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# Effect of local hydroclimate on phytoplankton groups in the Charente estuary

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ABSTRACT

This study aimed to describe seasonal variations of phytoplankton abundances in relation to the physical and chemical (nutrients and metals) environment under the influence of freshwater input in the Charente river estuary (Marennes-Oléron bay, France) over three years, from 2011 to 2014. Phytoplankton abundances were determined using microscopy and flow cytometry. Considering high frequency temperature and salinity data, breakpoints in each series led to the identification of two local hydroclimatic periods: the first (2011 and early 2012) being warmer and higher in salinity than the second (from spring 2012 to the beginning of 2014). A multiblock PLS analysis highlighted the significant contribution of the physical environment (temperature, salinity and Photosynthetically Active Radiation (PAR)) on phytoplankton abundances. Two partial triadic analyses (PTA) were run in order to visualize seasonal variations of i) phytoplankton groups and ii) nutrients and trace elements, irrespective of spatial gradient: picoeukaryote occurrence showed a difference between year 2011 and the years 2012 and 2013 (as did cadmium, nickel and silica levels). However, both PTA revealed greater differences between year 2013 and the years 2011 and 2012, as shown by occurrences of cryptophytes, dinoflagellates and nanoeukaryotes, as well as copper and phosphate levels. These results showed a shift between the hydroclimate breakpoint and some phytoplankton responses, suggesting that their development and succession might depend on conditions early in the year. Finally, a STATICO analysis was performed on the paired PTA in order to examine the relations of phytoplankton with nutrients and metals more closely. Most phytoplankton groups were represented on the first axis, together with cadmium on the one hand, and nitrates, silica and nickel on the other. This analysis revealed the separation of phytoplankton groups on the second axis that represented phosphates and copper. Hydroclimatic conditions and the nature of freshwater inputs, especially phosphates and copper content, might be key factors driving phytoplankton structure in the Charente estuary.



## 1. Introduction

Approximately 40% of the world population inhabits coastal and estuarine areas (MEA, 2005), concentrating human activities that cause damage to marine ecosystems (Halpern et al., 2008). Human activities exert intensive stresses on marine ecosystems, including chemical contamination (urbanization, agriculture, industry) and disturbances caused by the exploitation of marine resources (fishing, aquaculture, aggregate extraction, etc.) (Nogales et al., 2011). Coastal ecosystems are among the world's most productive ecosystems and provide many vital ecological services that need to be preserved (Costanza et al., 1997; MEA, 2005; Barbier et al., 2011; Liquete et al., 2013), such as shelters for reproduction and nurseries for marine species. Their role in nutrient cycling is essential,

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depending on the quantity and quality of terrigenous inputs, as nutrients act directly on the lowest trophic levels and induce changes in the composition of the microbial community (Nogales et al., 2011). Phytoplankton plays a major role in microbial communities, where it is responsible for primary production and represents the main trophic resource for higher trophic levels.

Natural phytoplankton communities have been greatly studied worldwide, in freshwater, coastal (Gasiunaite et al., 2005; Aktan, 2011) and estuarine environments (Muylaert et al., 2009; Rochelle-Newall et al., 2011). Classic analysis of phytoplankton communities using microscopy allows counts and determination of taxa to class or species level (Cloern and Dufford, 2005; Domingues et al., 2011; Hall et al., 2013; Paerl et al., 2014; Harding et al., 2015). Such studies can be used to describe the effect of environmental variables (nutrients, light) on phytoplankton dynamics and community structure evolution (Hall et al., 2013; Paerl et al., 2014). As shown by Harding et al. (2015), the seasonal pattern in the northern hemisphere has spring or summer blooms that are influenced from year to year by climatic events. Global change, especially temperature increase, is a key question in the study of phytoplankton communities (Edwards and Richardson, 2004; Morán et al., 2010). For instance, Thomas et al. (2012) demonstrated that temperature could impact the spatial distribution of communities, and thus cause changes in diversity.

Studies that deal with phytoplankton community evolution, dynamics and structure in space and time while considering different cell-size groups (from pico-to microplankton) are scarce (Sin et al., 2000; Huete-Ortega et al., 2011; Cerino et al., 2012), but are necessary to improve our understanding of ecosystem function based on phytoplankton communities (Segura et al., 2013; Marañón, 2015). The importance of understanding what factors drive phytoplankton communities and how they evolve is emphasized by their place in EU regulations (Water Framework Directive, WFD 2000/60/CE and Marine Strategy Framework Directive, MSFD 2008/56/CE) among the indicators of water mass ecological status. Lugoli et al. (2012) suggested the use of phytoplankton size-classes as an indicator of anthropogenic impact in marine and transition areas. However, as stated by Garmendia et al. (2013), many attributes of phytoplankton need to be considered before it is possible to develop a robust and sensitive indicator. There is thus a need to investigate whole phytoplankton communities, together with their physical and chemical environment, in order to define the baseline variations of all the parameters. Only such complete approaches will make it possible to discriminate for ‘events’ caused by environmental disturbances.

