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# Occurrence of harmful dinoflagellates in two different Tunisian ecosystems: the lake of Bizerte and the gulf of Gabès

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**Abstract:** The dinoflagellate phytoplanktonic species were studied in two different Tunisian ecosystems: the gulf of Gabès, and the lake of Bizerte, which are respectively situated South and North of Tunisia. The assemblage diversity of dinoflagellate populations was higher (3.59) in the gulf of Gabès than in the lake of Bizerte, which was closely similar for the two surveys (1.76 in summer to 1.84 in winter). In the gulf of Gabès, harmful microalgae were dominated by *Prorocentrum lima* (Ehrenberg) Dodge, 1975 and *Ostreopsis siamensis* Schmidt, 1901, which are known to be benthic or epiphytic species. In the lake of Bizerte, harmful microalgae were dominated by *Dinophysis sacculus* Stein, 1883 and *Dinophysis acuminata* Clarapède et Lachmann,1859, which are strictly planktonic species. These later species were most abundant in winter. The densities of *P. lima* and *O. siamensis* represented up to 86.4% of the phytoplankton community in the gulf of Gabès while in the lake of Bizerte, their density ranged only between 0-2%. The amount of *Dinophysis* species reached 41.7% in the lake of Bizerte while these species, dominated by *Dinophysis caudata*, did not exceed 8.2% in the gulf of Gabès.

**Résumé :** *Présence de Dinoflagellés toxiques dans deux écosystèmes tunisiens : le lac de Bizerte et le golfe de Gabès.* Les populations planctoniques de dinoflagellés ont été étudiées dans les eaux Tunisiennes dans deux milieux différents : le golfe de Gabès, situé au Sud de la Tunisie et le lac de Bizerte, situé au nord. La diversité spécifique des dinoflagellés a été plus élevée (3,59) dans le golfe de Gabès que dans le lac de Bizerte (1,76 à 1,84). Les microalgues toxiques étaient dominées par *Prorocentrum lima* et *Ostreopsis siamensis* dans le golfe de Gabès, ces espèces sont connues pour être benthiques ou épiphytes. Dans le lac de Bizerte, les espèces *Dinophysis sacculus* et *Dinophysis acuminata,* strictement planctoniques, sont les espèces dominantes. L'apparition de ces dernières a lieu particulièrement en hiver. Les concentrations de *P. lima* et *O. siamensis* représentent jusqu'à 86,4% des dinoflagellés dans le golfe de Gabès (27-30 octobre 2000), alors que dans le lac de Bizerte, leur fréquence varie à peine entre 0-2%. Les espèces du genre *Dinophysis* représentent 41,7% des dinoflagellés dans le lac de Bizerte alors que dans le golfe de Gabès, *Dinophysis caudata*, seule espèce du genre, a une fréquence de 8,2%.

*Keywords*: *Dinophysis* spp • *Prorocentrum lima* • *Ostreopsis siamensis* • Gulf of Gabès • Lake of Bizerte

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## Introduction

The Tunisian coastal zone is characterized by the absence of a permanent general circulation. Although the modified Atlantic water, which is confined in the upper 150 meters, light and cold, plays a role along the northern Tunisian coasts, it remains weak compared to the water flows induced by tides or by winds (Sammari et al., 2001).

The lake of Bizerte is located on the North coast of Tunisia and is connected to the Mediterranean sea through an artificial channel in its northern side and to the lake of Ichkeul in its western part. Its surface area is 128 km$^2$ and the mean depth is 7 meters. The hydrodynamic of this lake is also affected by Oued Tinja, an ephemeral stream situated on its western side, and also connected to lake Ichkeul. The water level between these two ecosystems depends on tides, wind and water flow (evaporation, rainfall and affluents). Numerical model simulations established by Harzallah & Koutitonsky (2001) revealed that tides would be delayed by about 1.5 hour from the entry from the sea until the inner lake, mixing only its northwestern side.

The largest tides in the Mediterranean are found in the gulf of Gabès. The amplitude of the tide rises to the maximum range in the inner part of the gulf (1.8 m in rise and 0.3 m in fall). The water mass of homogeneous temperature and salinity found at every season in the southern Tunisian area could therefore be a branch of the Atlantic current running into the eastern Mediterranean (Burollet, 1979). This ecosystem is characterized in particular by important inshore *Posidonia* beds (Ben Mustapha et al., 1999).

