PLANNING AND DESIGNING AN INTEGRATED MANAGEMENT OF COASTAL HYPOXIA IN THE EMILIA ROMAGNA REGION WATERS (NORTHERN ADRIATIC SEA)

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Abstract

The design of an integrated monitoring network useful for the early-warning, the management and mitigation of both the environmental and socio-economic costs of hypoxia/anoxia events in the Northern Adriatic coastal zone, south of the mouth of the Po river, is described in the contribute. It has been developed within the EMMA research project (Environmental Management through Monitoring and Modelling of Anoxia; LIFE04ENV/IT/0479) (2004-2007).

Over the past few decades, hypoxia events have recurrently affected the coastal zone of Emilia Romagna Region (Italy). Data collected by the C.Z. lying in the Province of Rimini, because of its economic importance, are presented. The area is subjected to intense anthropogenic pressure due to its high population (416 000 equivalent inhabitants) with tourist seasonal peaks of up to 973 110 equivalent inhabitants (in summer time), to industrial and agricultural activity, to maritime traffic and nutrient river discharges (about 600 tons y^{-1} of nitrogen and 300 tons y^{-1} of phosphorus, in 2002). Hypoxia and anoxia have a negative effect on the quality of bathing waters as well as on fishing and mussel farming, which are important activities for the economy of the area. The planning of the monitoring network has been carried out by analyzing the scientific knowledge on hypoxia in the local area; its integration with other existing monitoring activities, available facilities and data resources was considered in order to optimize cost effectiveness of the network.

INTRODUCTION

Over the past few decades both coastal eutrophication and hypoxia have become such widespread phenomena to be regarded on a larger, global scale rather than on local scale [1]. The causes of hypoxia have been generally associated with an excess of nutrient inputs (anthropogenic load), especially nitrogen, although the

response of each marine ecosystem to the anthropogenic pressure is strongly modulated by physical processes, such as timing of stratification, mixing and circulation at regional and local scales [2], [3], [1]. Even global scale factors, as climate change, may alter the coastal ecosystems [1] on a local scale and, coupled with the increase of human population in these areas, they could further exacerbate the problems related to the occurrence of anoxia and hypoxia [4]. The North Adriatic Sea is a highly productive area of the Mediterranean, nevertheless production processes in this basin show a high temporal and spatial variability, as a result of the interactions between meteorology, river inputs, nutrient dynamics, circulation and exchange with the central Adriatic basin [2], [5], [6]. These varying conditions play a role in the occurrence of large offshore anoxia and hypoxia events [7], [8] and mucilages [2], [9], [10], [11]. In the North Adriatic, hypoxia and anoxia events occur mainly in the western part and have been reported since the beginning of the last century [12]. The importance of the benthic-pelagic coupling is not negligible in the area and increases with decreasing water depth and nutrient loading. Knowledge of sea floor characteristics is therefore important for studying hypo-anoxia phenomenon, as they can determine conditions favourable for the local development of such events. In the North Western Adriatic shelf, the presence of organic matter deposits, very reactive to microbic degradation, can influence the oxygen budget in the bottom waters, both on seasonal and pluriannual time scales [13], [14], [15]. The continental inputs give large supplies of inorganic nutrients, dissolved organic matter and suspended matter which cause eutrophication and hypoxic events often debated since the 1970s [2]. As a consequence, regular monitoring programmes, supported by regional institutions, have been carried out since 1977 [16]). EMMA project has its focus on the coastal zone, including the City of Rimini, with the aim of building an integrated monitoring network for managing and reducing the impact of hypoxia events on the economy of this area. The project was carried out in collaboration with the National Institute of Biology of Slovenia (NIB), which was also involved in the monitoring programs of eutrophication and hypoxia events in the Slovenian part of the Adriatic Sea [17], [18], [19], [20], [21]. The aim of this contribute is to present the scientific background work for planning the activity and the building of a remote data acquisition system.

