Relationships between environmental conditions and phytoplankton in the Mellah lagoon (south western Mediterranean, Algeria), with an emphasis on HAB species

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Abstract

A bi-weekly monitoring of environmental parameters and microphytoplankton assemblages was conducted in the well-preserved Mellah lagoon ecosystem (south western Mediterranean). Sampling was performed at 3 stations in 2016. We aimed to study the evolution of the phytoplankton community with a focus on harmful species in relation with the environmental characteristics. Phytoplankton of Mellah Lagoon was characterized by a mixture of marine, brackish-water and freshwater taxa. In all of the stations, 227 species of phytoplankton were identified (160 diatoms and 53 dinoflagellates). The overall mean phytoplankton abundance was higher at station A ($2.24 \cdot 10^5$ cells l^{-1}, early September) and B ($2.98 \cdot 10^5$ cells l^{-1}, early October) near of marine inputs, compared to station C ($1.73 \cdot 10^5$ cells l^{-1}, early June) located in the south of the lagoon. Diatoms dominated in spring and dinoflagellates developed in summer and early autumn in the Mellah. The dynamic of the phytoplankton in Mellah was influenced by temperature and salinity. For the first time, a number of potentially toxic species have been identified, including 2 diatom species: *Pseudo-nitzschia delicatissima*-group (max.: $2.52 \cdot 10^3$ cells l^{-1}), *Pseudo-nitzschia seriata*-group (max.: 700 cells l^{-1}) and 6 dinoflagellate species: *Alexandrium minutum* (max.: $1.42 \cdot 10^3$ cells l^{-1}), *Alexandrium tamarense/catenella* (max.: $1.35 \cdot 10^3$ cells l^{-1}), *Dinophysis acuminata* (max.: 180 cells l^{-1}), *Dinophysis sacculus* (max.: 120 cells l^{-1}), *Akashiwo sanguinea* (max.: $7.20 \cdot 10^3$ cells l^{-1}), *Prorocentrum lima* (max.: 110 cells l^{-1}). Even the abundances of the HABs species were relatively low in Mellah lagoon, they could potentially form blooms in the coming decades at the favor of warming and trophic status changes observed in Mediterranean marine systems. Monitoring program of HABs species must be established to gain more insight in the development of potentially toxic species and the toxins produced.

Keywords: phytoplankton, HABs species, structure, Mellah lagoon, south western Mediterranean

Introduction

The lagoons are singular ecosystems, zones of transition between land and sea. Lagoon environments constitute about 13% of the world's coastlines (Larras 1964; Barnes 1994).

The intensity and frequency of harmful phytoplankton blooms in coastal ecosystems has continued to increase (Glibert et al., 2005; Anderson et al., 2008; Heisler et al., 2008). The multiplication of episodes of toxic algal blooms and their health and economic consequences justify the rise of research on this phenomenon. In recent years, harmful algal blooms have caused great economic loss to fisheries and aquaculture because of public health problems caused by toxic dinoflagellates (Matsuoka & Fukuyo, 2000). The development of toxic species leads each year to the closure of many aquaculture plants (mussels, oysters, clams). Indeed, some phytoplankton species (mainly dinoflagellates) produce powerful toxins that can be concentrated in the food chain mainly by filtering molluscs. The toxins accumulate in the tissues of filtering bivalves up to sometimes lethal concentrations for humans.

The Mellah Lagoon, the only lagoon ecosystem in Algeria with its environmental and economic interests, is a site to explore further. Fish and shellfish farming are practiced in this lagoon. The phytoplankton of this ecosystem has been studied only in one occasion (Draredja, 2007). The objective of this work is to study the evolution of the microphytoplankton community with a focus on Harmful Algal Blooms (HABs) species in relation to the environmental conditions.

Materials and Methods

The Mellah lagoon is located in the northeast of Algeria (36°54'N 8°20'E) far of all sources of pollution, within a protected natural reserve (Fig. 1). The lagoon (8.65 km^2) communicates with the sea by a long and narrow channel. During 2016, a monitoring program of microphytoplankton and physico-chemical parameters (temperature, salinity, dissolved oxygen, pH and suspended matter) was carried out fortnightly in 3 representative stations in the lagoon (Fig. 1).

