X	X									
Sellaphora sp.			X										
Navicula antonii (Lange-Bertalot)	X								X				
Navicula gregaria (Donkin)	X												
Navicula radiosa (Kützing)	X												
Navicula recens (Lange-Bertalot)	X			X					X				
Navicula rostellata (Kützing)											X		
Navicula symmetrica (Patrick)	X								X		X		
Navicula vandamii (Schoeman & Archibald) var. *vandamii*	X								X				
Navicula viridula (Kützing) Ehrenberg				X					X	X			

TAXA	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
	B1	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Navicula zanoni (Hustedt)	X			X					X			X	
Navicula sp.		X					X						
Diadesmidaceae													
Diadesmis confervacea (Kützing) D.G. Mann				X							X	X	
Diadesmis contenta (Grunow ex V. Heurck) D.G. Mann				X									
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann				X						X		X	
Luticola kotschyi (Grunow) in TDI3 Kelly				X									
Luticola mutica (Kützing) D.G. Mann	X			X									
Naviculales													
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin	X												
Amphipleuraceae													
Frustulia rhomboides (Ehrenberg) De Toni												X	
Frustulia sp.							X						
Stauroneidaceae													
Craticula buderi (Hustedt) Lange-Bertalot											X		
Craticula cuspidata (Kützing) Mann	X												
Craticula halophila (Grunow ex Van Heurck) Mann				X									
Craticula molestiformis (Hustedt) Lange-Bertalot												X	
Stauroneis sp.					X								
LICMOPHORALES													
Ulnariaceae													
Opephora schwartzii (Grunow) Petit ex Pelletan									X	X			
Tabularia fasciculata (Agardh) Williams et Round	X			X							X		
MASTOGLOIALES													
Mastogloiaceae													

	Sampling sites												
	Kossou lake			**Bandama river**				**Old mining pit**	**Bandama river's tributaries**				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
Mastogloia dansei (Thwaites) Wm.Smith											X		
Mastogloia smithii (Thwaites)											X		
BACILLARIALES													
Bacillariaceae													
Nitzschia amphibia (Grunow) f. *amphibia*									X	X	X		
Nitzschia capitellata (Hustedt in A.Schmidt & al.)												X	
Nitzschia clausii (Hantzsch)									X				
Nitzschia etoshensis (Cholnoky)												X	
Nitzschia filiformis (W.M.Smith) Van Heurck var. *filiformis*	X												
Nitzschia marginulata (Grunow) var. *marginulata*												X	
Nitzschia microcephala Grunow in Cleve & Moller											X		
Nitzschia gracilis Hantzsch			X	X	X			X			X		
Nitzschia flexoides Geitler			X				X		X				
Nitzschia palea (Kütz.) W.Sm.	X	X	X	X	X		X	X	X	X	X	X	X
Nitzschia gracilis Hantzsch	X			X	X		X			X			X
Nitzschia sigma (Kützing)W.M.Smith				X									
Hantzschia amphioxys (Ehrenb.) Grunow											X	X	
RHOPALODIALES													
Rhopalodiaceae													
Rhopalodia gibba (Ehr.) O.Muller var. *gibba*										X			
Rhopalodia gibberula (Ehrenberg) Otto Müller								X					
TABELLARIALES													
Tabellariaceae													
Tabellaria flocculosa (Roth) Kützing											X		
RHODOPHYTA													

	Sampling sites												
	Kossou lake			Bandama river				Old mining pit	Bandama river's tributaries				
TAXA	**B1**	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
FLORIDEOPHYCEAE													
ACROCHAETIALES													
Acrochaetiaceae													
Audouinella violacea (Kützing) Hamel	X										X		
CHRYSOPHYTA													
CHROMULINALES													
Dinobryaceae													
Dinobryon sertularia Ehrenberg					X								
Mallomonas sp.		X			X		X				X		X
XANTHOPHYTA													
XANTHOPHYCEAE													
MISCHOCOCCALES													
Centritactaceae													
Centritractus belonophorus (Schmidle) Lemmerm.				X									
Total : 287	110	56	104	68	47	2	43	49	26	49	47	28	23

At the level of the sampling sites, a total of 187 taxa were collected in the Kossou Lake at stations B1, B2 and B11. In the Bandama River, 115 taxa were reported at the different sampling sites, while 119 taxa were collected from the tributaries. Concerning the site near the old mining pit (B4), 49 taxa have been collected. The higher taxonomic richness recorded at the level of the Kossou Lake, compared to the other sampling sites, could be related to the fact that the Kossou dam waters are stagnant. Indeed, the development of the phytoplankton communities is highly dependent on the water column stability. Besides, the stagnant characteristics of the lake are favoring the biological processes such as the complete reproduction cycle and of development of the algae (Ouattara, 2000).

3.3.2 Taxonomic composition by habitats

At the level of the various habitats, Chlorophyta with close to 35 %, is the dominating taxon (Table 3-6). However, Euglenophyta is dominant in phytoplankton for the Kossou dam, the Bandama River and its tributaries, with respectively 31, 11 and 19 taxa. As far as diatoms are concerned, their diversity is remarkable within the phytoplankton such as periphyton collected in the substratum (stones and plants) at all sampling sites. Indeed diatoms are the most diversified autotroph organisms as they have the ability to colonise all available surfaces. This colonisation ease can justify their predominance within the taxonomic composition of algae fixed on leaves, woods and stones. In addition they can also detach from the supports and end up drifting in the water column, which also explains their important diversity both within the periphyton and the open water population.

