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# The response of phytoplankton community to anthropogenic pressure gradient in the coastal waters of the eastern Adriatic Sea

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ABSTRACT

In order to test the response of phytoplankton to anthropogenic pressure, data of chlorophyll *a* concentration, phytoplankton abundance, and composition are analyzed in relation to anthropogenic pressure gradient and environmental variables such as temperature, salinity and nutrients. Investigated sites encompassed wide tropic range according to a preliminary determination of anthropogenic pressure, quantified through the LUSI index. Statistical analyses indicated nitrates and silicates as proxies of freshwater influence, and phytoplankton single metrics such as concentrations of chlorophyll *a* and abundances as indicators of anthropogenic pressure. Boundary values for different water quality classes for coastal waters under indirect freshwater influence (Type II) are obtained according to gradient between concentration of chlorophyll a and pressure index (LUSI), which empirically fit to exponential equation. The response of phytoplankton diversity was not linear, as the highest diversity was observed in the area with intermediate disturbance level. CCA analysis identified *Skeletonema marinoii*, *Scrippsiella trochoidea*, *Guinardia flaccida*, *Leptocylindrus* spp., *Prorocentrum* spp., *Proboscia alata*, *Eutreptiella* spp., and *Pseudonitzschia* spp. as local eutrophication indicators, whose abundances increased with nutrients loads.



## 1. Introduction

Eutrophication as one of the oldest and major threats in coastal zones around the globe is well documented in scientific literature (Marasović et al., 2005; Smith et al., 2006; Garmendia et al., 2012; Sebilo et al., 2013). Within the European marine environment, eutrophication related processes are recognized as a problem to be monitored and managed by European directives, which established the framework for the protection of inland surface, transitional, coastal, and ground waters. Due to differences in operative indicators and assessment methodologies, it is often difficult to compare eutrophication status among regional marine water bodies. So far, trophic status assessment in the Adriatic Sea was mostly based on chlorophyll *a* concentration (Weinbauer et al., 1993; Zavatarelli et al., 2000) and TRIX index (Penna et al., 2004; Mozetič et al., 2008). There are also rare studies on trophic status assessment based on phytoplankton density and biovolume (Viličić, 1989). All these assessments were done without distinct criteria for classification of different water types and they encompassed both naturally and anthropogenically induced eutrophication in the Adriatic Sea. However, the implementation of the European directives requires the development of ecologically-based classification systems for anthropogenically-induced pressures in all types of water bodies.

Due to its importance as primary producer in marine food webs, pivotal role in marine ecosystem processes and fast response to the changes in nutrient loads and environmental conditions, phytoplankton is one of crucial biological elements considered within the Water Framework Directive (WFD). In accordance with the WFD, phytoplankton parameter should be expressed through phytoplankton biomass, composition, abundance, and bloom frequency. These indices are also to be used in good environmental status (GES) assessment within 4 out of 11 qualitative descriptors contained in Marine Strategy Framework Directive (MSFD): Biodiversity (D1), Non-indigenous species (D2), Marine food web (D4), and Eutrophication (D5).

Technical and scientific work for the purposes of the Water Framework Directive (WFD) has been carried out in the coastal and transitional waters across the European Union. The coastal and transitional waters intercalibration exercise was carried out within four Geographical Intercalibration Groups (GIGs) – Baltic, Black Sea, Mediterranean, and North East Atlantic. According to the

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report of Mediterranean intercalibration group (MED GIG) for phytoplankton, water typology has been defined through the salinity classes (WFD, Intercalibration technical report, 2009). Relationship between phytoplankton components and salinity has been well documented, and shown to be important in many cases (Levandowsky, 1972; Ahel et al., 1996; Marshall et al., 2006).

The aim of this study is to (1) contribute to the implementation of European directives in Croatian waters, (2) test the response of suggested phytoplankton indices to environmental disturbance, (3) select the most appropriate metrics for phytoplankton community that clearly signals the anthropogenic pressure, (4) describe the phytoplankton classification metrics for the assessment of ecological status of Croatian coastal water type II.

In the present study, the methodology of water quality assessment has been developed on 7 years dataset collected at sites which are not directly affected by freshwater inputs with annual salinity mean between 34.5 and 37.5 and belong to Type II according to report of MED GIG phytoplankton group.

## 2. Material and methods

### 2.1. Study area

The study area encompasses coastal waters under indirect freshwater influence, which constitute the major part of coastal waters in Croatia. Sampling was performed in three bays with different hydrophysiological characteristic along the Croatian eastern Adriatic coast (Fig. 1).

