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Continental fishery and risk of contamination of the halieutic ecosystems in the gbaga lagoon channel (Benin-Togo coastal zone)

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Abstract. The coastal zones are areas where a very high number of lagoon-marine species reproduce, grow or transit, which are most often the object of halieutic exploitation. The present study aims to analyze the risk of contamination of fisheries ecosystems and its consequences on the evolution of aquatic resources in the coastal zone, more precisely from southwest Benin to southeast Togo. The methodology adopted is based on the collection and processing of raw data such as: hydrometric data, granulometric data, climatological data, data from fauna and flora inventories, completed by those from in situ measurements and those from laboratory analyses made from sediment samples and some species caught during fishing activities during the different hydrological seasons. The analysis of the results revealed that the pollution of the lagoon channel in Cd, As, Pb and some major ions such as Cl^-, NO_3^- and PO_4^{3-} are responsible for its eutrophication. Furthermore, organic matter and high concentrations of SS lead to the covering of aquatic environments, particularly spawning grounds and the smothering of eggs through the reduction of essential metabolic exchanges (oxygen and nutrient supply, evacuation of metabolic waste) through the reduction of the concentration of dissolved oxygen within the substrate. Trace element analysis in the flesh of Captain (Polydactylus quadrifilis), white grouper (Epinephelus aeneus), tilefish (Tilapia zillii), and white catfish samples revealed their trace element contamination levels. Behavioral effects (abandonment of shelter areas and avoidance reaction); sublethal effects (short-term reduction in feeding rate; minor physiological stress; increase in coughing frequency; increase in the breathing rhythm; moderate physiological stress; major; delayed hatching; reduced number of fish; mortality) were recorded. According to 89 % of the fishermen, the decrease of the fished fish species is registered during the dry periods, when the channel has a high level of contaminating heavy metals and major ions.

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Keywords. Lagoon ecosystems; conservation; aquatic life

1 Introduction

The coasts ecosystems are more and more affected by human activities. Industrialization and urban, agricultural or tourist development in these areas are the main causes of the increase in pressure on these environments (Lougbégnon and Houessou, 2007). Indeed, the geographical location of the Gbaga hydrosystem makes it a defluent of human discharges from the Mono River (Ahéhéhinnou Yêdo, 2020a). Certainly, this reservoir of receptacle of liquid and solid flows, exposes its ecosystems to high risks of pollution (Hodabalo et al., 2014). Thus, the Gbaga lagoon system is characterized by its concentration of heavy metals and major ions (Ahéhéhinnou Yêdo, 2020b). The ichthyological fauna associated with this hydrosystem is therefore not immune to this contamination. Faced with the objectives of the MAB-UNESCO (Man and the Biosphere) program, this study aims to analyze the risk of pollution of the Gbaga lagoon channel and the consequences of the contamination of its fisheries ecosystems on their health.

2 Study area

The study area is part of the Benin-Togolese coastal plain that covers a small part of Togo and Benin, and is located in the lower Mono River valley. It is located between parallels 6°15′ and 6°20′ N latitude and meridians 1°35′ and 1°46′ E longitude (Fig. 1). It is a wetland straddling the togolese and beninese territories with an area of approximately 7272.69 ha (Ahéhéhinnou Yêdo, 2020a). Being a flood bed of the Mono River, it contained seventy-six species of fish belonging to thirteen different families (Lougbégnon and Hesou, 2007). This area belongs to the West Complex Ramsar Site 1017 (Benin) and the Coastal Wetlands Ramsar Site of Togo (Site 1722). On the Togo side, the lagoon channel communicates with the Atlantic Ocean by describing a wide meander giving birth to the Anécho lagoon.