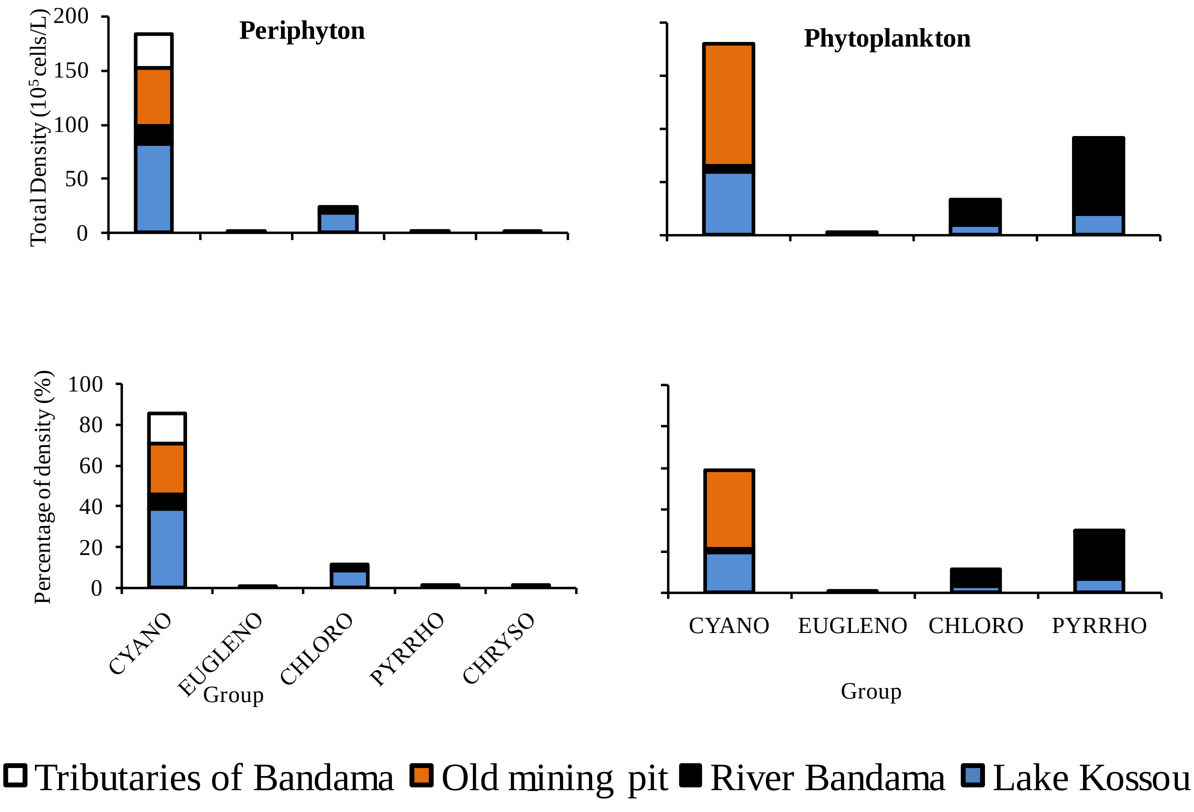
Table 3-6: Distribution of the taxa within the various habitats. P: phytoplankton; PC: periphyton on stones; PV: periphyton on plants.

Taxa	All sites (%)	Kossou Dam			Bandama River			Old mining pit			Tributaries		
		P	PC	PV	P	PC	PV	P	PC	PV	P	PC	PV
Cyanobacteria	(26 taxa) 9.06	10	4	8	5	0	5	8	7	4	5	3	4
Euglenophyta	(52 taxa) 18,12	31	2	7	11	0	6	2	0	5	19	2	5
Chlorophyta	(100 taxa) 34,84	57	5	44	30	0	26	4	8	9	13	1	7
Pyrrophyta	(7 taxa) 2,44	6	2	2	5	0	3	3	1	0	4	0	0
Bacillariophyta or Diatoms	(98 taxa) 34,15	9	7	15	6	0	13	2	4	4	10	9	10
Rhodophyta	(1 taxa) 0,35	0	1	0	0	0	0	0	0	0	0	1	0
Chrysophyta	(2 taxa) 0,70	0	0	1	1	0	2	0	0	0	0	0	1
Xanthophyta	(1 taxa) 0,35	0	0	0	1	0	0	0	0	0	0	0	0

3.3.3 Spatial Variation in the density of algal communities

Figure 3-5 shows that in relation to different groups in the population, the density of the Cyanobacteria is high at the Kossou dam, the old mining pit and at the Bandama River's tributaries for periphyton (respectively 83 10^5 cells/Liter, 54 10^5 cells/Liter et 31 10^5 cells/Liter) and phytoplankton (respectively 59 10^5 cells/Liter et 115 10^5 cells/Liter). This group has significant proportions (more than 20 %). The richness of Cyanobacteria in the different sites can be explained by the fact that the group are often associated with eutrophic conditions and high temperatures (Shapiro, 1990), low luminosity (Niklisch & Kohl, 1989), alkaline pH (Reynolds & Walsby, 1975), high concentrations of nutrients, especially phosphorus (Watson *et al*., 1997), and buoyancy regulation (Walsby *et al*., 1997). High values of pyrrhophyta are observed, however, in the stations of the Bandama River at the level of the phytoplankton (71 10^5 cells/Liter).

Figure 3-5: Absolute and relative density of phytoplankton and periphytic algae from the prospected sites. CYANO : Cyanobacteria ; EUGLENO : Euglenophyta ; CHLORO : Chlorophyta ; PYRRHO : Pyrrhophyta ; CHRYSO : Chrysophyta



3.3.4 Assessment of the Trophic states indexes based on the phytoplanktonic and periphytic organisms

The values of indexes A, B and C, for the sampling period are presented in Table 3-7**Error! Reference source not found.**. The values of indexes A and B are respectively 1.98 and 0.73 for the Kossou dam, 1.56 and 0.59 for the Bandama River, 3.75 and 1.13 for the old mining pit, and 4.3 and 0.7 at the tributaries level. On the other hand, those of the index C are respectively 0.05; 0.06; 0.2 and 0.67 at these different sampling sites.

By taking into account the trophic index proposed by Nygaard (1949), the results of the index A indicate that Kossou Dam and Bandama River are mesotrophic, whereas old mining pit and tributaries are eutrophic. However, the value of the index B suggests a eutrophic state at the old mining pit location, but oligotrophic state at the other sampling sites. On the other hand, the values of the index C indicate an oligotrophic state of the Kossou dam and the Bandama River, but a eutrophic state in the two other sites (i.e. old mining pit and tributaries). These values show the response variability with the use of different indexes, and express the mesotrophic states of the water sampled. However, the values of indexes in old mining pit show eutrophic state of the water.