In coastal areas, estuaries are transition areas between freshwater and marine ecosystems, subjected to strong anthropogenic pressure but achieving high productivity thanks to freshwater inputs. Among the most productive coastal areas on the French Atlantic coast, Marennes-Oléron bay (Région Poitou-Charentes, south-west France) is the top oyster producing area in France (Goulletquer and Héral, 1997): out of the 101 100 t of oysters produced in France in 2011/2012, 39 000 t were produced in Poitou-Charentes (CNC, 2014). This high oyster production relies mainly on primary production, which is largely due to phytoplankton. Nutrients are supplied by the Charente river, which discharges into the bay contributing about 90% of the freshwater input during summer (Ravail-Legrand et al., 1988). These nutrients were estimated to contribute annually to a primary production of 185 gC.m$^{-2}$.an$^{-1}$ in the water column of Marennes-Oléron bay (Struski and Bacher, 2006), underlining their importance for phytoplankton development.

The first aim of this study was to describe the seasonal variations of phytoplankton abundances in the transition area of the Charente estuary, during three years of monitoring (2011–2014). The second purpose was to understand to what extent local hydroclimate and freshwater inputs (nutrients and trace elements) drive phytoplankton abundances in this specific environment.

## 2. Materials and methods

### 2.1. Sampling site and strategy

The Charente estuary (45°70′N, 1°00′W) is located on the Atlantic coast of south-west France. The Charente river is 360 km long with a catchment basin of about 10 000 km$^2$, mostly occupied by agriculture (75% of its surface, Agreste, 2010). The flow amplitude ranges from several m$^3$.s$^{-1}$ to 700 m$^3$ s$^{-1}$, with an average of 70 m$^3$ s$^{-1}$ (Toublanc et al., 2015). The Charente estuary is a small, shallow, macrotidal estuary with a mean tidal range of 4.5 m and well-mixed waters (Toublanc et al., 2015). In addition, the asymmetric tide waves lead to continual resuspension of seabed sediments (Modéran et al., 2012). The present study was run along a transect of about 12 km that was not subject to water stratification.

Sampling campaigns were carried out every two weeks from February 2011 to January 2014, taking samples at low tide when the influence of freshwater inputs was the highest, thus allowing the quantification of trace elements. Four stations were sampled in the Charente estuary (Fig. 1): the depths of the four stations ranged from 4 to 11 m from the mean sea level (6 m for Station 1). The station the furthest upstream (Station 1: Lupin), which was located at 45.9538N −01.0544E, was equipped with multiparameter probes (YSI 6600 or NKE Smatch) that recorded continuously. The three other stations were mobile and their position was defined during each campaign depending on the salinity gradient, as follows. The most downstream station (Station 4) was defined as the place corresponding to the maximal salinity value that had occurred at high tide at Station 1 the day before. Locations of stations 2 and 3 were then defined in consequence so as to obtain a homogeneous

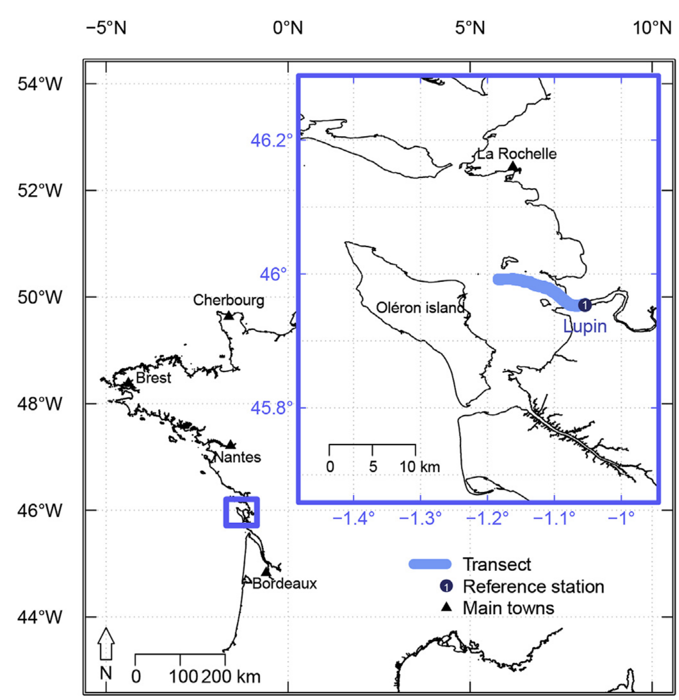


**Fig. 1.** Location of the Charente estuary and Marennes-Oleron basin (blue box) on the French west coast between Nantes and Bordeaux. The blue line represents the sampling transect including the fixed station “Lupin”. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)