3 Datas and methods

The analyses of the rate of organic matter and the rate of total organic carbon; of metallic traces elements; major ions; organic matter and dissolved organic carbon contained in the sediments and the four species of fish studied were carried out at the Laboratory of Quality Control of Water and Food (LCQEA) of the National Direction of Public Health (DNSP); at the Laboratory Central for the Control of Food Safety (LCSSA) of the MAEP and at the Laboratory of Soil, Water and Environmental Research (LSSEE) of the INRAB on 45 representatives samples of mud. They concern ETM (Cd, Pb, As); major ions (Cl^-, NO_3^- and PO_4^{3-}); DO and COT. These data allowed us to determine the degree of pollution of the channel and to analyze the consequences that this has on the biosphere of the Gbaga Channel. The data were obtained from analyses conducted in the LCQEA and LCSSA (Laboratory Central for the Control of Food Safety) laboratories of the MAEP using samples taken during high and low water periods.

The bioaccumulation factors of the fish studied were estimated from field data using the formula of Thomann et al. (1992): BSF = C_(b,L)/C_(s,oc); with : C_(b,L) = concentration of the substance in the organism (b) normalized to lipids;

C_(s,oc) = concentration of toxicant in silt normalized to total organic carbon. This bioaccumulation method allowed for a perspective analysis of the risk of channel eutrophication on the fish species studied. These data were processed using R software (Version 4.01). The SEPOCA analysis model was used to highlight the weaknesses in terms of failure to apply the environmental protection laws in force, the strengths in terms of success, the opportunities and the obstacles for a better appreciation of the ichthyological population of the Gbaga lagoon channel.

4 Results

4.1 Variation of the ecological monitoring parameters of the Gbaga lagoon channel during the different hydrological periods

The pollution of the lagoon channel can be evaluated by the variation of metallics traces elements and major ions on the one hand and that of dissolved oxygen on the other hand during the different hydrological periods.

4.1.1 Variation of trace metal elements and major ions during different hydrological periods

The Gbaga lagoon channel is subject to several anthropogenic pressures such as the discharge of pollutants. Toxic chemicals attach to or are absorbed by sediment particles, then transported and deposited in the bottom of the Gbaga channel resulting in eutrophication (Fig. 2).

From the analysis of Fig. 2, it is to be understood that the pollutants of the Gbaga channel mud have a very significant variation during the hydrological periods (high and low water periods) especially for trace elements Pb, As and major ions Cl^-, NO_3^-, PO_4^3; on the other hand, the pollutants Cd, MO and TOC have a not very significant variation during the high and low water periods. During low water periods, Pb concentrations in the channel exceed the legal concentration and vary between 159.99 and 273.64 $mg\,kg^{-1}$ with an average of 203.85 $mg\,kg^{-1}$. This explains why the ecosystems of the channel are subject to high levels of lead pollution during this period. However, during high water periods, Pb concentrations are relatively consistent with the very legal norm and vary between 16.57 and 58.32 $mg\,kg^{-1}$ es-