The values of indexes A, B and C at the different sampling sites are recorded in (Table 3-7**Error! Reference source not found.**). The sites B7, B3 and B13 indicate oligotrophic state of the water, whereas the sites B2 and B6 show mesotrophic state of water. The results of indexes A, B and C in the sites B1, B5, B10, B11 and B12 reveal an oligotrophic at mesotrophic state of waters, while the values of these indexes show an oligotrophic at eutrophic state of water in the sites B9 and B14. Site B4 showed eutrophic conditions, with elevated values of indexes A, B and C.

Table 3-7: Values of indexes A, B and C at the different sampling sites.

Indexes	Kossou Dam	Bandama River	Old mining pit	Tributaries
A	1.98	1.56	3.75	4.3
B	0.73	0.59	1.13	0.7
C	0.05	0.06	0.2	0.67
Water quality	Mesotrophic	Mesotrophic	Eutrophic	Mesotrophic

Table 3-8: Values of indexes A, B and C at the different sampling stations.

Indexes	Kossou Dam			Bandama River				Old mining pit	Tributaries				
	B1	**B2**	**B11**	**B5**	**B6**	**B7**	**B10**	**B4**	**B3**	**B9**	**B12**	**B13**	**B14**
A	1.69	1.63	1.64	1.24	1.38	0.00	1.78	3.75	0.00	2.67	1.75	0.00	0.00
B	0.65	0.56	0.58	0.53	0.46	0.00	0.33	1.13	0.00	0.67	0.25	0.00	0.00
C	0.03	0.22	0.15	0.08	0.29	0.00	0.11	0.20	0.00	0.13	0.06	0.07	0.50
Water quality	O -M	M	O-M	O-M	M	O	O-M	E	O	O-E	O-M	O	O-E

O : Oligotrophic ; M : mesotrophic ; E : eutrophic

All these results only show the qualitative aspect of the algal community. Therefore, for certain phytoplanktonic and periphytic organisms considered as trophic indicators (Hutchinson, 1967; Moss, 1972), it has been possible to assess the trophic characteristics of the sampling sites. Some phytoplankton species being pollution indicators have been observed in the various stations of sampling. These include species such as *Microcystis aeruginosa*, *Pediastrum duplex*, *Scenedesmus quadricauda* and *Peridiniumcinctum* (Table 3-9).

Table 3-9: Indicators taxa of pollution

Taxa	Kossou lake		Bandama river			Old mining pit	Bandama river's tributaries		
	B1	B2	B11	B5	B6	B10	B4	B9	B12
Microcystis aeruginosa	X	X							
Pediastrum duplex var. *gracillimum*	X		X						
Scenedesmus quadricauda	X	X	X	X	X	X			
Peridinium cinctum	X	X	X	X		X	X	X	X

3.3.5 Cross-validation

The ecological classification for water quality according to Van Dam *et al*. (1994) and Taylor *et al*. (2007) is recorded in Table 3-10.The diatom assemblages mainly comprised of species with a preference for alkaline (pH 7), fresh brackish (>500 - 1000 µS/cm) and nutrient rich (eutrophic) waters. All sites, excluding B13, comprised of diatom assemblages that were N-autotrophic Tolerant, indicating a tolerance of elevated concentrations of organically bound nitrogen. The oxygen saturation requirements ranged from moderate (>50%) to high (>75%). The pollution level ranged from moderately polluted at sites B5 and B9 to strongly polluted conditions at sites B1, B3 and B12. Site B13 showed hypereutrophic conditions, with elevated concentrations of organically bound nitrogen and extremely polluted conditions.

Table 3-10: Ecological descriptors for selected sampling sites based on the diatom community (Van Dam *et al.*, 1994)

Parameter	B1	B3	B5	B9	B12	B13
pH	Neutral	Alkaline	Alkaline	Alkaline	Alkaline	Neutral
Salinity	Fresh-Brackish	Fresh-Brackish	Fresh-Brackish	Fresh-Brackish	Fresh-Brackish	Fresh-Brackish
Nitrogen uptake	N-Autotrophic Tolerant	N-Autotrophic Tolerant	N-Autotrophic Tolerant	N-Autotrophic Tolerant	N-Autotrophic Tolerant	N-Heterotrophic Obligate
Oxygen	High	Moderate	High	Moderate	Moderate	Basic
Saprobity	B- ά-mesosaprobic	ά-mesosaprobic	B-mesosaprobic	B-mesosaprobic	ά-mesosaprobic	polysaprobic
Trophic State	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Eutrophic	Hypereutrophic

A total of 65 diatom species were recorded at the six sites (Table 3-11). The dominant diatom species recorded at all sites was *Achnanthidium minutissimum* which has in the past been associated with well oxygenated, clean, freshwaters (Taylor *et al*., 2007). However, this taxon has also been found in nutrient rich waters with higher pH (Round, 1993) and at sites contaminated with acid mine drainage precipitates and heavy metals associated with mining effluent (Deniseger *et al.,* 1986; Genter *et al.,* 1987; Ivorra *et al.,* 1999; Medley and Clements 1998; Gold *et al.,* 2002, 2003; Cattaneo *et al.,* 2004; Ferreira da Silva *et al.,* 2009). *Nitzschia palea* and *Nitzschia amphibia* were also dominant and commonly found in eutrophic and very heavily polluted to extremely polluted waters with moderate to high electrolyte content. In a study by Salomoni *et al*. (2006) it was shown that *N. palea* was an indicator of heavy organic pollution and eutrophication in the Gravatai River.

