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HARMFUL ALGAL FREQUENCY OVER THE LAST 30 YEARS IN THE GULF OF TRIESTE

FREQUENZA DELLE ALGHE TOSSICHE NEGLI ULTIMI 30 ANNI NEL GOLFO DI TRIESTE

Abstract - *In the present study, a 30 year (1986-2015) time-series of data on phytoplankton abundance collected in the Long Term Ecological Research (LTER) site in the Gulf of Trieste, North Adriatic Sea, has been reanalysed, with particular focus on the long-term dynamics of the occurrence of potentially toxic species, and on the possible effects on economic activities based on marine living resources, such as the mussel farming, traditionally well developed in the Gulf of Trieste.*

Key-words: *phytoplankton, harmful species, ecosystem services, mussel farms, Gulf of Trieste.*

Introduction - Being the base of the marine food web, phytoplankton plays a fundamental role on several ecosystem services, providing food for the higher trophic levels, regulating oxygen and carbon dioxide in seawater and atmosphere and contributing to nutrient cycling. Plankton biodiversity is fundamental to guarantee good ecological status and ecosystem integrity, and community changes may have profound effects on marine ecosystem services. Phytoplankton abundance, composition, bloom events, as well as increase of toxin production by harmful algae can influence the food web structure, as well seafood for human consumption. In the Gulf of Trieste, mussel farming has been a traditional activity since 18th century, which is tightly depending on water quality and which has experienced severe damages consequent to modifications in phytoplankton community composition, in particular to increase in toxic algae. The North Adriatic is a very dynamic ecosystem, which has experienced large fluctuations in oceanographic features, trophic conditions, plankton, fish and benthic abundance and composition (Giani *et al*., 2012). Phytoplankton dynamics in the North Adriatic have been described in several papers (Cabrini *et al*., 2012; Marić *et al*., 2012; Mozetič *et al*., 2012), however, none of them have focused specifically on potentially toxic species. Beside exploring the interannual variability of phytoplankton, considering the main functional groups (diatoms and dinoflagellates), this study focuses on potentially toxin-producing organisms, due to the important effect of harmful organisms on water quality and on socio-economic activities in the area. The interannual variability in the frequency of occurrence of harmful algae is explored, as the simple presence of toxic species is considered as an environmental disturbance, due to the high toxicity of some algal biotoxins. Even low biomass HABs (from a few hundred to thousands of cells/L) may threat human health directly or human use of the ecosystem (*e.g.* restricting fishing and shellfish activities). Toxic algal blooms can potentially occur in all coastal seas, as they are natural events, although, since the 1960s there seems to have been an increase in their intensity, frequency and distribution (Lassus *et al*., 2016). Therefore, a better knowledge of dynamics of toxin producing phytoplankton is highly required to enable a timely and adequate management of mussel farming, a resource traditionally recognized along the coastal line of the Gulf of Trieste.

Materials and methods - Data analysed in this study refer to surface samples collected in the time-series station C1 in the Gulf of Trieste (45°42'03"N, 13°42'36"E, Fig. 1), which is part of the North Adriatic Sea Long Term Ecological Research

site, from March 1986 to December 2015. Cell abundance and composition of phytoplankton were determined according to Utermöhl method (Zingone *et al*., 2010). Annual median cell abundance was computed in order to compare interannual variability of total phytoplankton, diatoms and dinoflagellates. The frequency of occurrence of toxin producing phytoplankton was calculated as percentage of the number of samples with presence of potentially toxic species in relation to the total number of samples (358) collected over the 1986-2015 time-series. The annual frequency of alerts due to the presence of biotoxins in the coastal waters of the Gulf of Trieste was derived from AlgaeAdria Electronic Bulletin (http://www.algaeadria.org/).

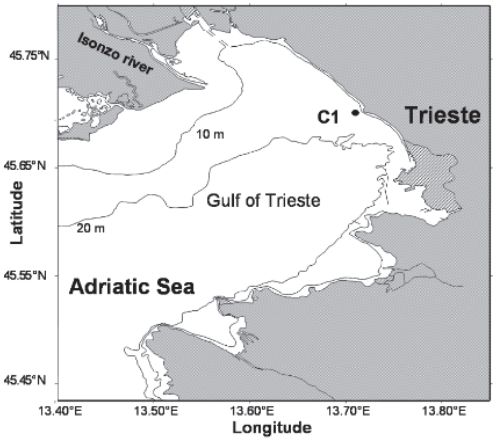

Fig. 1 - Study area. Long Term Ecological Research Station (LTER) C1 in the Gulf of Trieste, North Adriatic Sea.
Area studio. Stazione C1-LTER nel Golfo di Trieste, Mare Adriatico settentrionale.

