The Bay of Brest (France), a new risky site for toxic *Alexandrium minutum* blooms and PSP shellfish contamination

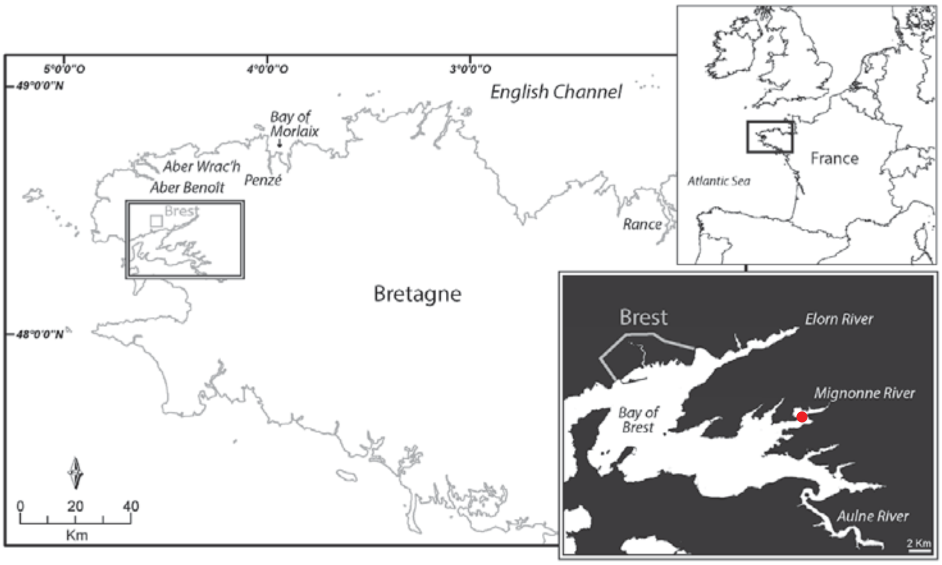

Fig. 1. Map with location of the Bay of Brest and other Breton estuaries where A. minutum *proliferates (● by the Mignonne estuary represents location of the sampling site)*

In summer 2012, a new toxic event occurred in the Bay of Brest (Fig. 1): a major PSP contamination event led to the prohibition of shellfish harvesting. It was the first time shellfish from the Bay of Brest were contaminated with these toxins. The maximal toxin level recorded in shellfish (over 8000 eq STX·kg^{-1}) was 10 times the sanitary threshold and *A. minutum* bloomed up to 41 x10^{6} cells L^{-1}. This first PSP event was followed by additional *A. minutum* blooms leading to shellfish toxicities in 2013 and 2014.

A three-year survey of the Bay of Brest (Daoulex project, 2012-2014) has been carried out with water sampling twice a week in the Mignonne estuary around high tide as soon as water temperature exceeded 15°C. Data issued from this survey, associated with those from the phytoplankton and biotoxin monitoring network REPHY [1] (since 1984) and the Oyster network VELYGER [2] (since 2008) have shown that *A. minutum* has been observed in the Bay of Brest since 1990 only. This confirms results of a 1990 sediment survey showing the absence of *A. minutum* cysts in this bay [3]. From 1990 to 2008, *A. minutum* occurred at low densities (lower than the alert threshold of 104 cells L^{-1}). Conversely, since 2009, *A. minutum* has bloomed recurrently, surpassing this threshold and leading to PSP toxicities since 2012 (Fig. 2).

The unsafe bloom period (concentrations higher than the alert threshold) extended from mid-May to the end of August. In 2012 *A. minutum* developed from June 15 to August 16 with a maximum density of 41 x10^{6} cell L^{-1} detected on July 15. In 2013, the bloom period was shorter (from July 5 to August 5) and with lower densities (maximum 3.6 x10^{5} cell L^{-1} on July 22). In 2014, *A. minutum* developed during a longer period from May 26 to September 4 and peaked up to 1.1 x10^{6} cell L^{-1} on June 6 and again to 1.5 x10^{6} cell L^{-1} on July 22.