Additional information is provided for the other dominant/sub-dominant species in order to make ecological inferences for the six sites (Taylor *et al.,* 2007):

- **B1:** *Eunotia minor* occurs in circumneutral waters, in pools and springs. The presence of *Navicula zanoni* is indicative of alkaline waters. *Gomphonema gracile* is indicative of electrolyte rich waters and is tolerant of moderate levels of pollution. The presence of *G. parvulum,* which is a pollution tolerant species, indicates low oxygenated, eutrophic waters.
- **B3:** The dominance of *Nitzschia amphibia* at this site indicates eutrophic waters ranging from electrolyte-poor to electrolyte-rich. *Cocconeis engelbrechtii* occurs in alkaline brackish waters. The sub-dominance of *C. placentula* is indicative of meso-to-eutrophic flowing and standing waters.
- **B5:** *Diadesmis contenta*occurs in small bodies of oligotrophic acidic water. *Luticola goeppertiana* is found in electrolyte rich waters; *L. mutica* is common in brackish conditions and in water bodies which are prone to drying out. Both *L. goeppertiana* and *L. mutica* are tolerant of pollution. The presence of *G. minutum* is indicative of eutrophic waters and is also tolerant to moderate levels of pollution.
- **B9:** The dominant *C. engelbrechtii* is indicative of meso-to-eutrophic flowing and standing waters. *Nitzschia amphibia* is indicative of eutrophic waters and can tolerate high levels of salinity. *Gomphonema venusta* is found in circumneutral waters with moderate electrolyte content. *Gomphonema minutum* occurs in eutrophic waters and is also tolerant to moderate levels of pollution. This site appears to suffer from salinity and nutrient related impacts.
- **B12:** *Nitzschia amphibia* is dominant indicating impacts of salinity and nutrients at this site.*Gomphonema parvulum,* which is a pollution tolerant species, indicates low oxygenated, eutrophic waters. The sub-dominant species *Achnanthidium exiguum* is found in many different types of water, including industrial and other waste water. It appears that the impacts at this site are primarily related to increased nutrients and pollution.
- **B13:** Shows a complete dominance of *N. palea* which indicates strongly eutrophic and polluted waters. The sub-dominant species *N. capitellata* occurs in electrolyte-rich waters and is tolerant of extremely polluted conditions. The dominance of two

pollutant tolerant species indicates that this site is affected by some form of pollution.

- According to the diatom community structure, the overall ecological water quality for sites B1, B3 and B9 were *Good*, however for sites B5 and B12 the water quality was *Poor* and for B13 it was *Bad* (Table 3-12Table 3-11).
- Sites B1, B3, B9 had low %PTV scores indicating that these sites are relatively free from organic pollution and the overall water quality was good.
- Site B5 had a fairly high %PTV (34.9) indicating some evidence of organic pollution. Both sites B5 and B12 had *Poor* water quality which is reflected by the high nutrient and pollution tolerant diatom species found at these sites.
- Site B13 displayed a very high %PTV (80.1) indicating that the water quality for this site is heavily contaminated with organic pollution. The dominant diatom species are also indicative of eutrophic and polluted waters.

Table 3-11: Species and their abundances for the Yaoure Gold Project selected sampling stations

Species	B1	B3	B5	B9	B12	B13
Achnanthes oblongella Oestrup	0	15	26	3	14	6
Achnanthes standeri Cholnoky	25	0	0	0	0	0
Achnanthes subaffinis Cholnoky	0	4	13	0	23	52
Achnanthidium affine (Grun) Czarnecki	0	0	0	8	0	0
Achnanthidium exiguum (Grunow) Czarnecki	0	0	0	0	40	0
Achnanthidium minutissimum (Kützing) Czarnecki	62	32	16	29	44	13
Achnanthidium saprophilum (Kobayasi et Mayama) Round & Bukhtiyarova	0	0	0	21	0	0
Amphora veneta Kützing	1	0	0	0	0	0
Brachysira neoexilis Lange-Bertalot	11	0	0	0	0	0
Caloneis bacillum (Grunow) Cleve	0	1	0	0	0	0
Cocconeis engelbrechtii Cholnoky	0	51	11	62	8	0
Cocconeis placentula Ehrenberg var. placentula	0	34	0	34	16	0
Craticula buderi (Hustedt) Lange-Bertalot	0	0	0	0	2	0
Craticula cuspidata (Kützing) Mann	7	0	0	0	0	0
Craticula halophila (Grunow ex Van Heurck) Mann	0	0	9	0	0	0
Craticula molestiformis (Hustedt) Lange-Bertalot	0	0	0	0	0	2
Cymbella tumida (Brebisson)Van Heurck	0	4	0	0	0	0
Cymbella turgidula Grunow	0	1	0	0	0	0
Diadesmis confervacea (Kützing) D.G. Mann	0	0	5	0	6	3
Diadesmis contenta (Grunow ex V. Heurck) D.G. Mann	0	0	90	0	0	0
Encyonema mesianum (Cholnoky) D.G. Mann	3	0	0	0	0	0
Encyonema ventricosum (Agardh) Grunow	0	0	0	0	4	0
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin	1	0	0	0	0	0
Eunotia minor (Kützing) Grunow in Van Heurck	40	16	0	16	4	0

