

The First Occurrence of Red Tide Caused by *Karenia* sp. in the Atlantic Moroccan Coast (Oualidia Lagoon)

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Abstract: An intense bloom of *Karenia* sp. was reported in the Oualidia lagoon, part of Atlantic Moroccan coast. The highest concentrations are 1.04×10^7 cells/L, and have been noted at the park station 7. High nutrient concentrations have been observed, and PO_4 was the highest value (av. 396.18 $\mu\text{g/L}$) recorded at Parc 7. This massive proliferation caused a red tide which extended over 25 km from the Atlantic coast. This event was accompanied by stranding of macroalgae.

Key words: Bloom, dinoflagellate, red tide, *Karenia* sp..

1. Introduction

Occurrence of HABs (Harmful Algal Blooms), commonly known as “red tides”, has increased and expanded in spatial extent worldwide in the recent decades in coastal waters [1, 2]. Indeed by several authors, the HAB problem was growing worse as a result of pollution [3] or other factors such as expanded aquaculture operations, superior competitive nutrient uptake, cyst formation or ballast water transfer of species [1]. In fact, the reasons for their substantial intensification can be associated with a set of physical, chemical and biological factors including climate changes and anthropogenic impacts [4].

So far, several phytoplankton blooms were frequently reported from the west coast of Atlantic Moroccan coast, among them, red tides are frequently occurring on blooms of *Lingulodinium poyedrum* (dinoflagellate) [5] and *Peridinium quinquecorne* [6].

In August 2014, a bloom of the dinoflagellate

Karenia sp. was observed in the lagoon of Oualidia and caused a red tide. The objective of this study is to describe the environmental conditions that accompanied this bloom.

Area Studied

Oualidia lagoon (32°40'42" N-32°47'07" N and 8°52'30" W-9°02'50" W) is located on the Atlantic Ocean (Fig. 1). This lagoon is 7 km long, on average 0.4 to 0.5 km wide, and its total area is estimated at 3 km² [7]. In Ref. [8], the lagoon of Oualidia is characterized by three areas [9]:

—A main pass of about 150 m wide, permanent and active all year, and a secondary pass 50 m wide, only active during tides freshwater; these two passes ensure the lagoon a continuous communication with the Atlantic Ocean;

—A main channel, the maximum depth of which is not more than 5-6 m, secondary channels (deep maximum 1 to 1.5 m), intertidal zones and schorres overgrown with halophyte vegetation;

—An artificial dike separating the marsh lagoon salt.

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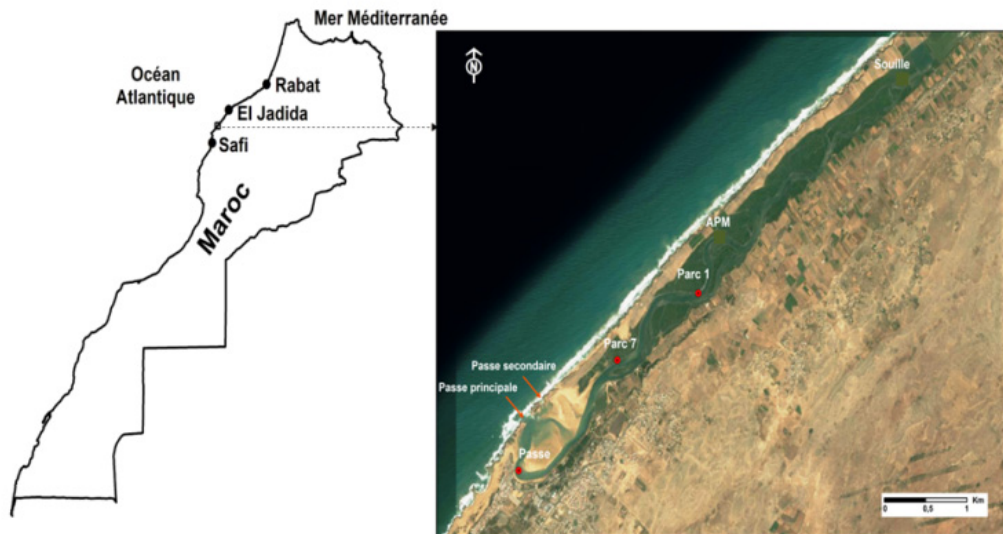


Fig. 1 The geographical location of the Oualidia lagoon and sampling sites.