Station SB 203 (Fig. 1A) is located outside the Šibenik Bay and is under the influence of Krka River. Station's depth is 13 m and distance from the nearest land is 760 m. Since vertical distribution of density is more influenced by temperature then salinity, the highest stability of water column is observed during the summer when seasonal thermocline appears. In the winter period, a negative thermocline can occur due to freshwater inflow in the surface layer.

Stations ST101 and ST103 are located in the Kaštela Bay, distanced from the nearest land by 1500 and 550 m, respectively, while station CJ007 is located out of the Bay with the distance from the nearest land of 5300 m (Fig. 1B). Kaštela Bay is a semi-enclosed bay (area 61 $km^2$), which is under considerable anthropogenic influence due to agricultural areas extending along its northern coast and municipal and industrial effluents that enter the Bay. The Bay communicates with the adjacent sea through a relatively wide (1.8 km) and deep mouth (mean depth about 40 m). The most important influx of fresh water to this Bay is the river Jadro.

Station PL105 is located in the inner part of Mali Ston Bay with the distance from the land of 300 m (Fig. 1C). The Bay is located at the end of the Neretva Channel. The outer part is under the influence of River Neretva, while this influence diminishes toward the inner part of the Bay (Vukadin, 1981). A special feature of the Bay is related to its complex hydrology, characterized by strong groundwater springs in the inner part of the Bay and the large fresh water inflow of Neretva River in the outer part of the Bay. Owing to the hydrographical features and favorable primary production, the Bay is a suitable area for cultivating shellfish, and shellfish farms are historically located there. Today it is one of the most important locations for shellfish farming in Croatia.

### 2.2. Physical and chemical conditions

Sampling of all analyzed physical, chemical and biological parameters was performed simultaneously within the frame of national monitoring program "Jadran" in the 2001–2007 period. Sampling was performed on monthly basis, with at least seven sampling occasions per year (all seasons included). Temperature and salinity were measured with an IDRONAUT 316 CTD probe (during 2001–2004) and after that period measurements were performed with a Seabird-25 CTD probe. The data obtained during all cruises were averaged for each meter of depth following the manufacturer's recommended procedure (Seabird Manual).

Dissolved inorganic nutrient concentrations (nitrates, nitrites, ammonia, orthophosphates, and silicates) were determined colorimetrically with an AutoAnalyzer-3, according to Grasshoff (Grasshoff, 1976).

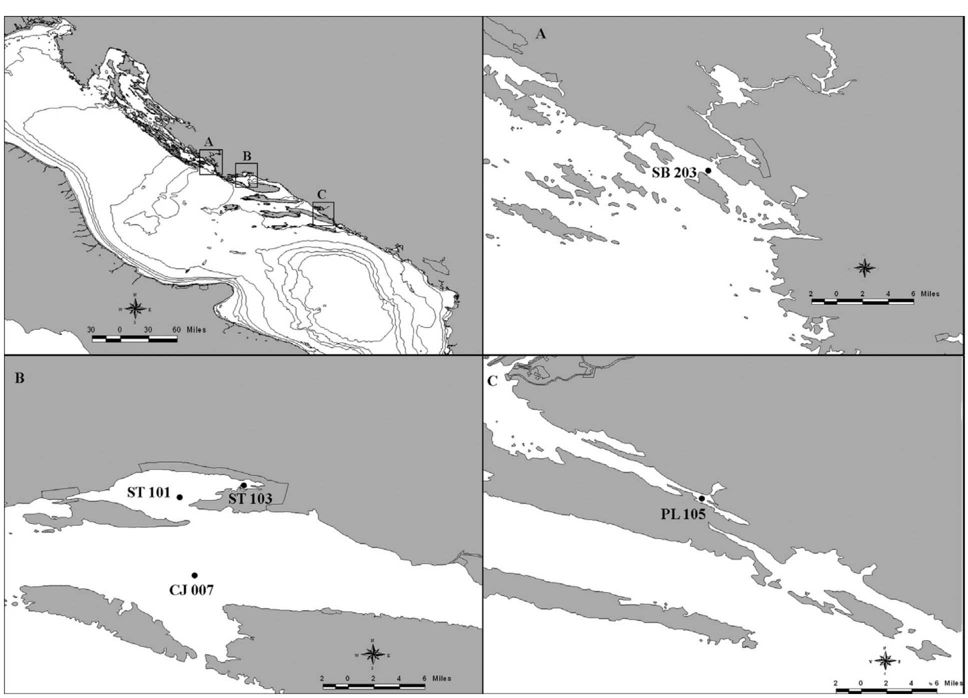


**Fig. 1.** Investigated area with sampling stations.