Species	B1	B3	B5	B9	B12	B13
Fragilaria capucina Desmazieres var.*capucina*	13	0	0	0	0	0
Fragilaria capucina Desm. ssp. rumpens (Kütz.) Lange-Bert. ex Bukht.	7	0	0	0	0	0
Gomphonema lagenula Kützing	1	0	0	0	0	0
Gomphonema gracile Ehrenberg	31	4	0	0	0	0
Gomphonema insigne Gregory	0	0	0	19	0	0
Gomphonema minutum(Agardh)	0	0	30	40	0	0
Gomphonema parvulius Lange-Bertalot & Reichardt	10	0	0	0	0	0
Gomphonema parvulum (Kützing)	35	0	0	0	23	0
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot	0	6	0	34	0	0
Gomphonema venusta Passy. Kociolek & Lowe	0	0	0	40	45	0
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann	0	0	35	3	0	14
Luticola kotschyi (Grunow) in TDI3 Kelly	0	0	3	0	0	0
Luticola mutica (Kützing) D.G. Mann	5	0	32	0	0	0
Mastogloia dansei (Thwaites) Wm.Smith	0	0	0	0	6	0
Mastogloia smithii (Thwaites)	0	0	0	0	10	0
Navicula antonii (Lange-Bertalot)	15	11	0	0	0	0
Navicula gregaria (Donkin)	4	0	0	0	0	0
Navicula radiosa (Kützing)	3	0	0	0	0	0
Navicula recens (Lange-Bertalot)	15	15	10	0	0	0
Navicula rostellata (Kützing)	0	0	0	0	8	0
Navicula symmetrica (Patrick)	2	1	0	0	3	0
Navicula vandamii (Schoeman & Archibald) var. *vandamii*	7	7	0	0	0	0
Navicula viridula (Kützing) Ehrenberg	0	25	5	3	0	0
Navicula zanoni (Hustedt)	33	8	27	0	0	10
Nitzschia amphibia (Grunow) f.amphibia	0	83	0	52	73	0
Nitzschia capitellata (Hustedt in A.Schmidt & al.)	0	0	0	0	0	82
Nitzschia clausii (Hantzsch)	0	1	0	0	0	0
Nitzschia etoshensis (Cholnoky)	0	0	0	0	0	2
Nitzschia filiformis (W.M.Smith) Van Heurck var. *filiformis*	1	0	0	0	0	0
Nitzschia marginulata (Grunow) var.*marginulata*	0	0	0	0	0	1
Nitzschia microcephala Grunow in Cleve & Moller	0	0	0	0	1	0
Nitzschia palea (Kützing) W.Smith	13	29	25	0	12	176
Nitzschia sigma (Kützing)W.M.Smith	0	0	15	0	0	0
Opephora schwartzii (Grunow) Petit ex Pelletan	0	6	0	2	0	0
Pinnularia subbrevistriata (Krammer)	0	1	3	0	0	0
Planothidium frequentissimum (Lange-Bertalot)	0	0	0	0	1	0
Planothidium rostratum (Oestrup) Lange-Bertalot	0	0	0	0	10	0
Rhopalodia gibba (Ehr.) O.Muller var.*gibba*	0	0	0	1	0	0
Surirella brebissonii Krammer & Lange-Bertalot var.*brebissonii*	0	0	1	0	0	0

Species	B1	B3	B5	B9	B12	B13
Tabellaria flocculosa (Roth)Kützing	0	0	0	0	1	0
Tabularia fasciculata (Agardh)Williams et Round	18	0	16	0	15	0
Total	**363**	**355**	**372**	**367**	**369**	**361**

Table 3-12: Diatom index scores for the study sites indicating the ecological water quality

Site	No. species	%PTV	SPI	BDI	Quality
B1	25	14,9	12,1	15,5	**Good Quality**
B3	22	8,5	8,9	13,3	**Good Quality**
B5	19	34,9	8,1	10,4	**Poor Quality**
B9	16	0	12,7	16,0	**Good Quality**
B12	24	9,4	8,6	11,3	**Poor Quality**
B13	13	80.1	1.5	4.8	**Bad Quality**

3.4 Summary of habitat quality

- The diatom assemblages were generally comprised of species characteristic of alkaline, fresh-brackish, eutrophic waters with moderate to high oxygen levels. However, at site B13 diatom assemblages comprised of species characteristic of extremely polluted, hypereutrophic waters with basic oxygen levels.
- Based on diatom community analyses, three sites showed *Good* water quality, whereas the other sites ranged from *Poor* to *Bad* water quality. The %PTV at site B13 was very high, indicating that this site is heavily contaminated with organic pollution.
- The results indicated that the aquatic habitats at most of these sites tended to be characterized by a moderately disturbed state, with no Critical[1] or Natural[2] aquatic habitats present within and around the Project area in accordance with the IFC Performance Standard 6 (IFC, 2012). The Bandama River and streams are impacted by artisanal mining and the presence of local villages. Indeed, the local population uses the water of the Bandama River for bathing and washing dishes, as well as to conduct underwater artisanal mining activities. These activities have led to sedimentation of the river column due to extensive digging up of the riparian zone (from artisanal mining), and flow fluctuations are regulated by the Kossou hydroelectric dam. These habitats are thus classified as Modified in accordance with IFC Performace Standard 6 (IFC, 2012).

[1]Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.

[2]Natural habitats are areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition.

4.0 IMPACT ASSESSMENT

4.1 Impact Description

Although the techniques and gold mining operations are experiencing a marked improvement, the risks to the environment, namely the aquatic environment, remain very much present. Negative impacts can be generated by several sources such as suspended solids, sedimentation, noise, vibration related to rock blasting, mechanical engine's liquids (hydrocarbon) and chemicals such as cyanide used in the extraction process.

One of the problem related to the mining activities is the technology development which allows more ore to be extracted from a mining site over a longer period of time (FEPS, 2015). Mining waste is therefore increasing with the advancement of technology, and it can be expected to continue increasing in the future.

4.2 Impact Assessment

With the requirement of uncovering huge surfaces, gold mining operations are an important source of soil erosion and habitat loss. The extraction involves moving a huge volume of soil over several meters depth. The bare soil is then able to be leached by rain washing particles into water bodies. The level of floating material and the water turbidity increases, thus limiting light penetration inside the water. The productivity of the primary producers is disturbed and impacted. The decrease in disolved oxygen in the water which follows can gradually cause asphyxiation of the hydrosystem and can impact the aquatic flora and fauna.

Althought all the taxa can potentially be disturbed by pollution related to the project's activities, some are more exposed. The most mobile species such as fish and certain crustaceans are less impacted as they can move to adjacent areas whereas benthic organisms such as mollusks are most likely to be impacted. Materials in suspension can clog the branchial systems of fish, crustaceans and molluscs and cause their death. The suspended particles can cover the spawning areas for many species of fish and amphibians, thus disturbing their reproduction cycle. Organisms with a strong preference for clear and pure water may die out. The neighboring aquatic organisms can be disturbed by the construction activities and noise generated by the exploration and exploitation works.

Indeed, Lévêque & Paugy (1999) highlight that continental hydrosystems are particularly impacted by the anthropic activities both happening within the aquatic environment and the draining Basin. According to Matthews & Styron (1981) and Wootton (1992), living conditions that result could be unfavorable to some species. As per Harmelin-Vivien (1992), Lévêque (1995) and Lemoalle (1999), the fish community react quickly to disturbances of their environment which therefore causes alterations of the species composition, the trophic structure and the size of individuals.