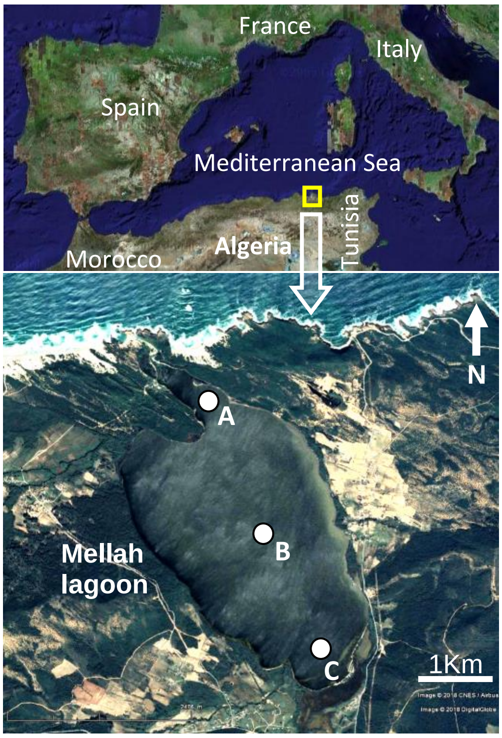


Fig. 1. Location of the Mellahlagoon and position of sampling stations.

Nutrient (NO3, NO2, NH4, PO4) and Chlorophyll-*a* analyses, were carried out by spectrophotometry. Microphytoplankton was sampled in surface waters, where a volume of 50 liters of water was filtered through a plankton net (20 µm mesh size) and fixed with neutralized formalin (4%). Both the identification and counting of phytoplankton (cells l^{-1}) were performed with an inverted light microscope (Leika 750 PM).
Statistical analyses were performed using R, version 3.4.2 (R Core Team, 2017) developed for Windows by (Ihaka & Gentleman 1996).

Results and Discussion

The seasonal values of environmental parameters are reported in Table 1. Unlike most Mediterranean lagoons (Dell'Anno et al., 2002; Bernardi-Aubry et al., 2004; Ifremer, 2006), Mellah appears less rich in nutrients. So we class it among Mediterranean lagoons meso oligotrophic (OECD, 1982). The low level of nutrients of the of the Mellah lagoon waters results in a moderate seasonal biomass in chlorophyll-*a* (between 0.70 and 5.45 µg l^{-1}) (Table 1), compared to other Mediterranean lagoons (Triantafyllou et al., 2000; Nuccio et al., 2003; Bernadi Aubry & Acri, 2004; Solidoro et al., 2004).

