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Dynamics of biogeochemical properties in temperate coastal areas of freshwater influence: Lessons from the Northern Adriatic Sea (Gulf of Trieste)

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ABSTRACT

High spatial and temporal variabilities of biogeochemical properties are prominent features of regions under freshwater influence as a result of multiple factors. Understanding the ecological functioning of these ecosystems, which provide important services for humans, is challenging since it requires adequate observational strategies and efforts.

Multi-years (1999–2006) continuous observations in the northernmost part of the Adriatic Sea (Gulf of Trieste) allowed us to compute a climatological description of seasonal dynamics of biogeochemical properties for three relevant sites: a coastal area directly influenced by a river, an off-shore area located in the centre of the Gulf and a coastal area located far from potential source of external nutrients.

The analysis of the climatologies provides a quantitative corroboration of the conceptual scheme for biogeochemical and ecological seasonal dynamics of temperate coastal areas under freshwater influence already proposed in literature, highlighting the role of river input, lateral transport, stratification regime and interaction with bottom environment as driving factors.

While all areas follow a common pattern of succession of ecological processes, spatial variability accounts for a significant decrease of the absolute trophic state, and for a phase delay in biogeochemical dynamics. Results show that spatial heterogeneity is an inherent structural feature of coastal ecosystems, suggesting that the evaluation of the quality status of coastal ecosystems should be made by using different reference terms for different sub-areas.

1. Introduction

Regions of freshwater influence (ROFI, Simpson, 1997) are subjected to variability from a range of sources that determine their seasonal and interannual highly dynamic patterns. Seasonal, daily and tidal cycles are among the more easily recognised sources of natural variability, but less regular influences can be also relevant. Riverine freshwater inputs and nutrient discharges alter the buoyancy of the area, which favours water column stratification, enriches the environment with additional nutrients, and generates dynamic fronts that divide the area into markedly different sub-areas. In addition to triggering surface circulation, winds can mix the water column, bringing nutrient enriched bottom water masses to the surface and homogenising the vertical distributions of dissolved substances. Benthic pelagic coupling may influence bottom water properties. The presence of cities, which are often localised along the coast and close to river mouths, represents another source of anthropogenic pressures, such as urban-derived nutrient and pollutant loads, industrial wastes, fishery impacts and aquaculture, tourism and other economic activities. Global changes, such as changes in run-off regimes (Howarth et al., 2000), are superimposed on the locally driven pressures along with environmental modifications caused by culturally driven policy strategies, such as oligotrophication (Stockner et al., 2000).

In such a heterogeneous context, paradigms for biological–physical interactions that drive biogeochemical dynamics in the open seas (e.g., the Gran–Sverdrup effect, Riley, 1942; Sverdrup, 1953) do not always apply – mainly because of the prevalence of coastal inputs and lateral transport on vertical processes and because of the much shallower water depth – and different physical and ecological structures and dynamics are in place (Cushing, 1989; Legendre and Rassoulzadegan, 1995; Mann and Lazier, 1998), which often depend on site specific characteristics.

Since the 1980s, possibly driven by problems related to coastal eutrophication and water quality, many studies have explored the

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