On the basis of the ecological niche, the taxa which could be more vulnerable to an eventual disturbance related to the project's activities are the benthopelagic species and those associated with the banks.

Various toxic substances used in the gold operation can end up in the hydrosystems. Once in the water, the chemical components can penetrate and contaminate the living organisms. Indeed, through the food chain (e.g. algal microflora, zooplankton, macroinvertebrates, and fishes), those compounds are accumulated and could then contaminate other fish-eating animals and human beings (bioamplification). High concentrations become toxic for many fish and animals but also for humans.

The Table 4-1**Error! Reference source not found.** summarises the impact assessment rating process.

Table 4-1: Assessment of the identified impacts' significance

Impact	Significance rating [(Duration+Extent+Magnitude) x Likelihood x Sensitivity]	Description of rating process
Habitat loss	**Medium** ((4 + 1 + 3) x 4 x 4 = 128)	Habitat loss will be localised and thus will not impact a large area. However, most biodiversity groups will likely be impacted, including some globally threatened species.
Habitat fragmentation	**Medium** ((3 + 2 + 3) x 3 x 4 = 96)	Habitat fragmentation is likely to occur following vegetation clearance throughout the Project. It effects are potentially reversible if proper mitigation measures are implemented given that adjacent vegetated areas have already been subject to significant degradation.
Habitat degradation	**Medium** ((3 + 2 + 3) x 3 x 4 = 96)	It is likely that certain species will be impacted by noise, vibration and general human disturbance. However, this impact is not expected to extent to a wide area and background threat levels are already high.
Hydrological impacts	**High** ((3 + 3 + 3) x 3 x 6 =162)	The receptor sensitivity is high with respect to the Endangered fish species that was recorded from the area, and the potential wider area of influence that can be impacted.
Water and soil pollution	**High** ((3 + 3 + 3) x 3 x 6 = 162)	Potential discharge of polluted water into the Bandama River or Lake Kossou would lead to detrimental changes to the aquatic fauna, and in particular to the Endangered fish species recorded from the Bandama River. Other fauna relying on these water sources during the dry season may be impacted as well. Pollution may also affect a wider area of influence.
Invasive species and pathogens	**Negligible** ((3 + 2 + 2) x 1 x 4 = 28)	If proper mitigation measures are implemented, it is not expected that this impact would pose a significant threat. Certain weed species have already been introduced and not much natural vegetation remains within the Project area.
Trophic network contamination	**Medium** ((3 + 3 + 2) x 3 x 4 = 96)	Ending up in the hydrosystems, the various toxic substance used in the gold operation can contaminate the food cycle. Once in the water, the chemicals can penetrate and contaminate living organisms. Indeed, through the food cycle (algal microflora, zooplankton, macroinvertebrates, fishes), those components can accumulate and reach other fish eaters and humans (bioamplification). High concentrations are toxic for several fishes and animals but also for humans.
Induced human access and in-migration	**High** ((4+3 + 3) x 4 x 4 = 160)	There is a high likelihood that an influx of people will come to the Project area, with their associated impacts probably occurring over the long-term, such as increase in fishing and habitat clearance.

4.3 Globally threatened fish species

Here are presented selected characteristics of fish species of conservation significance observed by N'Douba (2007) and also during this survey (Table 4-2).

Table 4-2: A selection of species characteristics (Froese & Pauly, 2014) of conservation significance, observed by N'Douba (2007) and during this survey (Table: KONAN K. Félix ; April 2015).

	Conservation status[1]	Maximal Length (cm) [2]	Infinity Length (cm)	K (1/year)	Natural mortality (1/ year)	Life span (year)	Generation time (year)	Age at first maturity (year)	Length of 1rst maturity (cm)	Trophic level[3]	Environment	Site
Epiplatys chaperi	(NT)	6,0 TL	6,5	-	3,04	-	-	-	4,5	3,2	Freshwater; benthopelagic ; tropical	B3, B7, B8
Epiplatys etzeli	(EN)	5.0 TL	5,5	-	-	-	-	-	-	3,2	Freshwater; benthopelagic; non-migratory; tropical	B3
Marcusenius furcidens	(NT)	28.6 SL	30.0	0,48	-	5,9	1,6	1,5	17,7	3,1	Freshwater; demersal; potamodromous ; tropical	B10
Mormyrus subundulatus	(EN)	27.1 SL	28.5	0.50	-	5.7	1,6	1,5	16,9	3,1	Freshwater ; demersal ; tropical	B10
Raiamas nigeriensis	(NT)	11.1 SL	11.8	0.59	-	4.7	1.9	1.4	7.7	2.9	Freshwater ; démersale; potamodromous ; tropical	B6, B10
Tilapia busumana	(VU)	18.0 SL	19,0	0.57	-	4,9	1,9	1,4	11,8	2,5	Freshwater ; demersal ; tropical	B1, B2, B6
Tilapia walteri	(NT)	27.0 TL	28.4	0.47	0.96	6.0	1.7	1.6	16.9	2.4	Freshwater ; benthopelagic ; tropical	B2, B11

[1]*NT = Near Threatened; EN = Endangered; VU = Vulnerable;*

[2]*TL = Total Length; TS = Standard Length;*

[3]*Trophic level: characterizes the position of a heterotrophic organism in a food web (Froese & Pauly 2015).*

5.0 MANAGEMENT & FOLLOW-UP REQUIREMENTS

5.1 Management requirements and impact mitigation

The application of mitigation measures should minimise the potential impacts of the Yaoure Gold Project on the aquatic communities and their habitats. For this purpose, it is necessary for the following to be included in the proposed framework:

- Design the operation for zero discharge of effluent
- Construct drainage chanels mostly for minimising erosion of the denuded land, as well as to prevent mud sliding into the hydrosystems of the project area;
- Stabilise the shores and banks either by planting small trees (shrubs), grass or other herbaceous plants;
- Rebuild the riparian vegetation of the water bodies within the extraction permit area;
- Create settling ponds and/or construct a lagoon to minimise the disturbances of the hydrographic network in the area;
- Construct a monitored processing unit of the mine's effluent and apply the dishcharge standards in force (as a back-up plan to the zero discharge design);
- Collect waste oil and other wastes for re-cycling; and
- Implement a semi-annual monitoring programme to survey the ecological quality of the hydrosystems in the area.