These two ecosystems are under the constant pressure of industrial pollution accentuated by an important urban discharge in the lake of Bizerte. Furthermore, the gulf of Gabès is characterized by the overfishing of demersal resources, which is responsible for the degradation of benthic habitats.

Since 1989, blooms of harmful algae associated with fish mortalities were detected mainly in southern Tunisian coasts and in lakes (Romdhane et al., 1998; Jenkinson & Arzul, 2001; Turki & El Abed, 2001; Hansen et al., 2004). The species, belonging to different families, were: *Trichodesmium erythraeum* Ehrenberg (Cyanophyceae); *Karenia selliformis* Haywood, Steidinger & Mackenzie 2004 (syn: *Gymnodinium cf maguelonnense* Biecheler 1939), *Karenia mikimotoi* (Miyake et Koominami ex Oda) Hansen et Moestrup 2000, *Gyrodinium aureolum* (Hulburt 1957), *Gymnodinium* sp. (Dinophyceae); *Tetraselmis* sp. (Prasinophyceae); *Rhodomonas* sp. (Cryptophyceae). *K. selliformis* morphologically similar to *K. mikimotoi* and *Karenia brevis* (Davis) Hansen & Moestrup 2000,was predominantly cytotoxic due to active oxygen radicals, which caused severe fish mortalities in aquatic farms during the fall of 1991, and several dystrophic crisis in southern Tunisian coasts since 1994 (Jenkinson & Arzul 2001; Hansen et al., 2004).

Based on literature records, Gomez (2003) reported 673 dinoflagellates species in the Mediterranean Sea, among which 283 were recorded in the Thyrrenian and Ionian basins, in which Tunisia waters were included.

We present in this work the results of a study concerning dinoflagellate species in two Tunisian ecosystems characterized by different geographic, hydrological and environmental conditions. Field work was realized on October 2000 in the gulf of Gabès, and on December 2000 and July 2001 in the lake of Bizerte. The main objective of this study was to increase our knowledge about dinoflagellate species, among which harmful microalgae were identified, taking into account the environmental factors that may influence the percentage of these specific species distributed in these two ecosystems.

## Materials and methods

Sampling were carried in the gulf of Gabès between 27-30 October 2000 (57 samples), and in the lake of Bizerte (12 December 2000 and 17 July 2001). Sampling stations (B1 to B9) were situated around the lake of Bizerte and 25 sampling stations situated along three transects in the gulf of Gabès (Fig. 1).

Physical and chemical parameters (temperature and salinity) were taken at surface and bottom in the lake of Bizerte by a conductimeter LF 340-A/SET WTW, and in the gulf of Gabès with a CTD, calibrated regularly by Sea bird (SBE 911), analysing vertical profiles of temperature and conductivity. These hydrological parameters were taken at sampling stations, with depth varying between 17 m to 92.5 m. Water samples were collected by plankton net (20 µm) from the whole water column in the lake of Bizerte. In the gulf of Gabès, Seabird model Niskin bottles mounted on a Rosette water sampler were used at different depths (surface, -5 m and 10 m). The samples were fixed *in situ* with neutralised formaldehyde at 2%. Microscopic analysis were done under inverted microscope Olympus IMT2 to identify *Gymnodiniale* species by using sedimentation technique (Uthermöhl, 1958).

Sub samples of 100 ml were taken and filtered through a polycarbonate Millipore isopore membrane filters 5.0 µm TMTP, 25 mm diameter with addition of 1 ml of white calcofluor M2R (stock solution: 10 mg.ml$^{-1}$ with a final concentration about 2 mg.l$^{-1}$). An epifluorescence microscope (Olympus BH2 equipped with reflected light fluorescence attachment BH2-RFC) was used for armoured and desmokont dinoflagellate species (Frietz & Triemer, 1985).