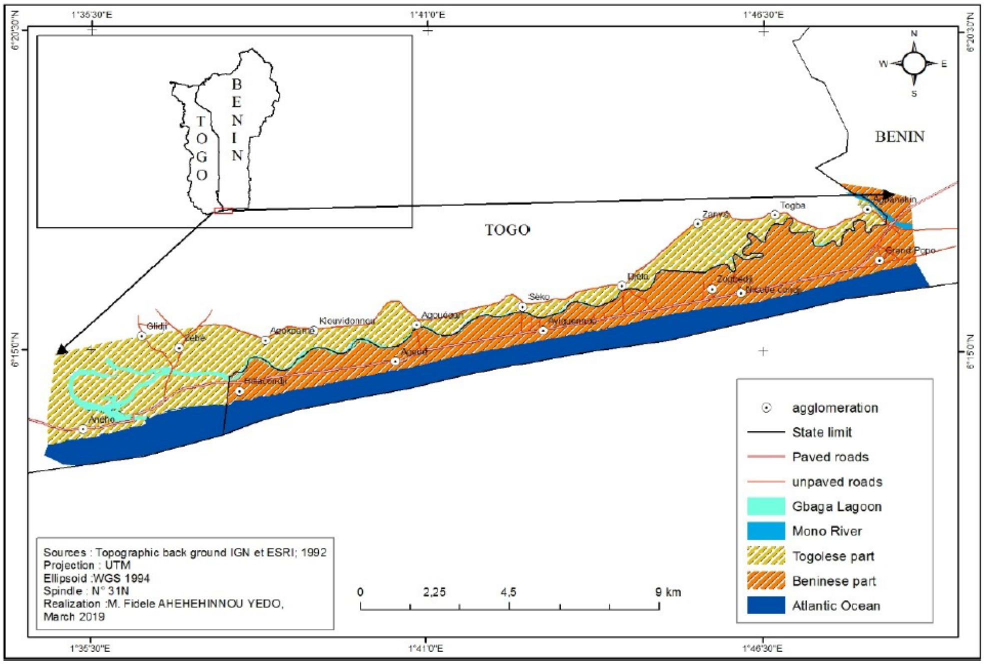

Figure 1. Geographic location of the Gbaga lagoon channel.

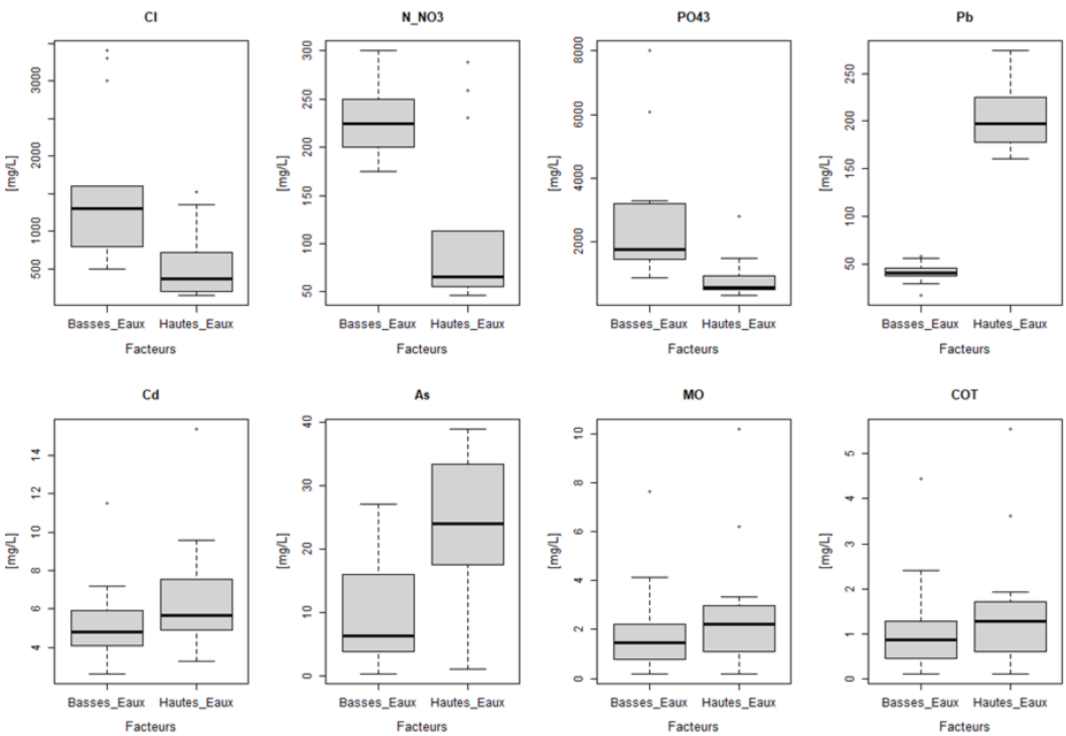

Figure 2. Temporal variation of available pollutants in the Gbaga Channel silt during high and low water periods. Source: Laboratory data processing, 2020.

Table 1. Average TME content in fresh fish caught in the Gbaga Channel.

