

Harmful Algal Blooms (HABs) in Marine Coastal Water in Côte d'Ivoire (Gulf of Guinea)

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Abstract No study relating to Harmful Algal Blooms (HABs) in the marine coastal waters of Côte d'Ivoire has been carried out. Given their harmful effect, the aim of this study is to identify and quantify HABs in Ivorian waters and monitoring their temporal distribution. Weekly sampling was carried. Samples were fixed in formalin solution (5% final concentration) and afterward, were examined using a standard optic microscope equipped with a digital camera. The quantitative estimation of the HABs species was performed by counting with an inverted diavert microscope, using Utermöhl' method. Seventeen (17) HABs were determined using the species' identification detailed in the literature. They are divided into two groups, those which don't produce toxins like genus *Ceratium*, *Dictyocha*, and two species of *Prorocentrum*, *P. micans*, and *P. gracile* and those which produce toxins like genus *Dinophysis*, *Pyrodinium* and species *Prorocentrum rhathymum*. The lowest densities of HABs were observed during the long and short rainy seasons and the highest were recorded in september with a significant peak on september 11. The species responsible for these high densities are: *Ceratium furca* (8444000 Cells.L⁻¹), *Dinophysis caudata* (4960000 Cells.L⁻¹) and *Protoperdium divergens* (2000000 Cells.L⁻¹). These high values are due to upwelling. The processes that develop during upwelling, in particular the rise of nutrients, are responsible of high biological productivity, hence the high values of HABs observed during this period.

Keywords: Harmful Algal Blooms, marine coastal water, Côte d'Ivoire, Gulf of Guinea

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1. Introduction

Ivorian coastline encompasses a variety of coastal habitats including coastal lagoons, estuaries, mangroves, swamps and humid zones. Due to the diversity and accessibility of coastal resources, several anthropogenic activities are taking place on it such as fishing, aquaculture, industrial plantations, petroleum activities, etc. Also, the coastal zone witnesses heavy shipping traffic [1]. These activities might disturb the hydrology and ecology of coastal ecosystems; and affect its biodiversity. The preservation and management of these environments requires knowledge of biotic and abiotic factors. Marine phytoplankton, autotrophic organisms at the base of the marine trophic web, constitutes an essential component of any marine ecosystem [2,3]. Phytoplankton populations transfer energy to other trophic levels, and comprise over 90% of existing organic matter. They also contribute to regulating biochemical cycles and in the stability of multiple aquatic ecosystems [4]. Due to the ecological importance of phytoplankton populations in the marine environment, and given the harmful nature of certain species, some studies have been carried out to investigate

these creatures and their environment in african marine areas. Some species of phytoplankton, known as Harmful Algal Blooms, may produce toxins known as marine biotoxins, which can cause economic, ecological and health impacts on humans [5,6]. HABs are getting remarkable focus of much scientific research in coastal waters worldwide, as it may have severe impacts on coastal societies. Some studies, tackling the Nigeria algal bloom and the presence of their biotoxins in Nigerian coastal waters have demonstrated the occurrence of the marine dinoflagellate toxins due to unfavourable environmental conditions, mainly low salinities [7,8]. Eleven Harmful algae blooms were identified in seawater along the coast of Ghana [9]. In Northern Africa, the most records of algal toxins are registered along the Moroccan coastline where an official monitoring program took place [10,11]. In Côte d'Ivoire, only few and old studies on marine phytoplankton have been carried out [12] (12a,12b,12c) [13,14,15,16,17], which shows the necessity to do a recent assessment about phytoplankton populations especially HABs in this under-studied area of the Gulf of Guinea. None of this study dealt with HABs. The aim of this study is to identify and quantify HABs in ivorian waters and to assess their temporal distribution.