Shannon-Wiener diversity was used to have a

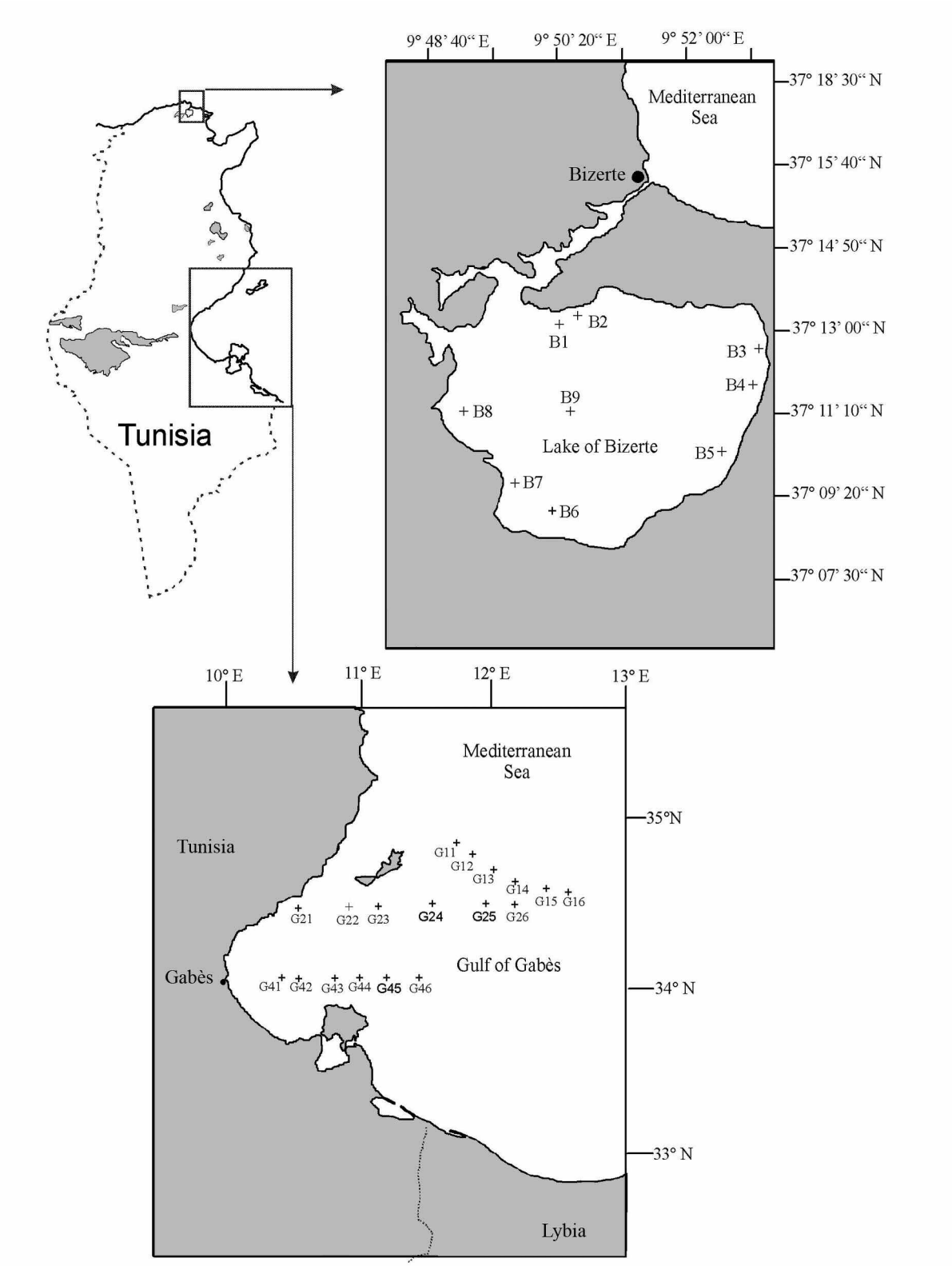


**Figure 1.** Sampling stations in the lake of Bizerte and in the gulf of Gabès.
**Figure 1.** Stations de prélèvement dans le lac de Bizerte et le golfe de Gabès.

knowledge of the global dinoflagellate populations in these two ecosystems (Hutchinson, 1967), as described by:

$$H = - \Sigma\, pi \log_2 pi$$

Where *pi* is the probability of occurrence of the i$^{th}$ species taken to be *Ni/Ns*;
Ni: abundance of the i$^{th}$ species in the sample;
Ns: total number of specimens in the sample.

