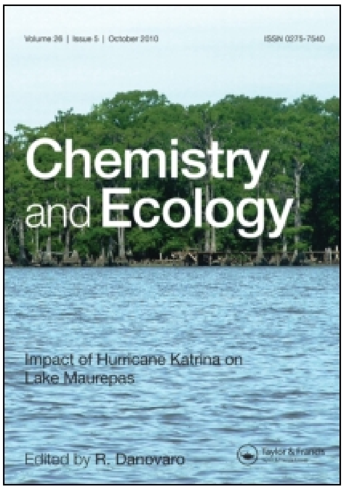

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Occurrence of the Dinoflagellate *Gymnodinium Catenatum* (Graham) Along the Mediterranean Coast of Alexandria (Egypt)

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OCCURRENCE OF THE DINOFLAGELLATE *GYMNODINIUM CATENATUM* (GRAHAM) ALONG THE MEDITERRANEAN COAST OF ALEXANDRIA (EGYPT)

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A monitoring programme during 4 years (1993–1996) was established in four eutrophic marine basins along the Mediterranean coast of Alexandria (Egypt) to follow the occurrence of a newly recorded dinoflagellate *Gymnodinium catenatum* and ambient environmental conditions. The species achieved its massive occurrence in warm seasons at low salinity, density stratified water column and different nutrient concentrations. A simple statistical approach showed temperature and phosphate to effect its distribution. Apparently no cases of toxic effect have accompanied the occurrence of *G. catenatum*. The regular occurrence of the species during the 4 year survey mean the existence of its benthic resting cysts, which certainly have important implications for its distribution dynamics.

Keywords: Gymnodinium catenatum; environmental conditions; Alexandria

INTRODUCTION

The coastal waters of Alexandria (Egypt) is subjected to land-runoff of agricultural, industrial and municipal wasted waters, which render the water eutrophic, creating rich spectra for algal growth.

The unarmoured, chain forming dinoflagellate, *Gymnodinium catenatum*, was first described from the Gulf of California over fifty years ago (Graham, 1943). The species is little known, but within the last two decades it has a widespread distribution (Spain, Estrada *et al.*, 1984; Mexico; Morey-Gaines, 1982; Mee *et al.*, 1986; Portugal, Franca and Almeida, 1989; Japan, Ikeda *et al.*, 1989; Tasmania, Hallegraeff and Sumner, 1986).

Gymnodinium catenatum was found by the author in the neritic Mediterranean waters of Alexandria during 1992. Then, a monitoring programme was begun to study the massive phytoplankton blooms, causing water discolouration, along the coast of Alexandria with much concern to the Eastern Harbour (Labib, 1992, 1994 a,b, 1996; Labib and Halim, 1995).

The causative species of the bloom were: *Amphicrysis compressa* (once in 1992), *Skeletonema costatum* (very common, reaching 7.35×10^6 cell l^{-1}, May 1993), *Prorocentrum triestinum* (71×10^6 cell l^{-1}, April 1993), *Prorocentrum minimum* (a major component of multi-species red tide blooms) and *Alexandrium minutum* (peak of 24.4×10^6 cell l^{-1} in October 1994, with evidence of toxicity).

The occurrence of *Gymnodinium catenatum* was followed between 1993 and 1996 in the 4 main marine basins of Alexandria (Mex Bay, Dekhila Harbour, Eastern Harbour and Abu Qir Bay).

Mex Bay, one of the main fishing grounds in Alexandria, lies at the west of the city, with a mean depth of about 10 m and a surface area of about 19.4 km^2. The bay receives a mean daily input of about 6×10^6 m^3 of agricultural waste waters, mixed with pesticides and fertilizers, and domestic and industrial wastes from Lake Maryout. Industrial waste waters from chemical wastes, tanneries, petroleum and cement factories are disposed directly into the western part of the bay. The bay is also indirectly affected, due to water circulation, by an additional amount of municipal waste waters from the main sewerage of Alexandria (Kayet Bey), located as its eastern region.

Dekhila Harbour, at the western region of Mex Bay has a surface area of about 12.5 km^2, maximum depth of 15 m, four quays and an artificial breakwater at the northern side, extending for about 2.5 km along. The harbour is deeply affected by discharge waters from Mex Bay.