2. Material and Methods

2.1. Study Area and Sampling Site

The shoreline of the Ivorian oceanic zone has a length of 566 km, and is characterized by a series of sandy beaches forming a wide arch opened to the Atlantic Ocean. The coastal zone covers an area of about 32 960 km², and it is bordered to the north by the Gulf of Guinea (GoG) shoreline stretching from the Cape of Palmes (7°30'W) and the Cape of Three Points (2°W). It can be subdivided into three directions: 70° from Tabou to Sassandra, 85° from Sassandra to Abidjan and 100° from Abidjan to the Cape of Three Points [18]. Samplings were done weekly in the eastern coastal part of the Atlantic Ocean in Côte d'Ivoire at the site of Jacquville (5.19°N, 4.45°W) from 29th April 2020 to 5th December 2020. Jacquville is located at the edge of the Atlantic Ocean, on the Gulf of Guinea, at around 50 km far from the economic capital, Abidjan (5.19°N, 4°W) of Côte d'Ivoire (Figure 1).

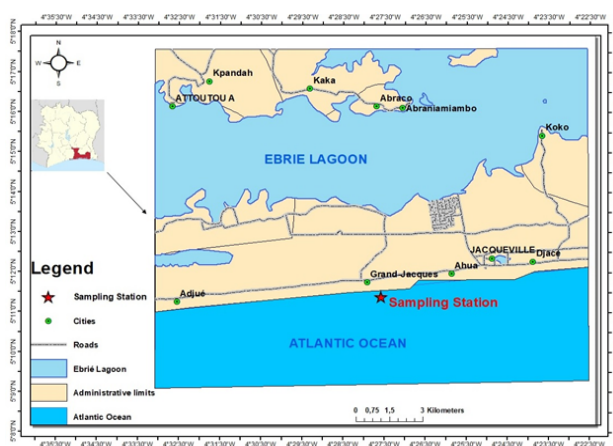


Figure 1. Geographical location of sampling site

2.2. HABs Sampling and Analysis

Plankton net of 20 µm mesh size was used to sample species of phytoplankton between 0 and 5 m depth. Samples were fixed in 5% final concentration of formalin solution, and afterward, were analyzed in the laboratory using a standard optic microscope (Olympus) equipped with a digital camera. The observations were made using the 40X magnification. An inverted diavert microscope and the method of [19] were used respectively to count

HABs species and to HABs quantitative estimation. Ten (10) mL and 25 mL of water samples were transferred into counting chambers for microscopic study and the sedimentation times reached 10 and 18 hours respectively. Some dilutions (1/2) were made for samples where a high concentration of cells was observed in sedimentation chambers. The species were identified with the books of certain authors like [20,21,22,23,24,25]. The densities of HABs were expressed as Cells.L⁻¹.

2.3. Statistical Analysis

Statistical analysis was implemented using Python software (version 3.11). All figures were drawn using software Python.

3. Results

Seventeen (17) harmful species were found afterward identification belonging 6 genera: *Ceratium*, *Dinophysis*, *Prorocentrum*, *Protoperidinium*, *Pyrodinium* and *Dictyocha*.

The highest species were recorded for genus *Ceratium* with 8 species: *C. candelabrum*, *C. furca*, *C. gibberum*, *C. hexacantum*, *C. humile*, *C. massiliense*, *C. tripos* and *C. trichoceros*. The most commonly encountered taxa during the sampling period was species *C. furca* (28 out of 32). The greatest specific diversities were observed in September with 11 and 10 species respectively in 04 and 11 September, the lowest was found in December with no HABs. Two groups of HABs were found, those producing toxins: *Dinophysis acuminata*, *D. caudata*, *D. rotundata*, *Prorocentrum rhathymum*, *Pyrodinium bahamense* (Figure 2) and those which were invasive and do not produce toxins: *C. candelabrum*, *C. furca*, *C. gibberum*, *C. hexacantum*, *C. humile*, *C. massiliense*, *C. trichoceros*, *C. tripos*, *Dictyocha fibula*, *Prorocentrum gracile*, *P. micans*, *Protoperidinium divergens* (Figure 3).