5.2 Monitoring Requirements

5.2.1 Environmental Monitoring

Environmental monitoring is an essential activity to ensure the sustainability of biological communities and to prevent ecological risks. To do this, it is necessary to assign a research structure to perform the ecological follow-up in the influence zone of the project in order to see the evolution of aquatic populations and water quality.

Considering the fact the project implementation will require the clearing and stripping, monitoring is required through biological methods such as PSI (Proportion of Sediment-sensitive Invertebrates) (Extence *et al.*, 2011). This monitoring should also assess the ecological quality of the water in the influence area of the project via biological tools such as SASS (South African Scoring System) (Dickens & Graham, 2002) and IBIP (Indice Biotique d'Intégrité Piscicole) (Karr, 1981).

5.2.2 Environnemental follow-up

For protecting the biological communities inside the influence area of the project, it will be necessary to develop a strict management and a rehabilitation program via a monitoring system for water quality in partnership with specialized professional bodies (university and laboratories). This program shall serve as assistance tools for decision making in terms of preservation of the quality of the resources. To do this, it is necessary to:

- Select the sampling points to obtain information on the water quality;
- Conduct ecological monitoring campaigns for water in the project area of influence under wet and dry seasons, during the implementation of the mine and during its operation by focusing on the evolution of diversity biological communities, trends in species abundance and proportions of taxa sensitive to disturbance;
- Develop a protection zone for the the most representative existing vegetation as near to the operation site as possible;
- Perform physico-chemical and noise analysis; and
- Produce a report on water quality and propose solutions for restoring the quality in case of quality deterioration.

The Table 5-1 proposes a matrix of the environmental follow-up plan.

Table 5-1: Matrix of the environmental follow-up plan

Specific Objectives	Activities	Follow up Indicators	Estimated Cost
Provide knowledge in the field of ecological management (biological and physico-chemical quality) of water systems in the area.	-An inventory of the ecological quality of water systems in the area is prepared. - A monitoring network of the hydrosystens in the area is set up.	- Two biological sampling campaigns for measuring the physico-chemical parameters per annum (1 during the dry season and 1 during rainy season). - The factors promoting the degradation of the ecological quality of the water body are identified. - The management strategies of water ecological quality are proposed.	25,000 USD/annum

6.0 SUMMARY AND CONCLUSION

6.1 Gap Analysis

The water level fluctuation set by the dam managers hampered the fishing operations during the survey.

The survey conducted in 2007 in the dry season (N'Douba, 2007) is now almost ten years old, thus it is recommendable to conduct a more recent survey to update the dry season data to facilitate the comparisons and have a more up-to-date list of the survey area.

6.2 Conclusion

Several species which are significant for conservation, i.e. reported species on the IUCN Red List (2014) and the endemic and restricted range species, are reported in the present survey area.

Species of major concern are also present upstream and downstream of the survey area. These species are also reported in other river basins and lagoons of Côte d'Ivoire.

The efficient and rigorous handling of the management plans, monitoring and mitigation plans defined in the present document will allow the continuation of the project by minimising the impacts on the hydrosystem of the area.

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8.0 APPENDICES

Appendix 1: Some pictures taken at the 13 sampling sites ***(Photos : KONAN K. Félix ; april 2015)***

B1

B2

B3

B4

B5

B6

B7

B9


B10


B11


B12


B13


B14

Appendix 2: ***Some fish species observed in the Basin of the Bandama River within the Yaoure Gold Project area. (Photos : KONAN K. Félix ; april 2015)***

 • *Papyrocranus afer*	 • *Raiamas nigeriensis*
 • *Pellonula leonensis*	 • *Pellonula vorax*
 • *Brycinus longipinnis*	 • *Brycinus macrolepidotus*
 • *Brycinus nurse*	 • *Brycinus imberi*
 • *Parailia pellucida*	 • *Schilbe mandibularis*

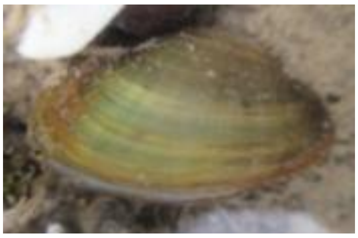
 • *Marcusenius senegalensis*	 • *Marcusenius furcidens*
 • *Brienomyrus brachyistius*	 • *Marcusenius ussheri*
 • *Mormyrops breviceps*	 • *Mormyrops anguilloides*
 • *Pollimyrus isidori*	 *Petrocephalus bovei*
 • *Distichodus rostratus*	 • *Tylochromis jentinki*

 • *Hydrocynus forskalii*	 • *Lates niloticus*
 • *Chrysichthys nigrodigitatus*	 • *Chrysichthys maurus*
 • *Heterobranchus longifilis*	 • *Heterobranchus isopterus*
 • *Chromidotilapia guntheri*	 • *Tilapia walteri*
 • *Tilapia zillii*	 • *Tilapia guineensis*

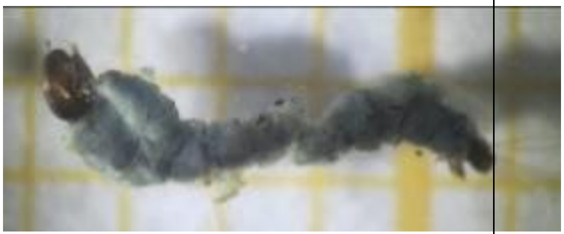
 • *Thysochromis ansorgii*	 • *Oreochromis niloticus*
 • *Hemichromis fasciatus*	 • *Hemichromis bimaculatus*
 • *Hepsetus odoe*	 • *Auchenoglanis occidentalis*
 • *Barbus trispilos*	 • *Barbus inaequalis*
 • *Barbus ablabes*	 • *Barbus wurtzi*
 • *Labeo parvus*	 • *Labeo coubie*