2. Materials and Methods

For this study, the sample was according to three sampling stations: Passe, Parc 7 and Parc1 (Fig. 1) during 2014. They were chosen along the lagoon, from the pass to the bottom to better represent the spatial distribution of phytoplankton populations in the water column. The frequency of sampling was bimonthly for analysis of phytoplankton, and seasonally for physico-chemical parameters. The sampling of the summer season coincided with the appearance of the red tide. That is why we will focus only on this period.

Water samples were performed at high tide surface (photic zone) using a zodiac, and are collected by a 1 L bottle, then they are fixed directly with Lugol 5 mL/L.

2.1 Identification of Dinoflagellate Species

Samples for different dosages and measures were taken during the red tide period, from small, large bottles previously washed with distilled water. The samples are kept cool and obscurity. Samples for phytoplankton analysis are homogenized, poured into sedimentation tanks (25 mL) and placed on a flat

surface without vibration in the dark at an ambient temperature for 6 to 8 hours.

After sedimentation, the identification and enumeration of species are using a type of inverted microscope (Nikon) according to the sedimentation method Utermöhl [10] after acid iodine fixation.

2.2 Physico-Chemical Analysis

For physico-chemical measurements, pH, salinity, temperature are measured directly *in situ*, using respectively, pH meter type WTW 597, salinometer type WTW LF 197, also using a thermometer.

The contents of nitrites, nitrates and orthophosphates were collected once, and determined, by chemical dosage according to the method of seawater analysis, reported in Ref. [11].

3. Results and Discussion

• Hydrographic Conditions

During the red tide period, the atmosphere over the region was sunny with weak winds (< 3 ms¹). Water temperature varied between 17 and 18 °C at all sampling points during the time of collection and salinity of 35 from the pass to 33 to the bottom of the

lagoon. pH did not show much variation, with averages of 8.01 and 7.9 (± 0.06) respectively. Concentration of PO_4 was the highest value (av. 396.18 $\mu\text{g/L}$) recorded at Parc 7, as compared to NH_4^+ (av. 48.65 $\mu\text{g/L}$), NO_3^- (av. 208.38 $\mu\text{g/L}$) and NO_2^- (av. 15.29 $\mu\text{g/L}$).

- Bloom Assemblage

Throughout the observation, the phytoplankton

density varied from $2.4 \times 10^5 \text{ cells}\cdot\text{L}^{-1}$ to $1.04 \times 10^7 \text{ cells}\cdot\text{L}^{-1}$, with a maximum density recorded on the first day of bloom at the Parc 7 station. Among these, dinoflagellate was numerically abundant group (72.2-99.2%) followed by diatoms (0.8-27.8%) and finally the Euglenophyceae (0.8-27.8%).

A total of 23 taxa of phytoplankton were identified in the bloom period (Table 1), four were diatoms, and

Table 1 Phytoplankton composition and abundances.