Surface water temperature seemed to be the major abiotic signal correlated to increased cell concentration above threshold limits and therefore to the risk period for shellfish contamination (Fig. 3). The temperature of 15°C seems to be a pre-requisite to allow bloom development above the threshold in the Bay of Brest as well as in other Breton estuaries [4]. In fact, 2014 showed initiation of an early *A. minutum* bloom in mid May when the water temperature reached 15°C. In contrast, 2013 showed a cold spring with water temperatures below 15°C until June 1 and the bloom this year initiated only in July. 2012 was an intermediate year for water temperature as well as for bloom initiation, with temperature of 15°C reached by May 24 (Fig. 3).

The main areas impacted by *A. minutum* are the upper estuaries of the Bay of Brest (Mignonne and other estuaries of the south-eastern Brest Bay, the Aulne and Elorn river outflows, Fig. 1). These areas correspond to shallow, sheltered estuaries, strongly influenced by tides. Along the Mignonne estuary, *A. minutum* maximum densities were observed with salinity values ranging from 29 to 34. These are transition waters between nutrient rich Mignonne waters (mean nitrate concentrations of 27 µg L^{-1}, mean phosphates 0.07 µg L^{-1}) and the Bay of Brest waters, which are phosphorus (P) limited for phytoplankton growth during spring and summer [5]. Nutrient concentrations in this estuary are closely linked to river Mignonne run-off and may impact *A. minutum* blooms, notably through phosphorus availability. In 2012, high spring and summer high river discharges (Fig. 3)

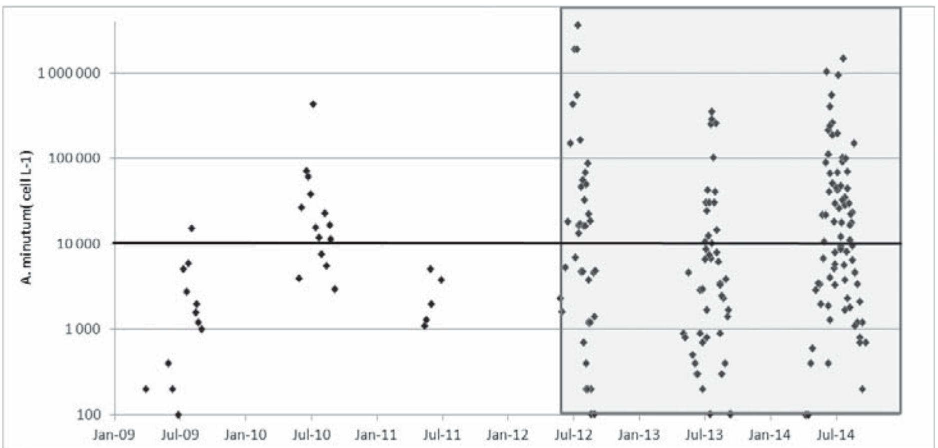

Fig. 2. Alexandrium minutum *abundances (data REPHY, VELYGER, DAOULEX) in the Bay of Brest. Grey box delimits the toxicity period. Black line stands for the alert threshold (10^{4} cell L^{-1}).*