ETM	Unity	Method used	White catfish	Grouper	Tilapia	Captain	Standards
Lead (Pb)	$mg\,kg^{-1}$	Chloroform extraction	± 0.271	± 0.226	± 0.213	± 0.177	0.2
Cadmium (Cd)	$mg\,kg^{-1}$	Chloroform extraction	± 0.045	± 0.0484	± 0.026	± 0.026	0.05
Arsenic (As)	$mg\,kg^{-1}$	Pyridine	± 0.002	± 0.002	± 0.002	± 0.002	0.1

Source: LCSSA data analysis, June 2020.

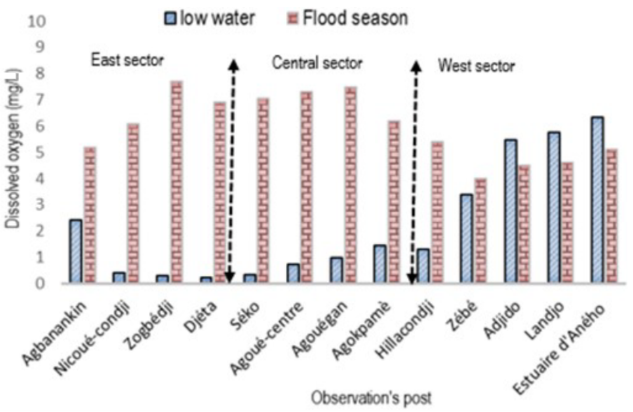

Figure 3. Temporal variation of dissolved oxygen in the Gbaga Channel during high and low water periods. Source: Field campaigns, September 2019 and January 2020.

Figure 4. Illustrates the behavior of crabs in the face of respiratory problems. Photo 1: Behavioral changes in crabs at Nicouécondji Shot: Ahéhéhinnou Yêdo, September 2020.

pecially in its western sector. As for Arsenic concentrations, they fluctuate between 1.4 and 27.2 $mg\,kg^{-1}$ with an average of 11.32 $mg\,kg^{-1}$ during the high water period. In fact, the lowest concentrations recorded are for Cadmium, which are lower than 2.613 $mg\,kg^{-1}$, whatever the hydrological period.

4.1.2 Dissolved oxygen variation in the Gbaga hydrosystem

Dissolved oxygen concentrations characterize and differentiate the sectors and hydrological periods of the channel. The following Fig. 3 presents the variation of dissolved oxygen in the Gbaga hydrosystem.

From the analysis of Fig. 3, it appears that the eastern and central sectors are very poor in dissolved oxygen during high water periods with an average of 0.76 $mg\,L^{-1}$.

While the western sector is very rich in dissolved oxygen with an average of 5.23 $mg\,L^{-1}$. On the other hand, the western sector is never devoid of dissolved oxygen, regardless of the hydrological period, just like the Agbanankin observation station. Variations in dissolved oxygen are dependent on exchanges with oceanic and continental waters and with the atmosphere.

It is to be understood that in the face of dissolved oxygen deficits in the aquatic environment, the crabs come to inhale oxygen on the hydrophytes, in order to survive during periods of high water.

4.2 Contamination of fish species with traces metals

Trace element analysis in the flesh of Captain (Polydactylus quadrifilis), white grouper (Epinephelus aeneus), Tilapia zillii, and white catfish allowed us to determine the average level of trace element contamination of these fish in the Gbaga Channel (Table 1).

Only the captain is safe from the effects that Pb produces in the flesh of fish. But there is a very strong alert of the effects that Cd produces in the Grouper. But these four endangered species are still safe from the effects of As in the waters of the Gbaga Channel.

The fish fauna is vulnerable to the phenomena of bioaccumulation and biomagnification of pollutants (Fig. 5).

The bioaccumulation estimate reveals that tilapia are the species most vulnerable to as bioaccumulation risk and groupers are also the least vulnerable to as bioaccumulation risk in the Gbaga Channel.