According to the quantitative estimation, the densities of HABs varied from 0 to 16504000 Cells.L⁻¹. Species *C. furca* (15202330 Cells.L⁻¹), *D. caudata* (6556670 Cells.L⁻¹), *Prorocentrum micans* (4925000 Cells.L⁻¹), *Protoperidinium divergens* (3366670 Cells.L⁻¹) and *Ceratium candelabrum* (1080000 Cells.L⁻¹) recorded the highest densities. Species *C. gibberum* (20000 Cells.L⁻¹), *D. rotundata* (60000 Cells.L⁻¹) and *C. massiliense* (85000 Cells.L⁻¹), recorded the lowest densities.

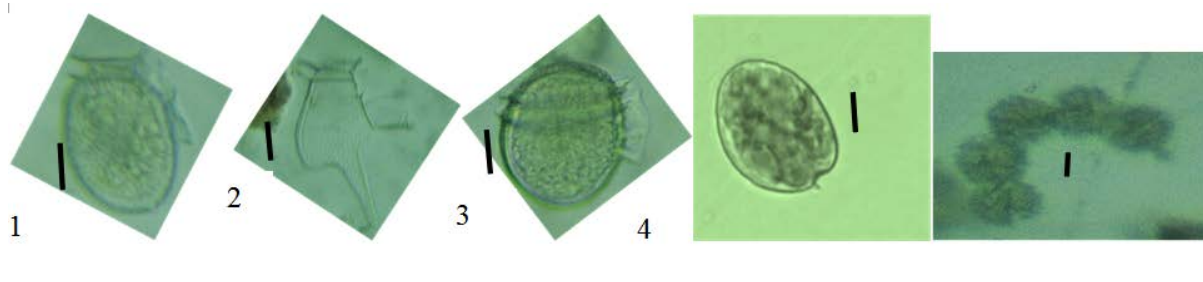


Figure 2. Toxic HABs: 1. *Dinophysis acuminata*, 2. *D. caudata*, 3. *D. rotundata*, 4. *Prorocentrum rhathymum*, 5. *Pyrodinium bahamense* (Scale bar = 10 µm)

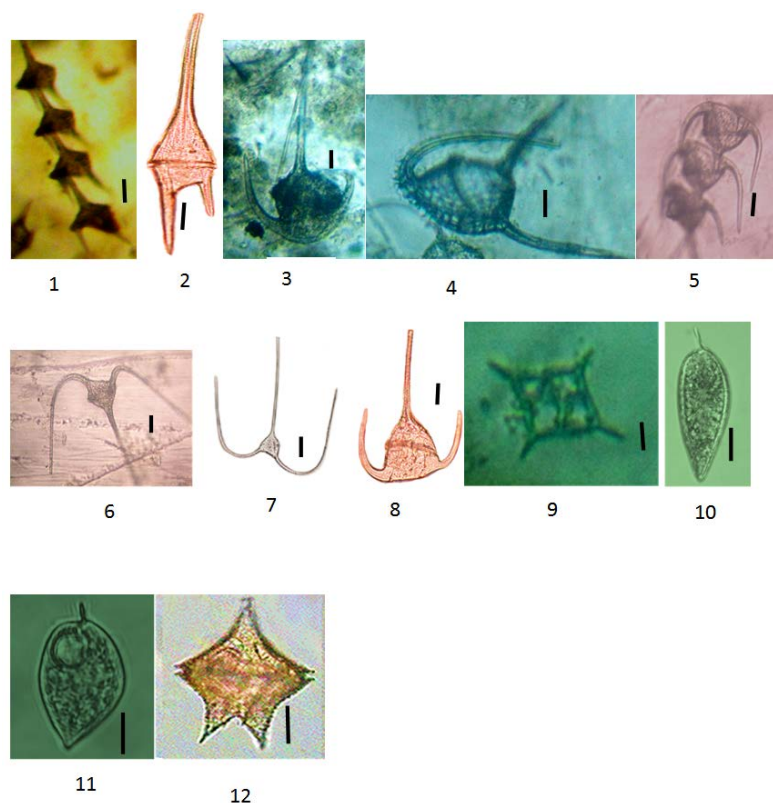


Figure 3. Non-toxic HABs : 1. *C. candelabrum*, 2. *C. furca*, 3. *C. gibberum*, 4. *C. hexacantum*, 5. *C. humile*, 6. *C. massiliense*, 7. *C. trichoceros*, 8. *C. tripos*, 9. *Dictyocha fibula*, 10. *Prorocentrum gracile*, 11. *P. micans*, 12. *Prorocentrum divergens* (Scale bar = 10 µm)