## Results

### *Physical and chemical parameters*

The analysis of CTD data and temporal series of current in the gulf of Gabès during October 2000, confirmed the impact of the semi-diurnal tide signal and revealed also the footprint of Levantine Intermediate Waters (LIW) in the water column deeper than 50 m. This intermediate water mass, known to be warm and very salty, was occupying the layer between 300 to 500 m. In the gulf of Gabès, it was characterized by a temperature of 14ºC and a salinity of 38.8, and located between the water depth ranged between 200 to 600 m (Sammari et al., 2001).

In the lake of Bizerte, water temperature varied between 12-14°C in winter and 26-28.5°C in summer (Table 1). Salinity varied weakly between 37.5 to 38.5 due to the absence of the inflow from Oued Tinja during winter. Dissolved oxygen varied from 5.9 et 6.7 mg.l$^{-1}$ (Table 1).

In the gulf of Gabès, thermic stratification was absent, temperature ranged between from 20°C and 24°C within the first 50 m and decrease until 17.6°C at – 80 m. Salinity varied from 37.4 to 39.7. (Fig. 2; Table 1)

**Table 1**. Physical and chemical parameters in the lake of Bizerte and the gulf of Gabès.

**Tableau 1**. Paramètres physico-chimiques dans le lac de Bizerte et le golfe de Gabès.

| Variable | Lake of Bizerte | Gulf of Gabès |
|---|---|---|
| Temperature | 12-14°C (Dec. 2000)<br>19-20°C (Jul. 2001) | 20-24°C (0-50 m)<br>17.6°C<br>(since the water depth 80 m) |
| Salinity | 37.5-38.5 | 37.4-39.7 |
| Dissolved oxygen | 5.9-6.,7 mg.l$^{-1}$ | 6.8-7.6 mg.l$^{-1}$ |

### *Phytoplankton analysis*

During the two surveys involved in the lake of Bizerte, dinoflagellates dominate the phytoplanktonic populations, which were also characterized by diatoms (*Navicula* sp., *Chaetoceros* sp.) and flagellate species (*Euglena* sp. and *Tetraselmis* sp.). The most abundant dinoflagellate species were *Ceratium furca* (Ehrenberg) Claparède & Lachmann 1859 (Max. 5380 cells.l$^{-1}$) and secondly *Protoperidinium depressum* (Bailey) Balech 1974 (Max. 2865 cells.l$^{-1}$). Abundance of these species was much higher in summer than in winter.

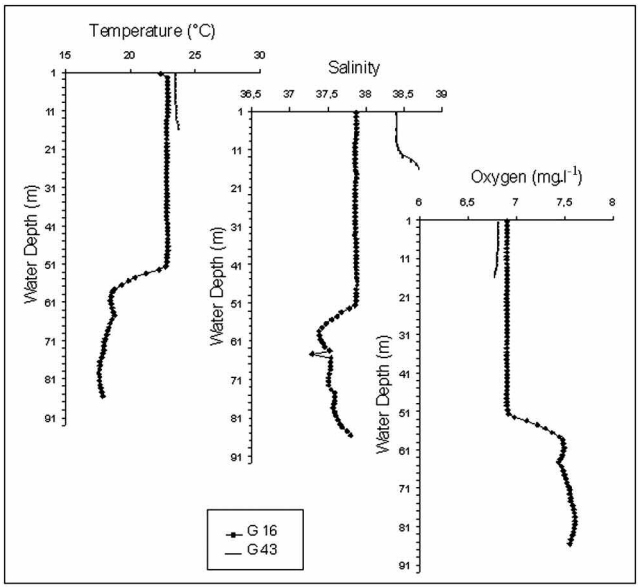


**Figure 2**. Physical and chemical parameters in the gulf of Gabès (G16 and G43).

**Figure 2**. Paramètres physico-chimiques aux stations G16 et G43 du golfe de Gabès.

Species richness of dinoflagellate populations was two times higher in the gulf of Gabès than in the lake of Bizerte with respectively 36 and 15 species observed during the different cruises. Among them, 10 species were potentially toxic. *Prorocentrum gracile* Schutt 1895 (Max. 2800 cells.l$^{-1}$) and *Diplopsalis* sp. (Max. 1600 cells.l$^{-1}$) were the most abundant species in the gulf of Gabès. Naked dinoflagellates were represented mainly by *Gymnodiniale* species: *Gymnodinium cf. catenatum*, *G. sanguineum* (Max. 1000 cells.l$^{-1}$) and *Gymnodinium* sp.