Results - An evident short-term as well as interannual variability, with a range of more than one order of magnitude, characterized the 30 year-time of phytoplankton cell abundance of the Gulf of Trieste (North Adriatic Sea). However, the timing of interannual variability was different for total phytoplankton and the major functional groups analysed in this study (diatoms and dinoflagellates). Total phytoplankton started to decline in the mid ’90s, presented the lowest abundances in 2006 and 2007 (Fig. 2a), and a new increase after 2008, with several cases of cell abundances which are even higher than during the ’80s and ’90s. The time-series of diatoms is characterised by a pronounced decrease in the mid ’90s and a prolonged one in the mid 2000, followed by an increase after 2009, with cell abundances exceeding 5 million cells/l (Fig. 2b). Dinoflagellates are characterised by a prolonged decrease from 2003 to 2010, followed by an increase in median abundance to values higher than during the beginning of the time series (Fig. 2c). The recent increase of dinoflagellates is of particular concern since the genus includes also toxin-producing genera, which may adversely affect aquaculture and shellfish-farming activities present in the area. Considering dinoflagellate community composition, some potentially toxic species (Tab. 1), mostly belonging to *Dinophysis* and *Alexandrium* genera, which have caused contamination of mussels in the Gulf of Trieste since 1989, have been encountered (Honsell *et al*., 1992; Cabrini *et al*., 1996). In terms of the frequency of occurrence, expressed as percentage of the presence of toxic algae related to the total number of samples, *Dinophysis caudata*, *D. sacculus* and *D. fortii*, together with undetermined *Alexandrium* species, *Gonyaulax polygramma* and *Lingulodinium polyedrum* are the most frequent in the Gulf of Trieste.

