Environmental conditions leading to a moderate *Alexandrium minutum* bloom in the Penze estuary, Brittany, France

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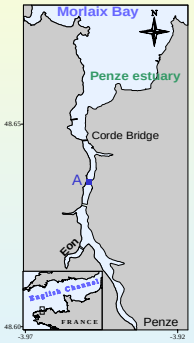
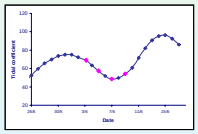
Introduction

The marine dinoflagellate *Alexandrium minutum* has formed regular blooms in the Penze estuary (northern Brittany, France) causing paralytic shellfish toxin contamination of mussels and oysters. Studies undertaken since 1997 enabled to determine the favorable period for the development of this species: maximums of these blooms occurred during neap tides of late May-late June if critical temperature of 16 °C was reached. It was the case in 1997, 1999 and 2001.
These necessary conditions enabled to determine the strategy of studies achieved in 2003 : to survey the environmental conditions from the beginning to the maximum of an *Alexandrium minutum* bloom and to compare with previous years. New insights on vertical distribution was also investigated.



Material and Methods

Complete tidal cycles (12 h) were surveyed every two days from spring to neap tides in June 2003 (3, 5, 7, 9 June) at a fixed station (station A). Sampling began at 8:00 a.m. and finished at 8:00 p.m.. Surface salinity 23, 26, 29 and 32 and corresponding bottom waters were sampled twice, at ebb and flood tide using common Niskin bottles. Salinity, temperature, PAR were measured, phytoplankton composition and nutrients were analysed.

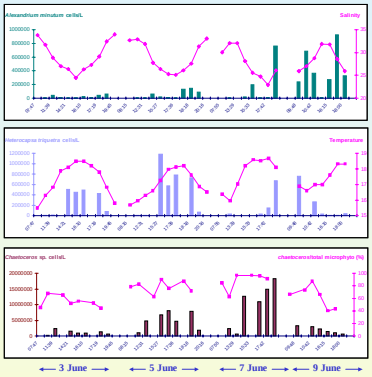


Additional fine scale sampling for surface salinity 26 - 27 was carried out on the water column every 10 cm on 1 m depth from the surface using a 10 syringes clipped on board system. Salinity, nutrients and *Alexandrium minutum* concentration cells were determined.

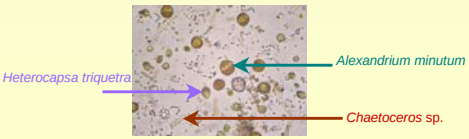
Results

1- Evolution of *Alexandrium minutum* cells, coexisting species and hydrological parameters at subsurface

Sampling at 8:00 a.m. began at high tide on 3rd June and finished at low tide on 9th June, explaining the salinity pattern each day. Throughout this period, temperature was higher than the critical value of 16 °C, favourable for *Alexandrium minutum* development. Common sampling at subsurface showed a progressive increase of *Alexandrium minutum* from spring to neap tides with maximum concentrations of 900000 cells/L observed at < 30 salinity. At this maximum, *Alexandrium minutum* cells represented only 3 % of the total algal populations. The investigations conducted after the 9 June revealed the disappearance of *Alexandrium minutum* cells.

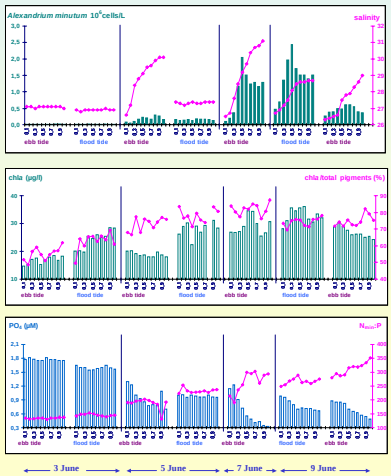


Throughout the studied period, *Heterocapsa triquetra* was present at similar concentrations. *Chaetoceros* sp. which progressively bloomed from spring to neap tides, was the major microphytoplanktonic species (71 %). However the entire algal community was dominated by nanoplankton (70%).



2- Vertical distribution of *Alexandrium minutum* cells, and hydrological parameters

Fine scale sampling put into relief some strong haline vertical gradient on 1 m depth (maximum salinity difference of 4.5). The depth of the water column corresponded approximately to that of the euphotic layer (PAR data, not figured). *Alexandrium minutum* cell concentration showed a great stratification at neap tides from subsurface (0.1 to 0.5 10^6 cells l^{-1}) to 50 cm depth (2 to 2.4 10^6 cells l^{-1}) corresponding to the halostratification. However, concentrations remained high at 1 meter (1.2 - 1.5 10^6 cells l^{-1}) and still reached 0.1 to 0.3 10^6 cells l^{-1} at the bottom (2 - 5 m, not figured). Total chla and proportion of active chla to total pigments increased from spring to neap tides suggesting a general development of algae. The corresponding PO_4 concentrations decreased and N_{min} : P increased from 100 to 350. Stratification of nutrients and distribution of PAR did not seem to explain *Alexandrium minutum* distribution which was probably more controlled by physical currents.

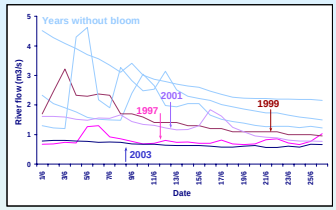


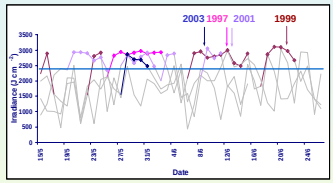
3- Comparison with previous years

In 2003, no paralytic shellfish toxin contamination was detected. Nevertheless the maximum of *Alexandrium minutum* cells could have been favourable for a toxic event in comparison with 2001 and in considering the variability of sampling. However the development of *Alexandrium minutum* was moderate in 2003 in comparison with previous favorable years (1997, 1999).

Year	Maximum *A.minutum* cells nb/ml	PSP shellfish contamination
1997	44 000 000	+
1998	500 000	-
1999	13 000 000	+
2000	350 000	-
2001	6 000 000	+
2002	40 000	-
2003	2 400 000	-

When an *Alexandrium minutum* bloom was observed, the environmental conditions were characterized by seawater temperature over 16°C, low river flow (0.7 - 1.7 m^3 s^{-1}) few days before and during the period of bloom and by a period of high irradiance (> 2500 J cm^{-2}) for 8 - 10 days before. 2003 was a particular dried year similar to 1997 (river flow of 0.7 m^3 s^{-1}). Seawater temperature was also favourable since critical temperature of 16 °C was reached at the beginning of *Alexandrium minutum* growth but a 10 days period of high irradiance was not observed in 2003.





Conclusions

The studies carried out in 2003 confirm some favourable conditions for the development of *Alexandrium minutum* : a critical temperature of 16°C, low river flow and neap tides to reach maximum concentrations. However the development clearly begins at spring tides. Even if a period of 10 days of high irradiance was not observed in 2003, light was probably not limiting at this period and should not be a key factor.
The distribution of *Alexandrium minutum* along the whole water column with maximums associated with halostratification was probably explained by physical constraints.
As for previous years, an *Alexandrium minutum* bloom in the Penzé estuary is a very locally and time limited event.