STUDY SITE.

Within the coastal zone under Emilia Romagna Region jurisdiction, 40 km of coast corresponding to the province of Rimini, between Cesenatico and Cattolica, was chosen for the EMMA project (Fig.1). The area is characterized by very shallow waters, the water column structure is strongly influenced by the freshwater inputs of the River Po and of other local water courses, which induce a complex pattern of circulation mostly dominated in the off-shore waters by a southward flowing current (West Adriatic Current) at surface [2], [6]. High levels of nutrients, dissolved organic matter [22], [23], [24], [25], [26] and suspended particulate matter [27]) are advected in this coastal zone in concomitance with the spreading of the coastal front. Primary production and chlorophyll-a (Chl-a) concentrations are high in these coastal waters [28], [29], particularly in a narrow coastal belt within few miles from the coast (260 g C m^{-2} $year^{-1}$ and 3.64 ± 4.69 μg dm^{-3}, respectively; [29]). Temporal variations in the extension of low-salinity coastal waters also exert a strong influence on the deposition and biogeochemistry of sediments [15], [14]). A net sediment accumulation characterizes the benthic compartment along the Italian coast South of the Po delta, including the area studied by EMMA (0.15 g cm^{-2} $year^{-1}$; [13]).

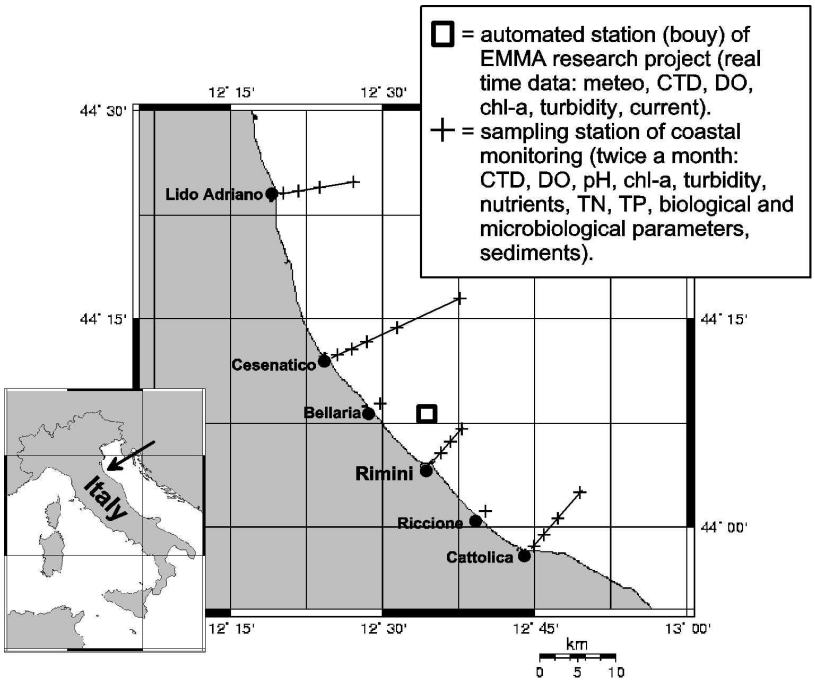

Fig. 1 - Study area

ANALYSIS OF HYPOXIC/ANOXIC EVENTS IN THE COASTAL ZONE OF RIMINI IN THE PAST

The coastal waters of the NW Adriatic are very eutrophic, particularly South of the Po River delta, along the coast of Emilia Romagna down to Mount Conero (Marche). High algal biomasses are formed as a consequence of diatom and dinoflagellate blooms. Hyperproduction of exudates and possible formation of large mucilage aggregates have also affected this area.