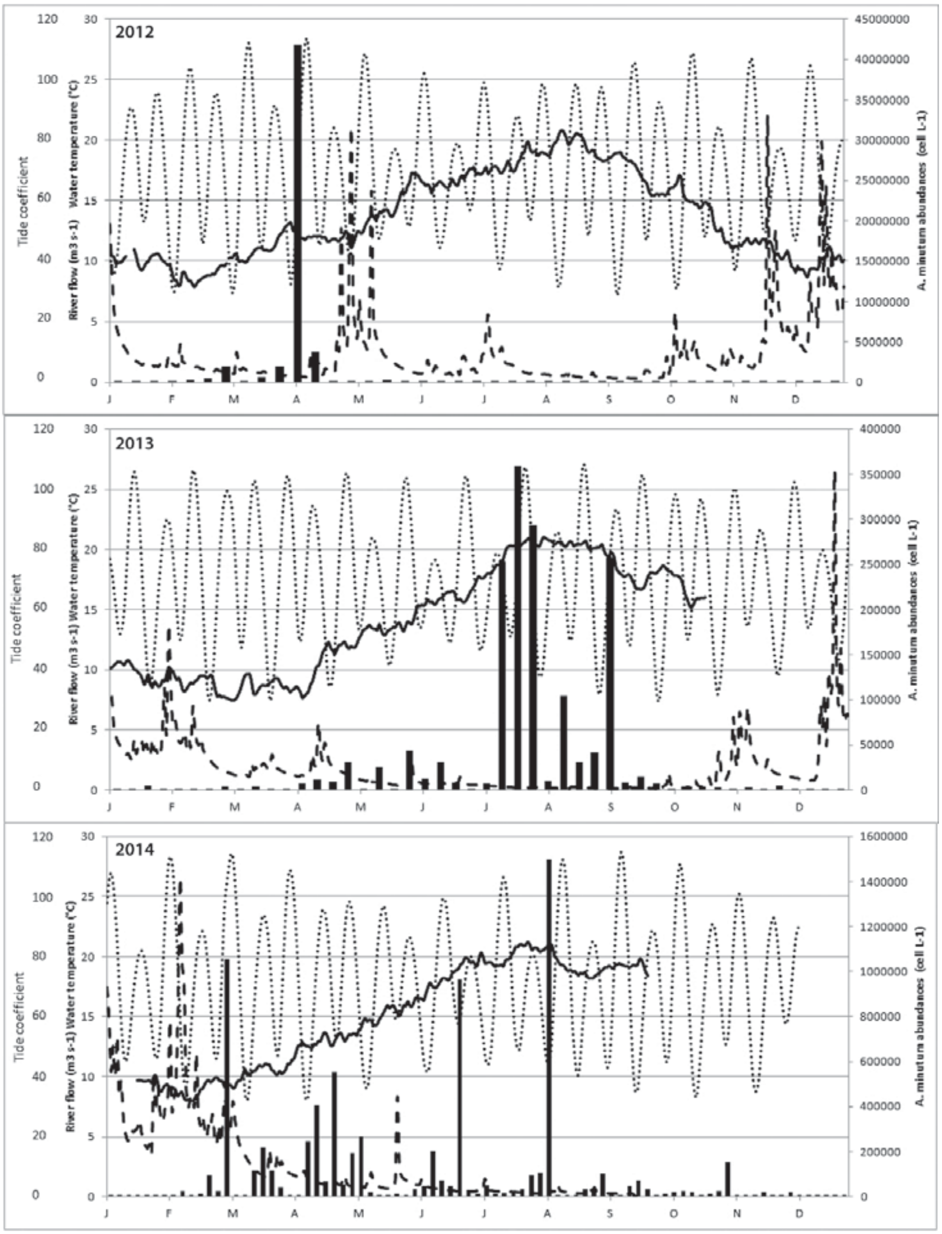

Fig. 3. Alexandrium minutum *densities (vertical bars, right axis), water temperature measurements (black line, left axis), river outflow (dashed line), and tidal coefficient (dotted line).*

may have been linked to the exceptional *A. minutum* bloom (>41 x10^6 cells L^{-1}). In 2013, river outflow was much lower, whereas 2014 presented intermediate river outflow in correlation with intermediate (between those of 2013 and 2012) densities of *A. minutum*.

Another environmental factor that seems to affect *A. minutum* maxima are tides. In fact, maximal abundances are observed when tides coefficients are lower than 80 (neap tides or little spring tides) (Fig. 3). This could be explained by lower bloom dispersion out of the estuary by lower tidal currents, allowing *A. minutum* to stay in its optimal (upper estuary) environmental condition for development.

In conclusion, the Bay of Brest represents today a new risky area for *A. minutum* blooms and occurrence of PSP toxins. These bloom events present similar temporal and geographical patterns as others that have already occurred in estuarine ecosystems of northern Brittany (Penzé, Morlaix, Rance, Aber Benoit and Aber Wrac'h estuaries, Fig.1) [4, 6, 7] as well as in Ireland [8]. They appear in rich-nutrient confined ecosystems, mostly estuaries, from mid-May to August, when nutrients, water temperature and irradiance support sufficient *A. minutum* growth to compensate mortality rates mostly due to tidal dilution.

Acknowledgements

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