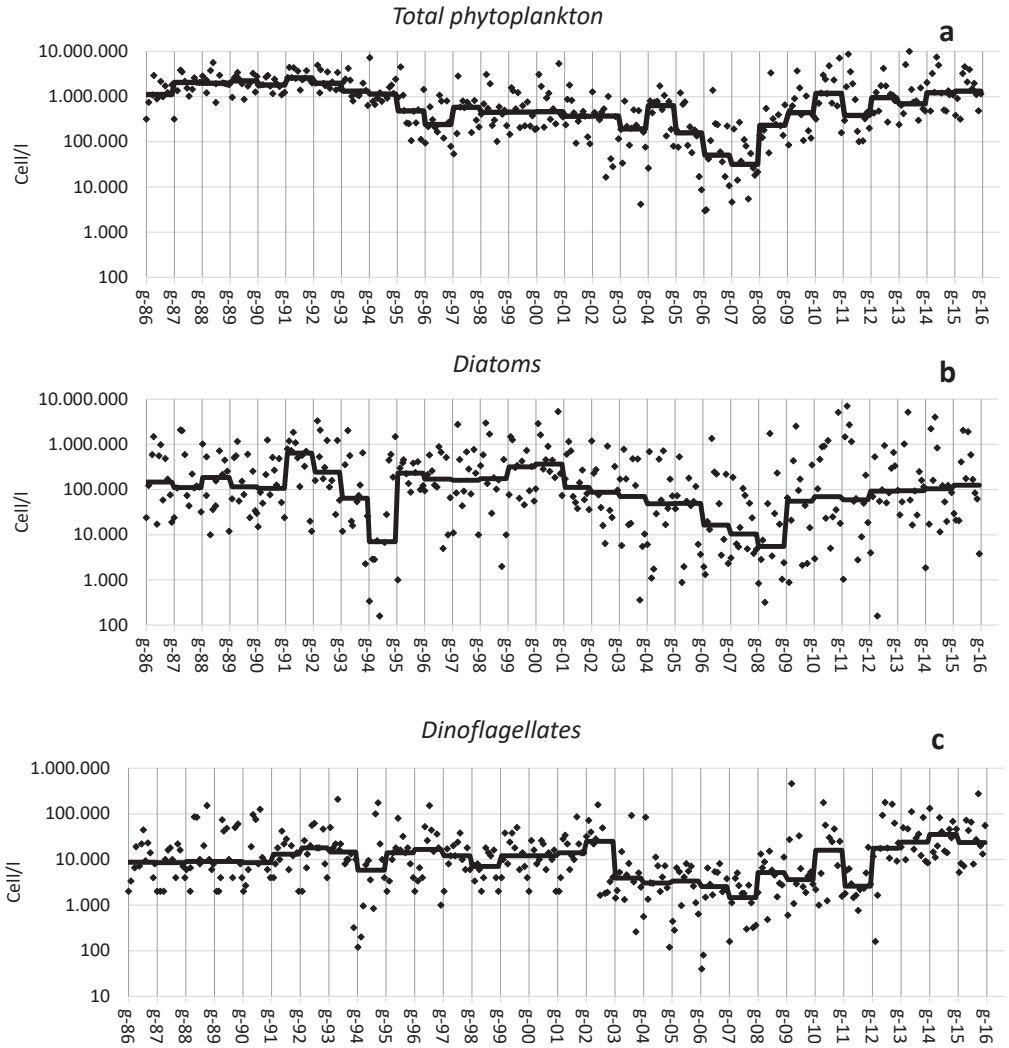

Fig. 2 - Time series of cell abundance of total phytoplankton (a), diatoms (b) and dinoflagellates (c) in the surface of the Long Term Ecological Research station C1, in the Gulf of Trieste. Annual median (solid line) is superimposed on monthly data (dots).

Serie temporali dell'abbondanza cellulare del fitoplancton totale (a), delle diatomee (b) e dei dinoflagellati (c) nella superficie della stazione C1-LTER nel Golfo di Trieste. Mediana annuale (linea continua) sovrapposta ai dati mensili (punti).

Considering the number of cases per year, both *Dinophysis* and *Alexandrium* genera increased in frequency after 2003 (Fig. 3). *Alexandrium* spp. was present in 8 out of 12 cases in 2003, 2004 and 2006 while *Dinophysis* spp. was more frequently found in 2010 and 2014 (7 out of 12 cases). The presence and the abundance of toxin-producing plankton are key indicators to determine the quality of waters used for aquaculture (European Commission, 2004) and their occurrence in the environment determine the temporary banning of shellfish-farm activities.

Tab. 1 - Frequency of occurrence (calculated as percentage of the total number of samples, 358) and number of presences of potentially toxic dinoflagellates in surface samples during from 1986 to 2015.

Frequenza della presenza (calcolata come percentuale su un totale di 358 campioni) e numero delle osservazioni dei dinoflagellati potenzialmente tossici in superficie dal 1986 al 2015.

	% of occurrence	No. of cases
***Dinophysis*-spp.**	**28.2**	**101**
Dinophysis caudata	19.8	35
Dinophysis sacculus	7.5	27
Dinophysis fortii	5.3	19
Dinophysis spp.	2.2	8
Dinophysis cf. *sacculus*	0.8	3
Dinophysis tripos	0.8	3
Dinophysis acuminata	0.6	2
Dinophysis acuta	0.3	1
Dinophysis cf. *acuminata*	0.3	1
Dinophysis cf. *norvegica*	0.3	1
Dinophysis ovum	0.3	1
***Alexandrium*-spp.**	**23.5**	**84**
Alexandrium spp.	21.8	78
Alexandrium pseudogonyaulax	1.4	5
Alexandrium cf. *minutum*	0.3	1
Gonyaulax polygramma	7.8	28
Lingulodinium polyedrum	5.0	18
Phalacroma rotundatum	4.2	15
Gonyaulax spinifera	3.6	13
Noctiluca scintillans	3.1	11
Karenia spp.	0.8	3
Prorocentrum cf. *lima*	0.6	2
Prorocentrum lima	0.3	1

In order to verify the possible effects of modification in phytoplankton community structure, in particular of the increase of toxin-producing plankton, on local mussel-farm activities, data of alerts due to the presence of biotoxins in the Gulf of Trieste have been compared with long-term dynamic of toxic algae occurrence in the LTER station. Until 2012, the interannual variability of the number of alerts due to biotoxins fits well with the frequency of *Dinophysis*, with the highest number of alerts coinciding with the highest *Dinophysis* frequency in 2010 (Figg. 3, 4). *Dinophysis* spp. result, thus, to be the main toxin-producing plankton in the Gulf of Trieste (Tab. 1) and the main responsible for periodic mussel farm banning.