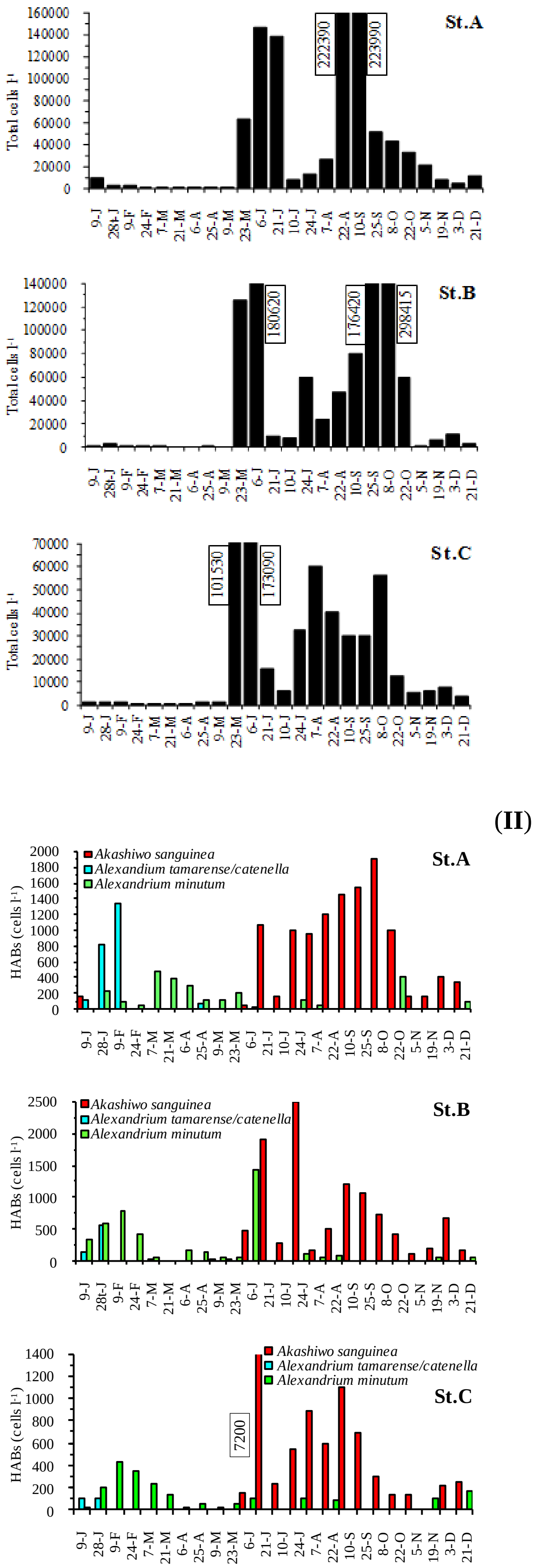
Table 1. Seasonal extremes of physico-chemical parameters and chlorophyll-*a* of the Mellah lagoon waters (2016).

	Winter		Spring		Summer		Autumn	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Temperature (°C)	12.26	16.98	18.89	25.25	25.80	29.00	14.30	24.80
Salinity	24.00	27.42	27.41	28.84	30.40	35.44	30.65	36.23
Dissolved oxygen (mg l^{-1})	6.89	8.38	5.73	8.59	5.25	7.88	5.71	7.88
pH	7.88	8.23	7.75	8.55	7.95	8.35	7.95	8.51
Suspended matter (mg l^{-1})	17.36	34.38	8.28	23.85	6.25	20.02	5.12	16.00
Ammonium (NH4) (µmoles l^{-1})	0.05	6.60	1.12	3.75	0.00	4.12	0.00	3.37
Nitrites (NO2) (µmoles l^{-1})	0.12	0.53	0.02	1.08	0.05	0.24	0.07	0.46
Nitrates (NO3) (µmoles l^{-1})	0.23	1.15	0.04	3.20	0.01	3.84	0.10	1.37
DIN* (µmoles l^{-1})	1.27	8.09	0.92	6.14	0.54	5.65	0.38	5.81
Phosphate (P04) (µmoles l^{-1})	0.11	1.55	0.08	1.57	0.14	0.99	0.02	1.68
Chlorophyll-*a* (µg l^{-1})	0.26	1.78	0.62	5.59	0.27	5.58	0.08	5.59

(*): Dissolved inorganic nitrogen (DIN = NH4+ NO2+ NO3).

In total, 227 microphytoplankton species belonging mainly to diatoms (160 species) and dinoflagellates (53 species), were inventoried in the Mellah lagoon. In this list of species, we found height potentially HAB species (2 diatoms and 6 dinoflagellates) (Table 2). The lagoon was characterized by a clear dominance of diatoms (63%) compared to dinoflagellates (37%). This trend is observed in many Mediterranean lagoons (Tolomio et al., 1999; Bernardi Aubry & Acri, 2004), but also in Algerian coastal marine waters