The Eastern Harbour of Alexandria is located in the centre of the city. It is a relatively, shallow, semi-enclosed basin, sheltered from the open sea by a breakwater of two inlets. It has an area of about 2.53 km^2, average depth of 5 m and a water volume of about 15.2×10^6 m^3. Since 1970, the harbour is the recipient of agricultural drainage water (35.2×10^6 m^3, annually) (Aboul-Kassim, 1987).

Abu Qir Bay, a main fishing ground, is a semi-circular estuary lying 35 km east of Alexandria City. The bay has a surface area of about 360 km^2, a maximum depth of about 16 m and a water volume of about 4.3 km^3. The bay is subjected daily to about $2 \times 10^6 m^3$ of agricultural and industrial waste waters, including fertilizers, food processing and paper industrial wastes. The bay also receives fresh water from Lake Idku and the Rosetta Nile branch.

The present study represents the first attempt to follow the occurrence of the newly recorded dinoflagellate *Gymnodinium catenatum* in the waters of Alexandria. The prevailing environmental conditions are discussed.

MATERIALS AND METHODS

Monthly sampling collection, within a 4 year survey, took place as follows: during 1993 (February to October) from Mex; 1994–1995 (April 1994 to May 1995) from Mex and Dekhila; 1996 (March to October) from Mex and the Eastern Harbour as well as in July from Abu Qir Bay.

The surface measurements included water temperature, salinity (salinity refractometer, S/Mill, after calibration), oxygen (Winkler method), ammonia, nitrate, phosphate and chlorophyll-*a* (Strickland and Parsons, 1972). The phytoplankton samples were first examined by microscope, then preserved by the addition of neutral formalin (4%) and a few drops of Lugol's solution, and counted using the settling method (Utermohl, 1958). Duplicated samples were examined.

The occurrence of *Gymnodinium catenatum*, based on short-term sampling collection, were studied in Mex Bay during October 1994 and in the Eastern Harbour during July 1996. Temperature and salinity were measured at the surface and just above the bottom (5 m).

A stepwise statistical analysis was used to correlate the occurrence of the species with associated environmental conditions.

RESULTS AND CONCLUSIONS

The measured physico-chemical parameters and the counts of *Gymnodinium catenatum* from 1993 to 1996 are shown in Figure 1.

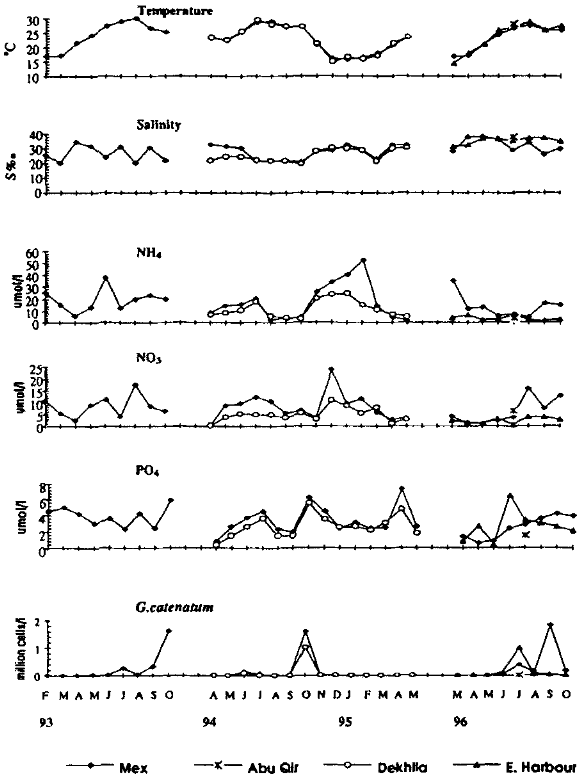

FIGURE 1 Physico-chemical parameters and counts of *Gymnodinium catenatum* during the 4 years survey (1993–1996).

1993 Survey (Mex Bay)

The species started to be numerically important by May, attaining 0.015×10^6 cell l^{-1}, with water temperature of 24° C; salinity, 31.4‰; ammonia, 13.5 μmol l^{-1}; nitrate, 9 μmol l^{-1}; and phosphate, 3 μmol l^{-1}. A minor peak was recorded in September (0.34×10^6 cell l^{-1}), accompanied with higher ammonia (20 μmol l^{-1}). *Gymnodinium catenatum* reached its massive occurrence in October (maximum of 1.7×10^6 cell l^{-1}, 76.5% of the total standing crop by number), with higher temperature (25.3 °C), lower salinity (22‰), ammonia (19.5 μmol l^{-1}), nitrate (6 μmol l^{-1}) and higher phosphate (5.9 μmol l^{-1}).