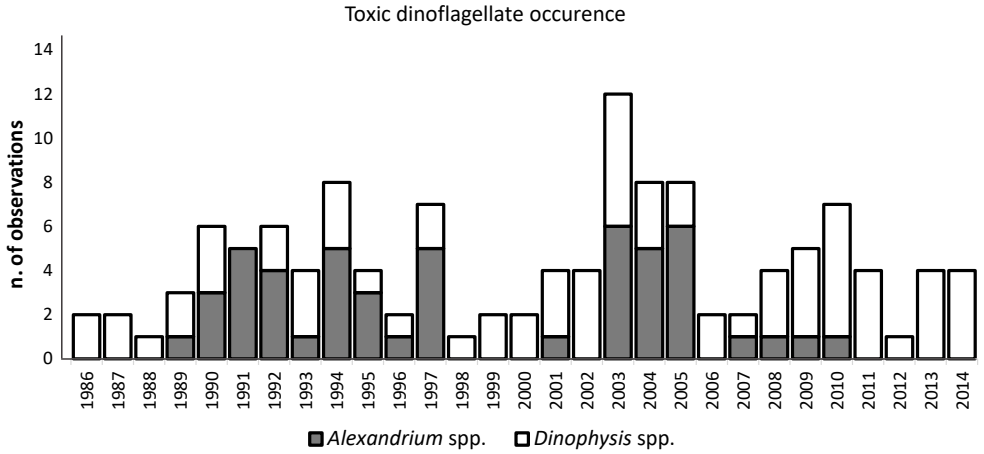

Fig. 3 - Number of samples per year where toxin producing phytoplankton was present.
Numero dei campioni per anno con presenza di organismi fitoplanctonici responsabili di produzione di biotossine.

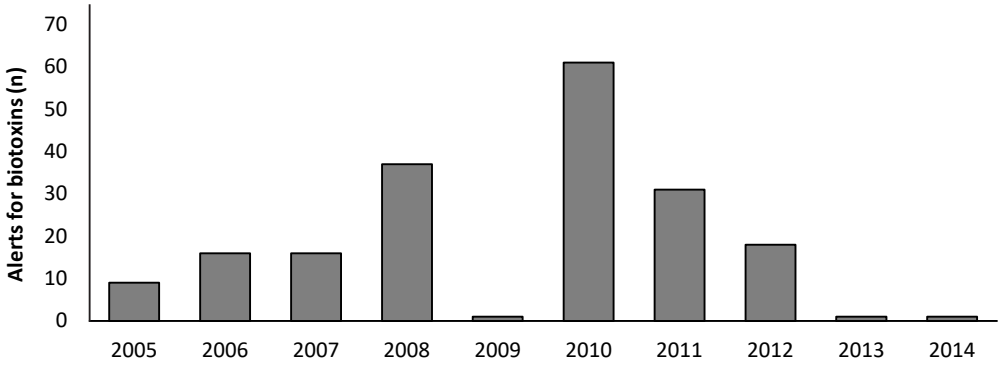

Fig. 4 - Alerts due to the presence of biotoxins in the Gulf of Trieste according to AlgaeAdria Electronic Bulletin (http://www.algaeadria.org/, last visited 01/03/2017).
Allerte dovute alla presenza di biotossine nel Golfo di Trieste secondo il Bollettino telematico AlgaeAdria (http://www.algaeadria.org/, ultimo accesso 01/03/2017).

Conclusions - During the last 30 years several changes in phytoplankton abundance and community composition were observed. After a general decrease in all functional groups starting in 2003, an increase was observed in the last years, particularly in dinoflagellates. Among dinoflagellates, several potentially toxin producing species were recognised, the most frequent belonging to the genus *Dinophysis* and *Alexandrium*. Episodic alerts due to the presence of biotoxins, leading to the bans of shellfish harvesting, were concomitant with the highest frequency of *Dinophysis* occurrence. Biotoxin emergencies are among the major threats to productivity indicated by local mussel farmers (Melaku Canu and Solidoro, 2014) and improved knowledge on their temporal trends and triggering factors are highly needed to protect public health and shellfish farming activities against economic losses.

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