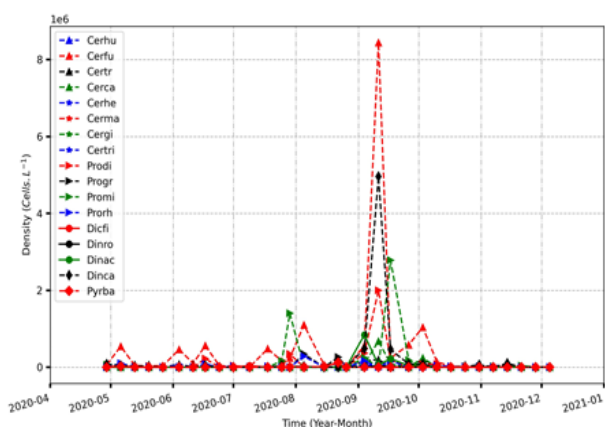


Figure 4. Temporal variation of HABs from 29 april to 5 december

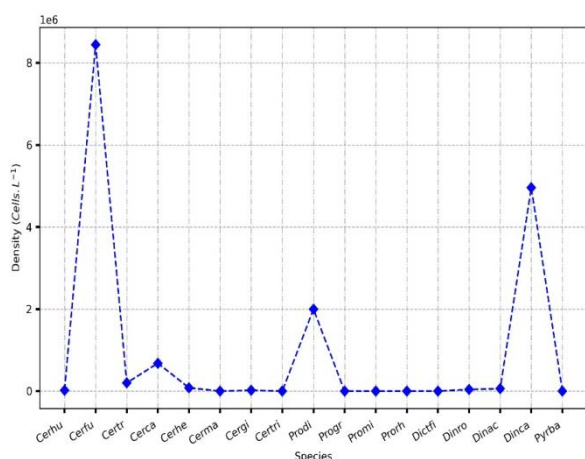


Figure 5. Densities of HABs of high peak observed in 11 september

According to the temporal variation (Figure 4), the lowest densities were recorded from 29 April to 26 août and from 10 October to 05 December. However, some small peaks were observed from 29 July to 05 août and 03 October. The high densities were observed from 04 September to 17 September with a significant peak on 11 September. A total of 16504000 Cells.L⁻¹ were responsible of this peak. *C. furca* with 8444000 Cells.L⁻¹, *D. caudata* 4960000 Cells.L⁻¹ and *P. divergens* 2000000 Cells.L⁻¹ were the important species that contributed to this increase (Figure 5).

4. Discussion

The structure of HABs population in ivoirien coastal waters is characterized by a predominance of genus *Ceratium*. Among all the genera encountered, *Ceratium* appeared the most, during almost the period of sampling. In the oceanic zone, this genus is very popular. Studies carried out several decades earlier in the marine waters of Côte d'Ivoire [14] showed the predominance of this genus. The same results were reported in studies carried out in Mediterranean with the predominance of the genus *Ceratium*. *Ceratium* has long been used as a hydrographic indicator of water in the Mediterranean Sea. It has been recognized that species that make up the genus *Ceratium* are a good biological model to examine the potential effects of global changes on phytoplankton biodiversity [26]. Among the species of the genus *Ceratium*, species *C. furca* the most encountered taxa in this study (28 out of 32) is regarded as the most common species to form blooms in coastal waters worldwide [27]. A study done in Iranian waters of the Gulf of Oman showed also *Ceratium furca*