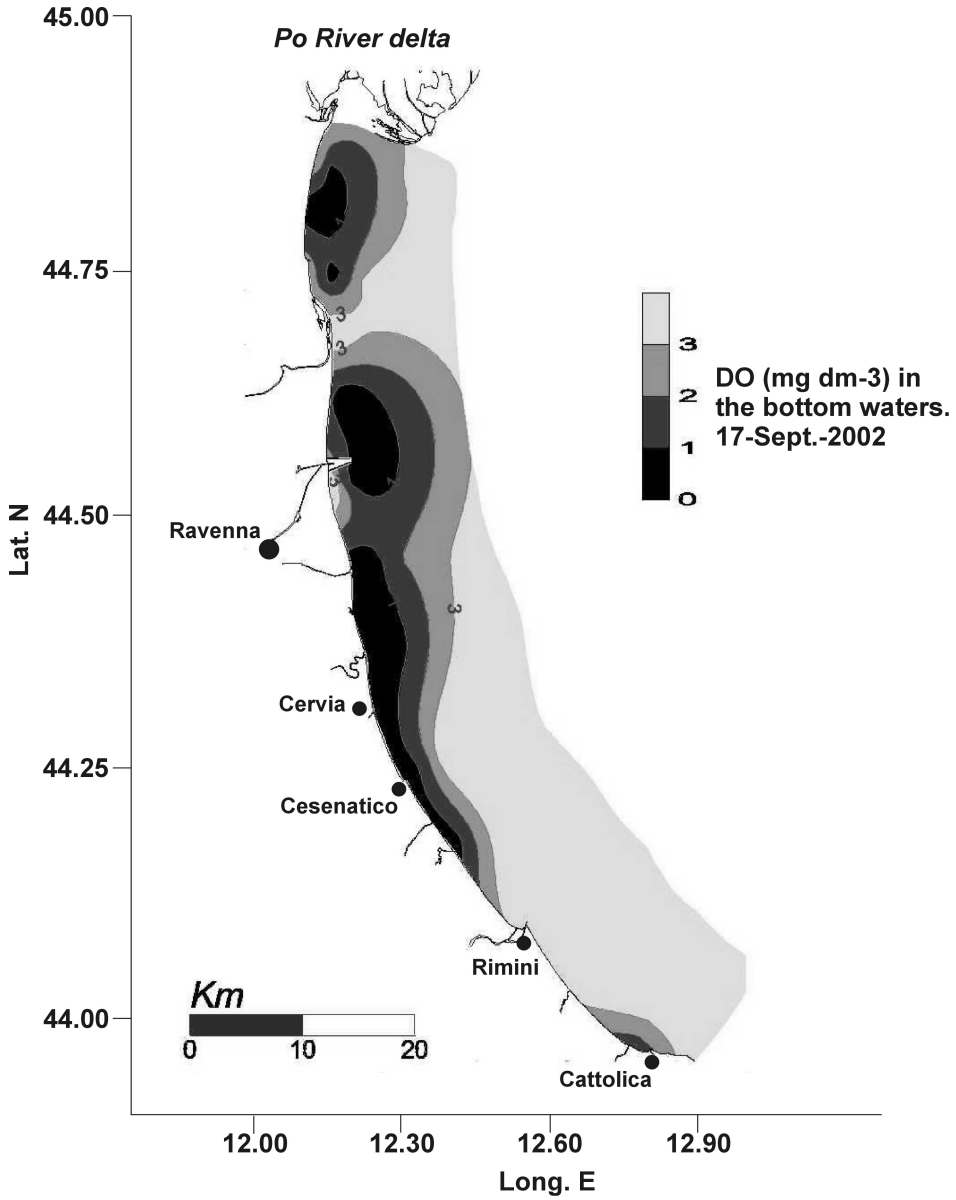

Fig. 2 - Anoxic and hypoxic conditions in coastal waters of E. R. in September 2002