(Frehi, 1995; Illoul, 2014). The overall mean phytoplankton abundance was higher at St.A ($223.99 \cdot 10^3$ cells l^{-1}, early September) and St.B ($298.41 \cdot 10^3$ cells l^{-1}, early October) near marine inputs, compared to St.C ($173.13 \cdot 10^3$ cells l^{-1}, early June) under land influence (Fig. 2, I).
Proliferations of harmful species as *Akashiwo sanguinea* at St.C ($7.20 \cdot 10^3$ cells l^{-1}, end of June), were noted in summer (Fig. 2, II). This species is toxic to several models with a hemolytic effect (Xu et al., 2017). Other potentially neurotoxic species as *Alexandrium minutum* at St.B ($1.42 \cdot 10^3$ cells l^{-1}, early June) and *A. tamarense/*catenella at St.A ($1.35 \cdot 10^3$ cells l^{-1}, early February) were observed in winter and spring respectively (Fig. 2, II). The abundance of these HAB species remained relatively low, but they could potentially form blooms in the future at the favor of warming and trophic status changes affecting Mediterranean waters (Benedetti, 2016; Karidis & Kitsiou, 2011). Other HAB species were present (Table 2) but poorly represented (< 700 cells l^{-1}). They included *Prorocentrum lima*, *Dinophysis* sp. *and Pseudo-nitzschia* spp., responsible of DSP and ASP syndromes. The distribution of these HAB species is very similar in the three stations prospected (Fig. 2, II), hence the role of the hydrodynamic action in the lagoon.
The Pearson analyses showed that the microphytoplankton densities in the Mellah lagoon were positively correlated with temperature (0.46 to 0.56) and salinity (0.16 to 0.43), $p<0.05$. Finally, unlike the majority of Mediterranean lagoons, which are eutrophic, the Mellah lagoon is distinguished by its meso oligotrophy, due to its remoteness from any source of pollution.
Despite the meso oligotrophy of the Mellah lagoon specific microphytoplankton richness (227 species) is higher than some eutrophic Mediterranean lagoons.
The proliferation of dinoflagellates coincides with the warming of the waters and the increase of the Mellah waters salinity during the summer season.
A regular dredging of the channel must be established to improve the water exchange between the Mellah and Mediterranean Sea to stabilize the quality of lagoon waters and to increase phytoplankton species diversity.



(II)

(I)

Fig. 2. Abundance (cells l^{-1}) of total microphytoplankton (**I**) and harmful species (HABs) (**II**) in the Mellah waters (2016).

Table 2. Check list of potentially harmful species (HABs) encountered in Mellah lagoon (2016). (M: marine species, L: lagoon species).

DIATOMOPHYCEAE (Rabenhorst, 1864)
PENNATE DIATOMS
Bacillariaceae Ehrenberg, 1831 *Pseudo-nitzschia delicatissima*-group (Cleve) Heiden, 1928 (M) *Pseudo-nitzschia seriata*-group (Cleve) H. Peragallo, 1899 (M)
DINOPHYCEAE (G.S. West & Fritsch, 1927)
DINOPHYSALES (Lindemann, 1928)
Dinophysiaceae Stein, 1883 *Dinophysis acuminata* Claparède & Lachmann, 1859 (M) *Dinophysis sacculus* Stein, 1883 (M)
GYMNODINIALES Lemmermann, 1970
Gymnodiniaceae Lankester, 1885 *Akashiwo sanguinea* (K. Hirasaka) G. Hansen & Ø. Moestrup, 2000 (M, L)
PERIDINIALES Haeckel, 1894
Gonyaulacaceae Lindemann, 1928 *Alexandrium tamarense/catenella* (Lebour, 1925) Balech, 1995 / (Whedon & Kofoid) Balech, 1985 (M) *Alexandrium minutum* Halim, 1960 (M)
PROROCENTRALES Lemmermann, 1910
Prorocentraceae Stein, 1883 *Prorocentrum lima* (Ehrenberg) F. Stein, 1878 (M)

Microphytoplankton of the Mellah lagoon is dominated by diatoms. The presence of HABs species related to PSP, DSP and ASP syndromes stresses the need to implement a monitoring program to detect the related toxic species order to prevent any human intoxication due to the consumption of contaminated shellfish.

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