| Species name | Abundance ($\text{cells}\cdot\text{L}^{-1}$) | | | | | |
|--------------------------------|--|---------|--------|-------|--------|--------|
| | Passe | Parc 1 | Parc 7 | Passe | Parc 1 | Parc 7 |
| Diatoms | | | | | | |
| <i>Amphora</i> sp. | 0 | 80 | 0 | 0 | 0 | 0 |
| <i>Coscinodiscus</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Diploneis</i> sp. | 0 | 40 | 0 | 0 | 0 | 0 |
| <i>Grammatophora</i> sp. | 0 | 80 | 0 | 0 | 0 | 0 |
| <i>Guinardia stouterfothii</i> | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Gyrosigma</i> sp. | 0 | 0 | 0 | 0 | 40 | 0 |
| <i>Licmophora</i> sp. | 0 | 0 | 0 | 0 | 40 | 0 |
| <i>Navicula</i> sp. | 0 | 800 | 0 | 0 | 0 | 0 |
| <i>Nitzshia</i> sp. | 0 | 200 | 0 | 40 | 40 | 0 |
| <i>Paralia sulcata</i> | 0 | 0 | 0 | 320 | 0 | 0 |
| <i>Pseudonitzshia</i> sp. | 0 | 0 | 80 | 80 | 0 | 0 |
| <i>Thalassiosiera</i> sp. | 0 | 3,320 | 0 | 1,520 | 1,320 | 0 |
| Dinoflagellates | | | | | | |
| <i>Alexandrium</i> sp. | 0 | 40 | 40 | 0 | 120 | 0 |
| <i>Ceratium</i> | 120 | 0 | 0 | 0 | 0 | 0 |
| <i>Ceratium fusus</i> | 200 | 120 | 0 | 0 | 0 | 0 |
| <i>Dinoflagellés</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Dinophysis</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Eutripsiella</i> | 0 | 0 | 0 | 120 | 0 | 0 |
| <i>Gonyaulax</i> sp. | 0 | 0 | 0 | 0 | 40 | 0 |
| <i>Gymnodinium</i> sp. | 80 | 0 | 0 | 0 | 0 | 0 |
| <i>Gyrodinium</i> sp. | 0 | 160 | 0 | 0 | 0 | 0 |
| <i>Lingulodinium polyedrum</i> | 40 | 0 | 80 | 0 | 0 | 0 |
| <i>Peridinium quiquecorne</i> | 0 | 0 | 0 | 0 | 160 | 0 |
| <i>Prorocentrum micans</i> | 0 | 640 | 0 | 0 | 0 | 0 |
| <i>Prorocentrum scutellum</i> | 6,960 | 0 | 0 | 0 | 40 | 0 |
| <i>Prorocentrum</i> sp. | 0 | 8,960 | 0 | 120 | 0 | 0 |
| <i>Proto-peridinium</i> sp. | 0 | 80 | 0 | 40 | 0 | 0 |
| <i>Pyrophacus</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>scripsiella</i> sp. | 160 | 2640 | 0 | 40 | 0 | 0 |
| <i>Osteopsis</i> sp. | 0 | 0 | 40 | 0 | 0 | 0 |
| <i>Karenia</i> sp. | 1,044,000 | 245,880 | 0 | 0 | 0 | 120 |
| EUGLENOPHYCEAE | 18,080 | 2,140 | 7,450 | 1,980 | 4,910 | 3,912 |

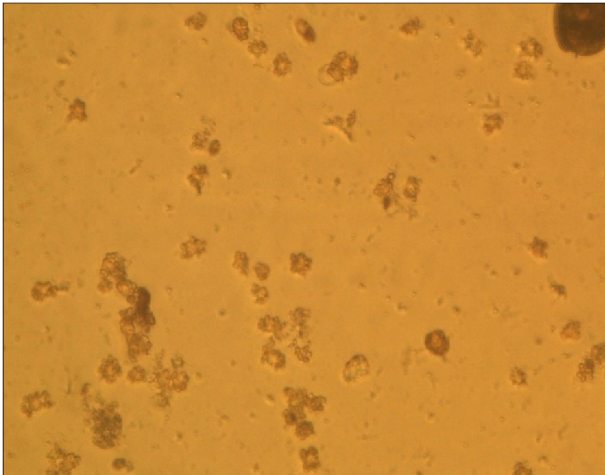


Fig. 2 Bloom of *Karenia* sp.

19 were dinoflagellate and Euglenophyceae. Among the diatoms, *Nitzshia* sp. (av. 46.6 cells·L⁻¹), *Navicula* sp. (av. 133.3 cells·L⁻¹) and *Thalassiosiera* sp. (av. 133.3 cells·L⁻¹) were observed. Whereas *Ceratium fusus* (53.3 cells·L⁻¹), *Peridinium quinquecorne* (av. 1.06×10^2 cells·L⁻¹), and *Prorocentrum scutellum* (1.16×10^3 cells·L⁻¹), *Prorocentrum* sp. (av. 1.5×10^3 cells·L⁻¹), *Scrippsiella* sp. (av. 4.73×10^2 cells·L⁻¹), and *Karenia* sp. (av. 2×10^5 cells·L⁻¹), were identified under dinoflagellate. Microscopic analysis revealed that the discoloration was caused by an unarmored dinoflagellate (Fig. 2), *Karenia* sp. [12]. It contributed up to 98%, which belongs to order Gymnodiniales, family Gymnodiniaceae. Earlier, it was known as Gymnodinium and recently has been changed to the genus *Karenia* [13].