As bioaccumulation risk and groupers are also the least vulnerable to As bioaccumulation risk in the Gbaga Channel. It appears that only the captain is safe from the effects of Pb in the flesh of the fish. But we note a very strong alert of the effects that Cd produces in the Grouper. These species of fish being on the verge of extinction in the Gbaga channel, one can therefore deduce that beyond these concentrations, the species still present will end up having an emblaved reproduction.

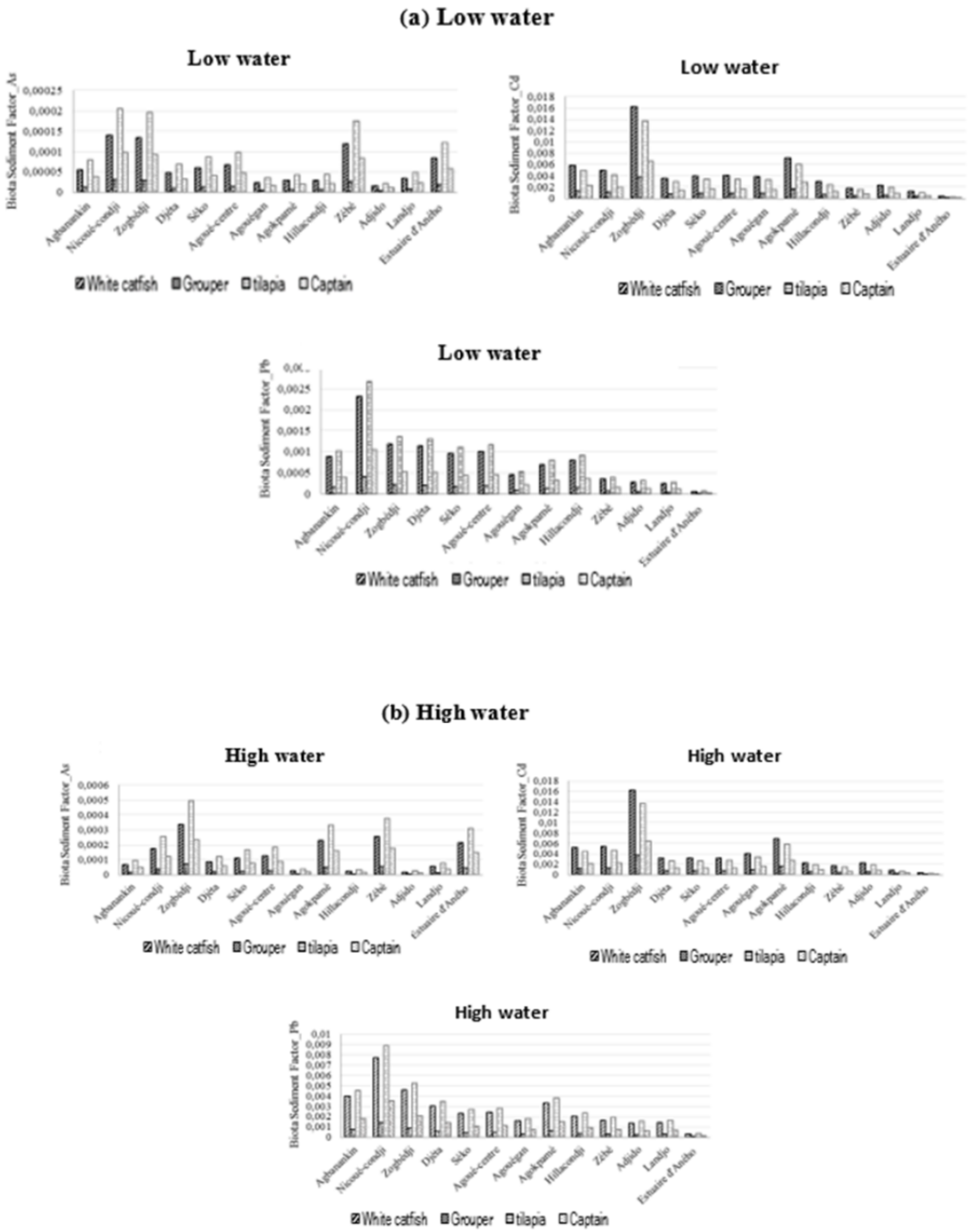

Figure 5. Risk of bioaccumulation of ETM in fish flesh during high and low water periods in the Gbaga Channel. Source: Laboratory data processing, 2020.