The frequency of *Prorocentrum lima*, *Prorocentrum concavum* Fukuyo 1981, *Prorocentrum mexicanum* Tafall 1942, *Prorocentrum compressum* (Bailey) Abé ex Dodge 1975, *Ostreopsis siamensis* and *Coolia monotis* (Figs 3 & 4) represented up to 50% of sampling stations G21, G16 and G25. In the lake of Bizerte, *Dinophysis sacculus* and *Dinophysis acuminata* (Fig. 5), strictly planktonic species, were the most dominant in winter, and in the North West of the lake.

Shanon diversity of dinoflagellate populations was higher (3.59) in the gulf of Gabès than in the lake of Bizerte

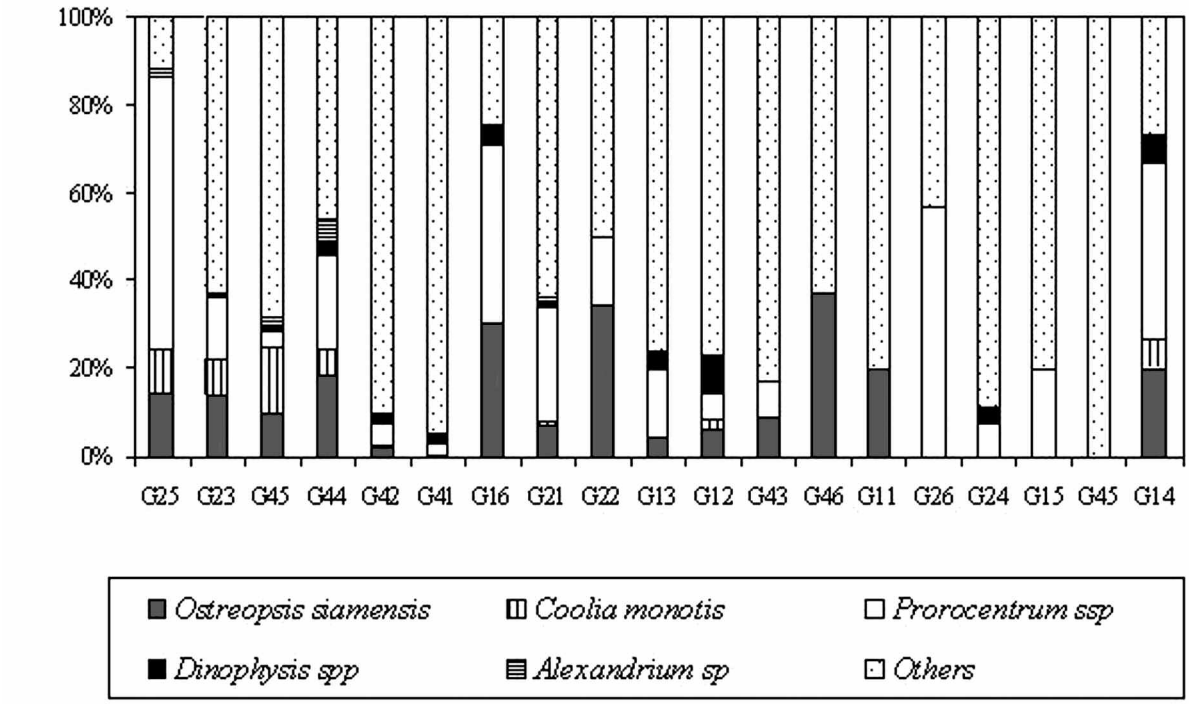


**Figure 3.** Percentage of harmful microalgae in the gulf of Gabès (October 2000).
**Figure 3.** Fréquence des microalgues potentiellement toxiques dans le golfe de Gabès (octobre 2000).