1994–1995 Survey (Mex and Dekhila)

Samples were collected from April 1994 to May 1995. *Gymnodinium catenatum* was not observed during winter. The species contributed 0.13×10^6 cell l^{-1} in Mex and 0.09×10^6 cell l^{-1} in Dekhila during June. This was followed by a sharp decrease from July to September. Again, October represented its major peak (*G. catenatum* at 1.01×10^6 cell l^{-1}, Dekhila). The associated physico-chemical conditions in Dekhila showed low salinity, ammonia and nitrate concentrations, but high phosphate (5.5 μmol l^{-1}). The intensive occurrence of *G. catenatum* in Mex is discussed as follows.

The sampling procedure was carried out daily between 6 and 9 October. The results are shown in Figure 2. More than 0.9×10^6 cell l^{-1} of *G. catenatum* were accumulated at the surface on 6 October, under thermo-haline stratification of the water column within 3°C and 13.5‰ of temperature and salinity, respectively, and much high nutrient concentrations. Severe impoverishment of ammonia and nitrate occurred with the bloom peak on the next day (*G. catenatum* at 1.59×10^6 cell l^{-1}), raising chlorophyll-*a* to the maximum of 60.3 μg l^{-1} and dissolved oxygen to 11.3 ml l^{-1}. Ammonia and nitrate regeneration, affected by the daily injection of land-runoff was very fast. The density dropped dramatically on 9 October. It is hard to pin-point reasons for its dissipation, since the measured physico-chemical parameters were still useful for continued growth. Other biological factors, as grazing, must be considered.

The accompanied phytoplankton species during this period were: the diatoms, *Cyclotella meneghiniana*, with its highest of 21×10^3 cell l^{-1} on the peak day, *Skeletonema costatum* (rare occurrence), *Nitzschia closterium* dominated the community on 10 October, 1.3×10^6 cell l^{-1}; the dinoflagellates *Protoperidinium depressum, Protoperidinium pulucidium* and *Protoperidinium steinii* (114.7×10^3 cell l^{-1}, collectively, on the peak day); the chlorophycean, *Sprirulina princepus*, and the euglinoid, *Euglena granulata*.

1996 Survey (Mex, Eastern Harbour and Abu Qir)

Sampling collection was carried out in Mex and in the Eastern Harbour from March to October and in Abu Qir Bay during July.

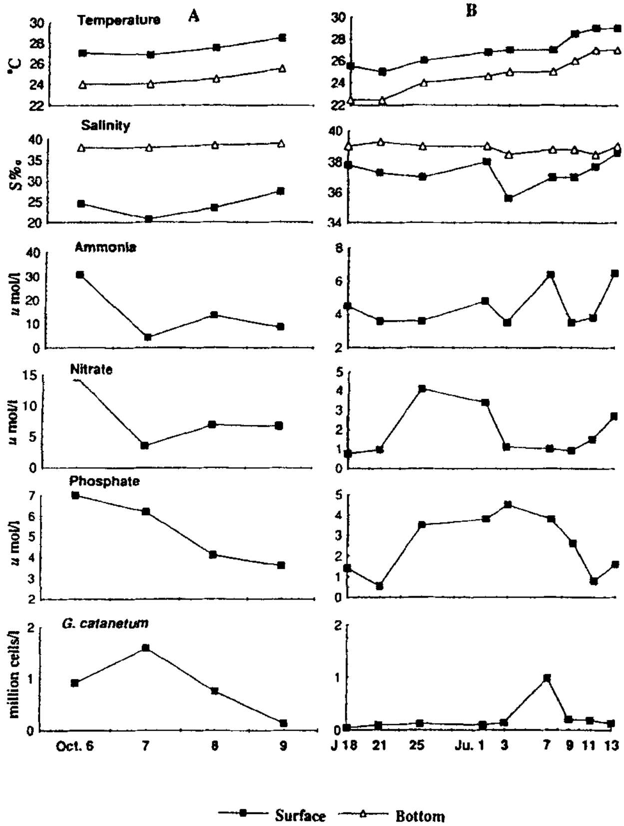

FIGURE 2 Physico-chemical parameters and counts of *Gymnodinium catenatum* in Mex Bay between 6 and 9 October 1994 (A) and in the Eastern Harbour between 18 June and 13 July 1996 (B).