5 Discussion

At the end of this study, the Gbaga lagoon channel contains in its silt, a significant concentration of trace metal elements and major ions. These results obtained are in agreement with those obtained from the studies of Shaker (2016), who had stated that the lowest concentrations of heavy metals were recorded for Cd with less than $3\,\mathrm{mg\,kg^{-1}}$, regardless of the season and sampling location. It is also worth noting that the silt of the Gbaga channel is less polluted with heavy

metals than that of Lake Ahémé in Benin (Adéchina, 2018). This could be explained by the topographic aspect of the Gbaga Channel whose waters flow unlike those of Lake Ahémé whose waters are stagnant. This also corroborates the results obtained from the studies of Moussa Moumouni Djermakoye (2005) who demonstrated that the mineralization of the silt is strong, but the lowest values were recorded during the flood, due to the phenomenon of water dilution.

In addition, the pollution of the hydrosystems are the basis of the contamination of the ichthyological fauna and the constraints that hinder their blooming and development. These results obtained reinforce the results obtained from studies conducted on Lake Ahémé by Hounkpè (2017). These manifestations which are more frequent favor the transformation of water into brown or cloudy water with proliferation of hydrophytes such as algae which ecologically unbalance the Gbaga channel through their strong consumption of dissolved oxygen. The manifestations of this imbalance are complicated by excessive phosphate (PO_4^{3-}) and nitrogen (NO_3^-) inputs.

6 Conclusions

This study shows that eutrophication of the channel is occurring due to pollution by Cd, As, Pb and certain major ions such as Cl^-, NO_3^- and PO_4^{3-}. High concentrations of organic matter and suspended solids cause aquatic habitats to cover over, particularly spawning grounds, and suffocate eggs by reducing essential metabolic exchanges (supply of oxygen and nutrients, evacuation of metabolic waste) through lower concentrations of dissolved oxygen in the substrate. This zone is made up of highly fragile ecosystems, and every species found there is fortuitously threatened and endangered.

Code availability. No licensed data processing software was used for this article. For its writing, we used Excèl and the R software (Version 4.01 free).

Data availability. The data related to TME (Cd, Pb, As); major ions (Cl^-, NO_3^- and PO_4^{3-}), MO and TOC come from the analyses made on the samples of mud and fish of the channel in the laboratories LCQEA and LCSSA of the MAEP and LSSEE of the INRAB; taken during the periods of high water and low water. The results of these analyses are delivered on behalf of MFAY in 2020 by the heads of these institutes and are available at their levels and not online. The socio-economic data were obtained through our own investigations of the Gbaga Channel sectors and direct observations. In order to appreciate the evolution of the populations of these fish species, these data were completed by data from previous work carried out by the NGOs: Cooperative de Solidarité Partenê Group (COSOL PG – NGO); Actions d'aide Humanitaire pour le Développement (AHD NGO); the NGO Pro-Sol and the Association FAH-Gbaga (Federation of Associations of the Gbaga riverine villages); the NGO Borne Fonden, the NGO OFEDI and the NGO Action Plus, ECO-ECOLO.

Author contributions. MFAY designed the study, collected the samples that were analyzed by the different laboratories mentioned above, analyzed and processed the data, and wrote the manuscript. MMA developed the model and performed the simulations. EA provided the scientific orientations for this study. MMA, DJK, SHTV contributed to the improvement of the adopted methodology, the analysis of the data and the proofreading of this work.

Competing interests. The contact author has declared that none of the authors has any competing interests.

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