 • *Chiloglanis occidentalis*	 • *Ctenopoma petherici*

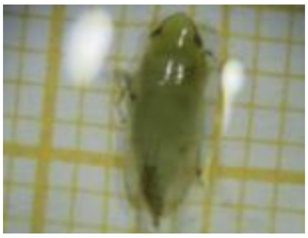
Appendix 3: ***A selection of benthic macroinvertebrate taxa collected in the Basin of the Bandama River within the Yaoure Gold Project area (Photos: BONY K. Yves ; April 2015).***

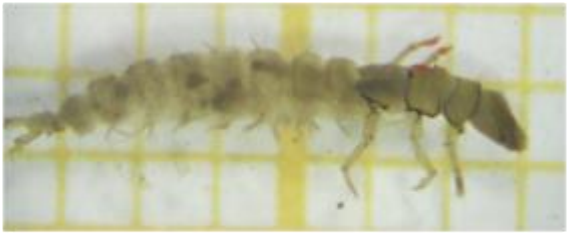
Mollusks			**Ostracods**
Planorbidae  *Bulinus sp. 1*	Planorbidae  *Bulinus sp. 2*	Planorbidae  *Biomphalaria sp*	Thiaridae  *Melanoides tuberculata*
Donacidae  *Iphigenia truncata*		**Decapods** Atyidae  *Atyoida serrata*	**Decapods** Varunidae  *Varuna litterata*

Éphemeroptera	
Leptophlebiidae  *Adenophlebiodes sp.*	Baetidae  *Centroptilum* sp.

Diptera	
Chironomidae  *Chironomus sp.*	Aedidae  *Aedes* sp.C
Culicinae  *Culex sp.*	Chironomidae  *Chironomus formosipennis*
Ceratopogonidae 	Thaumaleidae 
Psychodidae 	Syrphidae 

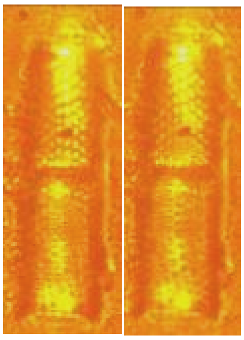
Coleoptera	
Hydrophilidae  *Enochrus sp.*	Hydrophilidae  *Hydrobiinae sp. 1*
Dytiscidae  *Hydaticus sp*	Dytiscidae  *Laccophilus sp.*
Elmidae  *ind*	Elmidae  *Leptelmis sp*
Gyrinidae  *Orectogyrus sp*	Naucoridae  *Ilyocoris cimicoides*

Veliidae  *Microvelia sp*	Belostomatidae  *Diplonychus* sp.
Ranatridae  *Ranatra sp*	Corixidae  *Stenocorixa*
Nepidae  *Laccotrephes*	Belostomatidae  Limnogiton Abedus lutarium

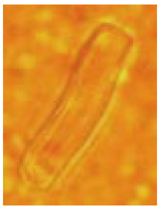
Trichoptères	
Ecnomidae  *Ecnomus sp.*	Hydropsychidae 

Appendix 4: ***A selection of Diatom taxa identified in the basin of the river Bandama within the Yaoure Gold Project area (Photos: ADON Marie Paulette ; April 2015).***

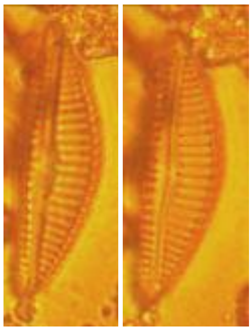
Ulnaria ulna



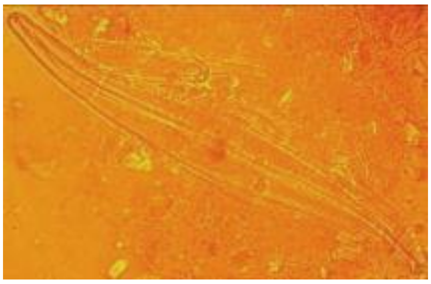
Aulacoseira sp.



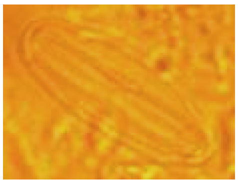
Eunotia sp.



Encyonema silesiacum

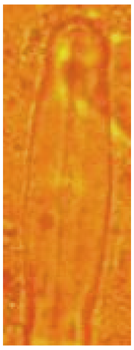


Gyrosigma kuetzingii

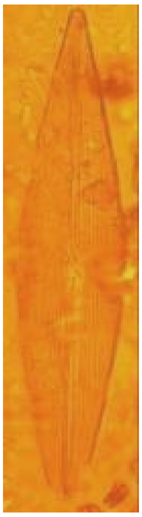


Fallacia pygmaea

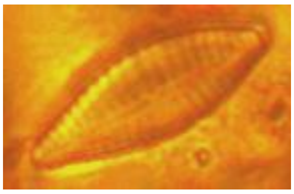
Pinnularia brauniana



Sellaphora pupula



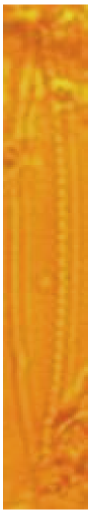
Navicula sp.



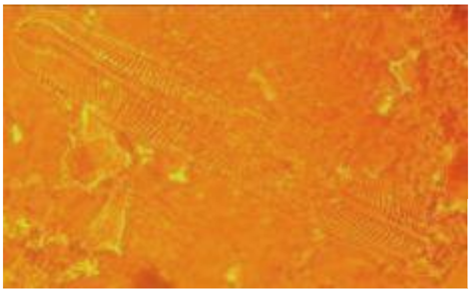
Gomphonema parvulum

Gomphonema affine

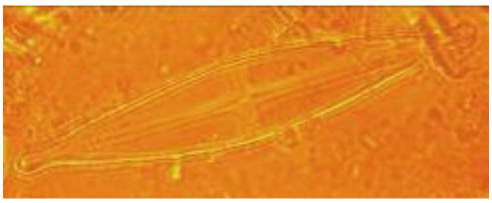
Pinnularia divergens



Nitzschia palea



Pinnularia gibba



Stauroneis sp.