In Mex, *Gymnodinium catenatum* was rarely recorded till June. It became a major component of the community in July (0.37×10^6 cell l^{-1}, 28.4% of the total), achieving its maximum density (1.8×10^6 cell l^{-1}) in September, a month earlier than the previous records. Temperature was at 25°C, salinity 26‰, ammonia and nitrate concentrations were high (20.3, and 7.4 μmol l^{-1}), while phosphate reduced to 3.8 $\mu mol\, l^{-1}$.

In the Eastern Harbour, the species was not observed in March and April, and started to be shown in May, with spring warming (difference in temperature of 4°C between April and May). It had a regular occurrence during the warm seasons, attaining its highest density of 0.98×10^6 cell l^{-1} in July. The intensive study carried out in the harbour between 18 June and 13 July is described as follows.

The measured physico-chemical parameters and the density of *G. catenatum* are shown in Figure 2. The Eastern Harbour has different environmental conditions compared with Mex and Dekhila. This period was characterized by a gradual temperature increase as days went by, with considerable variations of salinity, warmer and less saline surface water than near the bottom, stable water column and relatively low nutrient concentrations. The species attained its peak on 7 July (71.5% of the total), associated chlorophyll-*a* of 38.5 μg l^{-1} and dissolved oxygen of 8.5 ml l^{-1}. The density dropped dramatically to 0.13×10^6 cell l^{-1} on 13 July. Reasons for the decline of *G. catenatum* could include factors such as the increased temperature and salinity by 2°C and 1.6‰, compared with the peak day. Other measured parameters were sufficient for continuous growth.

The accompanied phytoplankton species with the peak of *G. catenatum* were the diatoms, *Skeletonema costatum* (0.14×10^6 cell l^{-1}), *Chaetoceros affine* and the dinoflagellates, *Prorocentrum minimum*, *P. triestinum*, *P. micans* and *Scrippsiella trochoidea* (6.6×10^3, 7.7×10^3, 10.8×10^3, 14.9×10^3 cell l^{-1}).

In Abu Qir, *G. catenatum* was found at a maximum of 0.75×10^6 cell l^{-1} at relatively higher temperature (28.8°C), salinity (37.5‰) and nitrate (6.4 μmol l^{-1}), but lower ammonia (3.5 μmol l^{-1}) and phosphate (1 μmol l^{-1}).

Statistical Analysis

The multiple regression analysis was computed to correlate the occurrence of *G. catenatum* and the measured physico-chemical variables, at a given concentrations using the number cruncher statistical system (NCSS) by Hintze (1993).

The results showed *Gymnodinium catenatum* to be positively correlated with temperature and phosphate, while a negative correlation was found with salinity. Temperature and phosphate seem to be the major factors affecting its variation ($R^2 = 0.24$). However, any conclusion about the significance of a simple correlation must be tentative, the actual growth is controlled simultaneously by several factors. The corresponding equation is:

G. catenatum (cell l^{-1}) = $-1.058+0.029^{*}Temp+0.211^{*}PO_4$

In Conclusion

Gymnodinium catenatum bloomed in the Mediterranean waters of Alexandria during the warm seasons. The bloom peak was at 25.3–26°C and in 26‰ salinity. The counts were positively correlated with temperature and phosphate, inversely with salinity. The thermo-haline stratification of the water column was a constant factor. The ambient nutrient concentrations, particularly ammonia, exhibited large fluctuations, and the regeneration, affected by the daily land-runoff, was very fast. Apparently no cases of toxicity have accompanied the occurrence of *G. catenatum*, and its density never exceeded 1.8×10^{6} cell l^{-1}. The dinoflagellate, *Alexandrium minutum*, gave evidences of toxicity in the Eastern Harbour at much higher density (Labib and Halim, 1995). Temperature and phosphate seem to extend the occurrence of *G. catenatum*, with a bloom generally maintained high levels of phosphate. The insignificant correlation of *G. catenatum* with the measured physico-chemical variables explains the interference of other physical, chemical and biological aspects. The regular occurrence of *G. catenatum* during the 4 year survey mean the existence of its benthic resting crysts, which certainly have important implications for its distribution dynamics. A survey for the resting cysts is needed.

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