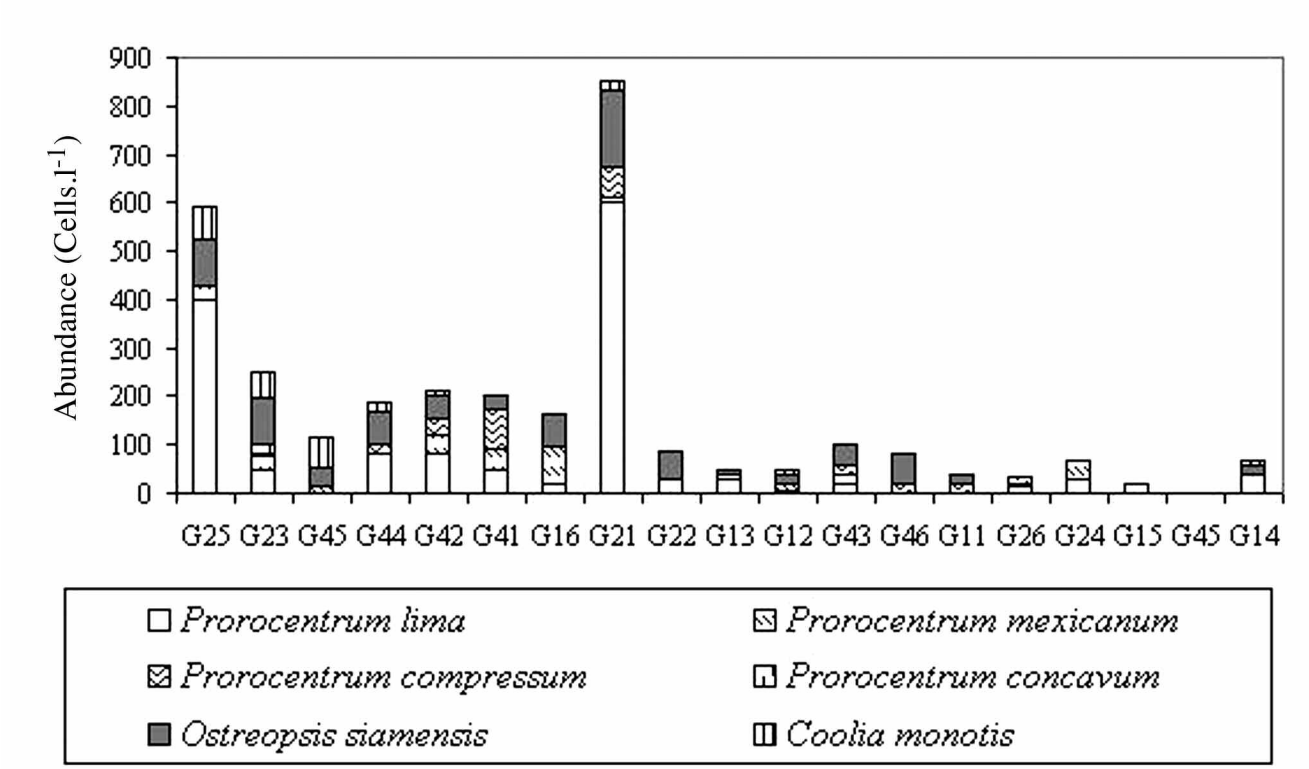


**Figure 4.** Abundance of *Prorocentrum* spp, *O. siamensis* and *C. monotis* in the gulf of Gabès (October 2000).
**Figure 4.** Abondance des espèces de *Prorocentrum* spp, *O. siamensis* et *C. monotis* dans le golfe de Gabès (octobre 2000).