as a predominant species for Dinoflagellates phylum [28]. *C. furca* is non-toxic, but it has the potentials to form massive blooms [29], such blooms are capable of killing aquatic biota. Species *C. tripos* is after *C. furca*, the most common species in ivorian coastal waters. A bloom of this species, can provoke both hypoxic and anoxic conditions [30], events that deplete oxygen in water and cause biota kills. Apart of species *Dictyocha fibula*, the others species encountered are Dinoflagellates. Indeed, in most toxic episodes, Dinoflagellates' species are involved. Dinoflagellates is the phylum of phytoplankton with the most species likely to cause bloom. In this study, 3 dinoflagellates' species of genus *Dinophysis* (*D. acuminata*, *D. caudata*, *D. rotundata*) were identified. They can produce biotoxins of the okadaic acid and pectenotoxin groups. The lipophilic produced by these species, that accumulate in filter-feeding shellfish and cause an illness in consumers are called Diarrhetic Shellfish Poisoning [31]. Three species of genus *Prorocentrum* were found: *P. gracile*, *P. micans* and *P. rhathymum*. Highest density was observed for species *P. micans*. *P. micans* is mainly found in neritic and estuarine waters, but it has also been observed in oceanic environments [32]. This species can form extensive blooms, but it is considered harmless, it may excrete chemicals that inhibit diatom growth, but these substances do not affect organisms in higher trophic levels [32]. Just like *P. micans*, species *P. gracile* is not a known toxin producer. It might deplete nutrients during blooms and cause anoxia. Species *P. rhathymum* is widely distributed in tropical and subtropical environments [33,34]. Unlike the 2 previous *Prorocentrum*, *P. rhathymum* have been reported to be capable of producing certain toxins like okadaic acid and *Dinophysis* toxins that can result in diarrhetic shellfish poisoning [35]. Toxicity studies of *P. rhathymum* still have ambiguities regarding the type of toxin produced. Studies carried out in the coastal waters of western India on the toxin production of *P. rhathymum* showed the production of dinophysistoxin-1 with no detection of okadaic acid [36]. Only one Species of genus *Pyrodinium* and *Protoperidium* were found. The thecate *Pyrodinium bahamense* is a very important member of Paralytic Shellfish Toxin or Poisoning (PST or PSP) in tropical waters. This species has caused more human illnesses and fatalities than any other PST producing dinoflagellates [37,38,39,40]. Concerning species *Protoperidium divergens*, it forms extensive cells, called blooms and causes oxygen depletion in surrounding waters. These blooms discolor the seawater and these HABs are commonly referred to as 'red tide' which can cause massive fish mortality and contaminate the seafood [41]. In general, HABs do not only affect marine organisms but can also have consequences on human health [42,43] as well as socio-economic impacts and costs [44]. These increasingly frequent natural phenomena seem to be accentuated by certain factors such as eutrophication of the environment linked to human activities [45,46]. Moreover, many studies around the globe are attributing the increase of frequency and intensity of HABs to climate change, and global warming [46].

Regarding the temporal variation of HABs, the highest specific richness and the densities observed in september could be attributed to the upwelling which might be

promoting the proliferation of phytoplankton. In fact, the highest densities were observed in june, july, september and october, a period that corresponds to the upwelling of the great cold season (from July to October). The upwelling of this great cold season leads to the greatest enrichment of surface water. Its fertilizing effect is amplified by the terrigenous inputs resulting from the flood of continental water [47]. The lowest densities were observed in November and December. In fact, the short hot season (November-December) and especially the great hot season (March to June) are generally characterized by poor phytoplankton community, but one or more phases of activity can occur during the great hot season, thanks to a rise of the thermocline on the surface. The absence of upward movements during this period favors the formation of a thermocline in the shallow waters which become poor in nutrients. This water column stratification constitutes an obstacle to the rise of these nutrients towards the surface. This nutrients' shortage could lead to the depletion of phytoplankton to the top [47].

5. Conclusion

A total of 17 HABs were found in ivorian marine coastal water. HABs' identification shown the significant densities in upwelling period. Various HABs relating depletion oxygen, red tides, marine animals' mortality, Diarrhetic Shellfish Poisoning, Paralytic Shellfish Toxin or Poisoning were found. Even if, high densities of HABs were observed during certain periods of this work, no health cases or mortality of marine animals were revealed.

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