High production events and stable meteorological conditions often lead to hypoxia or even anoxia in deeper waters, which can extend over hundreds of square kilometres. Usually, the major events break out in proximity to the Po Delta spreading southward, showing dynamics strongly related to riverine discharges and the circulation. Actually, analysis of the data provided by the regional monitoring of the Emilia Romagna coast confirms that wide hypoxia almost never originates in the area between Cesenatico and Cattolica, but start to develop in the northern coastal area and are advected southward, as shown by the episode in September 2002 (fig.1). Concentrations of dissolved oxygen less than 3 mg dm^{-3} are considered critical for marine benthonic organisms, below these values their metabolism slows, they suffer and are in danger of life [1]. In the North Adriatic, in particular, massive mortality of benthonic communities starts at values around 0.7 mg dm^{-3}, while the mortality of more sensitive and weaker individuals has been observed at values below 1.4 mg dm^{-3} .

Past data show that the frequency of hypoxia events has increased since the 1970s [30]. Studies on the local benthic foraminiferal associations in the sediments near the delta of the Po have suggested a steadily increasing eutrophication since 1900, with a more frequent marked occurrence of hypoxia and anoxia during summers from the 1960s onwards [31]. Recently, national legislation has reduced the amount of phosphorus in detergents progressively from 6%, in 1982, to 1% in 1989. On a local scale, the analysis of data gathered by the regional monitoring network in the coastal zone of Rimini shows that oxygen deficiencies have occurred quite often in the period 1994-2004. Hypoxia has affected waters extending from the beach to 6 km offshore. These events often occur in summer and autumn (particularly October and November). Other hypoxia events have been reported on a local scale, within the bathing belt (500 m from the coast) or in the inner brackish canals connected to the sea. They were caused by the degradation of high algal biomasses, accumulated from strong runoff and scarce circulation. Overall, these studies indicate the presence of three main types of hypoxia and anoxia events in the area:

- large coastal events, often originating in the North Emilia Romagna coast and advected southward to the coastal zone of Rimini;

- coastal events originating in the Rimini area, which may extend to offshore waters or be exacerbated by the influx of low-oxygen offshore waters toward the coast.
- Local events, originating in brackish waters by unusual conditions of high runoff, scarce circulation and strong stratification.

SOCIO-ECONOMIC RELEVANCE OF THE REGION AND INVENTORY OF ANTHROPOGENIC LOADS IN THE PROVINCE OF RIMINI.

Undoubtedly, from a demographic and socio-economic perspective, Emilia Romagna is important not only for Italy, but for the European Community as a whole. The population in this region has increased markedly from World War II up to the 1970s, later stabilizing to around 4m inhabitants, corresponding to 6.9% of the national population. The population density is high (180 inhab. km^{-2}), especially in the plain and along the coast, with peaks of 871 inhab./km^2 in Rimini. Industry employs 1.5 million people, and tourism shows a constant increment of visitors (+15% over the decade 1992-2001 with 37.4m visitors in 2001) particularly along the coast (74%). Fishing contributed to the regional economy in 2001 with 14 587 t y^{-1} of fish, corresponding to a wholesale value of 34 000 000 €, and with amounts ranging from 800 to 1 800 t y^{-1} over the decade 1994-2004, whereas aquaculture over the same period ranged from 1 500 to 3 000 tons/y^{-1}. From these data it is clear that anthropogenic loads in coastal waters of the region are high. Estimated as equivalent inhabitants (resident population + tourism + industry), they peak at 6.7m in summer, corresponding to a 5.4m annual average, whereas sewage disposal plants operating in the area are able to treat loads corresponding to 6.2m eq. inh. [32].

The Province of Rimini has increased its economic activities and population over the past few decades (up to 416 000 eq.inh.). The city and the coast attract most of the tourism of the four Riviera provinces (Fig. 3). It amounts to the 20% of visitors to the whole region. Fishing and aquaculture contributes both to the local and regional economies in a significant way (about 1 000 tons $y^{-1}$and 1 400 tons y^{-1}, while contributions from agriculture and industry can not be neglected.