- *Karenia* sp. [12]

Karenia is genus containing at least 12 species of marine unarmored dinoflagellates [14]. Most produce toxins (during proliferation) and have been described as a result of investigations on massive fish kills causing an important economic losses or human health problems. That is why; this species has been the subject of several studies in order to predict the economic consequences.

Bloom of *Karenia* species dates back a long time, in Florida, the first blooms of *K. brevis* were reported in 1844 predating the rapid economic growth and

development of the mid to late twentieth century by many decades [15]. Historical records demonstrate that these blooms have occurred almost annually in the years since the 1940s (FFWCC, 2001). According to Oda [16], in 1953, *Karenia mikimotoi* was responsible for an episode of mortality in oysters and fish in Japan.

In the Gulf of Mexico, animal mass mortality, and respiratory distress were caused by frequent blooms of *K. brevis* [17]. However, blooms of newly discovered species of *Karenia* have developed in many parts of the world. In Irish water, a protracted toxic bloom of *Karenia mikimotoi* occurred in summer 2005 along the northern half of the western Irish coastline. Major mortalities of benthic and pelagic marine organisms were observed and a complete decimation of marine faunal communities was reported and observed in several locations [18]. In the Southwest coast of India, an intense brownish discoloration was observed in the surface waters in 2009 [19]. Moreover, between 1997 and 2007, the dinoflagellate *Karenia selliformis* represents 68% of the blooms occurred in the gulf of Gabès in Tunisia [20].

Actually, prolonged dense blooms of *Karenia mikimotoi* in other regions of the world are frequently, but not always, associated with fish kills and the death of invertebrate species, although it is common in many other regions of the world (Texas, Gulf of Mexico, Arabian Sea, Australia, China, Ireland, England, France, Hong Kong, western India, Japan, New Zealand, North Sea, Norway and Scotland).

In Morocco, the first observation of a red tide due to the *Karenia mikimotoi* was in 2005 in TanTan, the southern of Morocco. This has caused significant mortality of fish [21].

In Oualidia lagoon waters, the first occurrence of red tide is caused by *Karenia* sp.. It is possible that similar blooms have occurred, but have not been recognized. The massive proliferation of *Karenia* sp. was accompanied with macroalgae bleaching. Nevertheless, there were no fish kills visible from the

area during the occurrence of present bloom. The same case was noted by Madhu, et al. [19], which could be explained by dilution of water to the adjacent coastal waters by tidal effect.

The close relationship between HAB's and nutrient growth has often been reported in coastal waters [22-24]. In this study, the bloom of *Karenia* sp. coincided with an increase of orthophosphate. This obtained result is an agreement with the study of Robin, et al. [25], where they explain that explosive growth of *Karenia mikimotoi* in the water of Southeast Arabian Sea is due to sudden increase in supply of nutrients, especially PO_4^{3-} . On the other hand, this latter conditioned negatively the presence of *Karenia stelliformis*, which prefers and proliferates in waters rich in nitrate [26].

Furthermore, the amount of Euglenophyceae during the bloom reflects a good exposure to sunlight [27], which could lead to the proliferation of *Karenia* sp. According to Barnes et al. [28], the precursor causes of large *Karenia mikimotoi* blooms are suggested to include enhanced growth by sunlight-driven phototaxis.

4. Conclusion

Even though many studies are available on red tides, the information on the incidence of *Karenia* sp. bloom in the Oualidia lagoon waters proves the theory of extension of HAB events. In this study, authors tried to highlight the different environmental conditions that could start the bloom of *Karenia* sp.. The results obtained show that orthophosphate and sunlight reflects the favorable conditions for the proliferation of *Karenia* sp.. However, it remains essential to study the cysts, in parallel, to be able to define the different phases of the life cycle of *Karenia* species, and then provide these blooms.

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