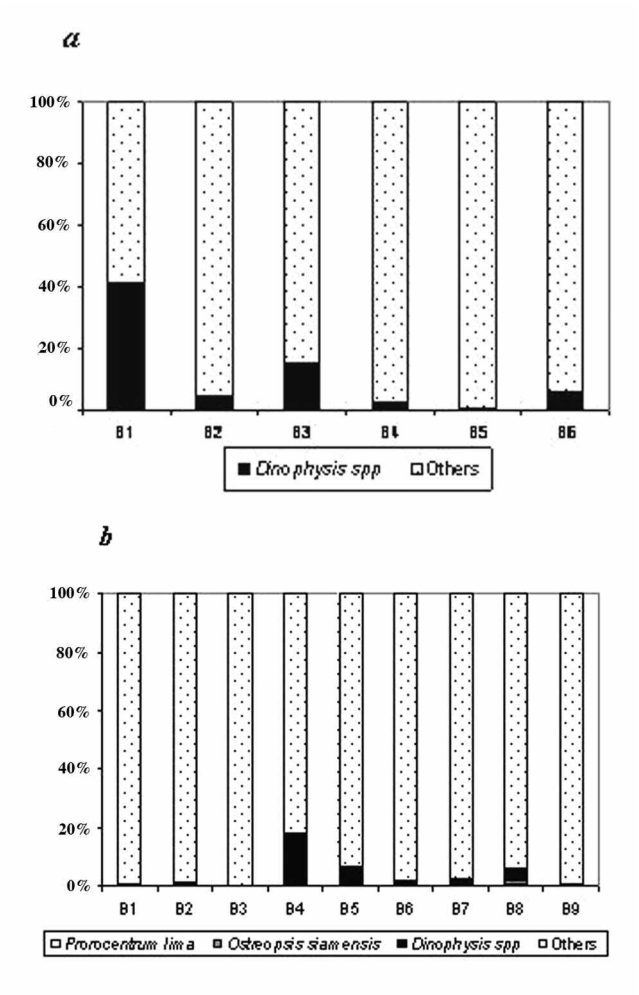


**Figure 5.** Percentage of *Dinophysis* spp in the sampling stations from the lake of Bizerte: (a) December 2000, (b) July 2001.

**Figure 5.** Fréquence des microalgues potentiellement toxiques du genre *Dinophysis* dans le lac de Bizerte : (a) décembre 2000, (b) juillet 2001.

which was closely similar for the two surveys (1.76 in summer and 1.84 in winter).

## Discussion

Within this study, harmful species observed in the gulf of Gabès were potentially toxin producers, and known to be commonly distributed in sediments or along the leaves of the phanerogam plants (Faust et al., 1999; Rhodes et al., 2000). These species: *P. lima*, *P. concavum*, *P. mexicanum*, *O. siamensis* and *Coolia monotis*, with the abundance below 1000 cells.l$^{-1}$, were characterized by a percentage up to 50% in stations G25, G44, G16, G26 and G14 (Figs 2 & 3). Their presence offshore could be an important source of the biotoxin accumulation in marine products. In term of the harmful algal effects, the gulf of Gabès was characterized by the toxic producers and the high biomass producers which the species responsible were: *Karenia selliformis* and the cyanobacteria *Trichodesmium erythreum* (Hamza & El Abed, 1994). These later species occurred almost throughout the year near the coasts and dominated both in summer and fall. In the bay of Tunis, the abundance of toxic dinoflagellates occurred along the leaves of seagrass: *P. lima O. siamensis* and *Coolia monotis,* was higher from August to October (Turki, 2005).

*P. lima* occurs in coastal areas worldwide, in temperate and tropical oceans while the other species, and particularly *P. mexicanum* is generally described as a tropical or subtropical species (Tindall & Morton, 1998). Physical and chemical parameters were similar in the gulf of Gabès (water temperature was about 20 to 24°C and water saliniy varying between 37.4 to 39.7 in the present study.

In the lake of Bizerte, The harmful dinoflagellate species were dominant by *D. sacculus* and *D. acuminata*. The percentage was higher in station B1 (40%), situated near Menzel Abderrahmane, which is characterized by the most urban discharge (Dellali et al., 2001). *D. caudata* was only found in very low concentrations in the gulf of Gabès which is influenced by huge phosphate inputs.

The results of this study confirm the presence of different potentially toxic dinoflagellates assemblages within the two ecosystems, with a typical composition occurring in the gulf of Gabès. However, further work should be realised to check whether this is due to local environments. The distribution of harmful dinoflagellate species in the gulf of Gabès has integrated all the biotopes (pelagic, benthic and epiphytic community) to document the knowledge concerning harmful algae blooms occurring in marine waters, a pre-requisite for designing responsible strategies for better management of marine resources.

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