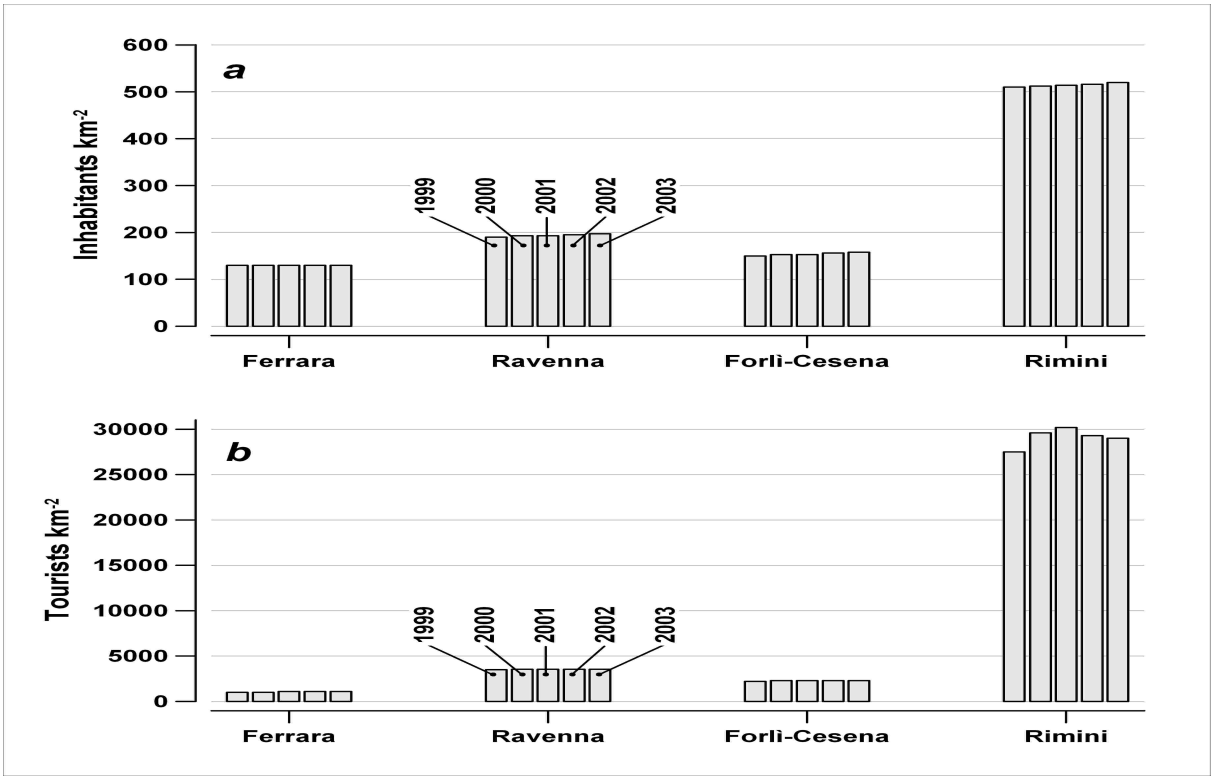

Fig. 3 - Density of inhabitants and tourists in 4 provinces along the coast of Emilia Romagna from 1999 to 2003

The anthropogenic loads into fresh and marine coastal waters of the province are high (peaks of almost 1m eq.inh. in summer), and may not be completely compensated by the available disposal plants (corresponding to about 900 000 eq.inh.), that in 2002 discharged at sea about 15 tons y^{-1} of P and about 250 tons y^{-1} of N. The river Marecchia discharge, in the same year, was about 300 tons y^{-1} and 600 tonsy^{-1} respectively (ARPAER-SOD data). For these reasons, the area of Rimini may be considered as a case study exportable to other coastal zones affected by environmental problems due to similar combinations of high human population, tourism, maritime traffic, industrial activities, fishing and aquaculture.

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