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Patterns of seasonal variation in lagoonal macrozoobenthic assemblages (Mellah lagoon, Algeria)

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ABSTRACT

In coastal lagoons, many studies indicated that macrozoobenthic assemblages undergo marked temporal fluctuations as related to the strong environmental variability of these systems. However, most of these studies have not assessed the seasonal patterns of these fluctuations and none of them has investigated the consistency of this variation in different areas within the same lagoon system. In this study, we assessed patterns of variation at multiple temporal (date, season and year) scales in two different areas in the coastal lagoon of Mellah (northeast Algeria). These areas (hereafter *Shore* and *Center*) are representative of two different environments typically found in coastal lagoons. The *Shore* (water depth of about 1.5–2 m) is characterized by relatively higher hydrodynamics, sand to silty-sand sediments and the presence of vegetation (*Ruppia maritima*), the *Center* (water depth of about 3–3.5 m) is characterized by mud to sandy-mud, organic-enriched sediments due to fine particle accumulation. Results showed two distinct patterns of seasonal variation in *Shore* and *Center* assemblages for two consecutive years. In *Shore*, species richness (*S*), total abundance (*N*) and the abundance of several dominant taxa were highest in summer and/or autumn. This pattern can be related to the local environmental conditions maintaining relatively well oxidized conditions, while increasing food availability, and favoring the recruitment of species and individuals in summer/autumn. On the contrary in *Center*, *S* was lowest in summer and autumn, and *N* and the abundance of fewer dominant taxa were lowest in summer. In *Center*, the bivalve *Loripes lucinalis* showed a 10-fold increase from summer to autumn in both years, likely related to the lagoon's hydrodynamics favoring larval transport and settlement in the central sector of the lagoon. Overall, the seasonal variation found in *Center* followed a regression/recovery pattern typical of opportunistic assemblages occurring in confined organic-enriched environments. In conclusion, our results provide new insight into the patterns of seasonal variation in lagoon soft-sediment benthos and highlight the importance of local environmental conditions on this variation. This study provides a valuable tool for adopting appropriate monitoring strategies in these systems, with special reference to Southern-Eastern Mediterranean lagoons which are expected to suffer from increasing coastal development and human pressure in the near future.

1. Introduction

Coastal lagoons are receiving increasing attention worldwide in recognition of their multiple uses and services (Elliott, 2011; Basset et al., 2013a; Camacho-Valdez et al., 2013), but also because of their fragility to the synergistic effect of climate change (CC) and human pressure (Anthony et al., 2009; Tagliapietra et al., 2011; Basset et al., 2013b). For instance, CC-related variation in timing and quantity of wet deposition may alter the runoff and river hydrology, with effects on freshwater and nutrient delivery to coastal lagoons, and nutrient stoichiometry within lagoons (Cossarini et al., 2008; Padedda et al., 2012). At the same time, human installation of artificial structures and barriers at the lagoon's inlets often impairs the water and sediment exchange between lagoon and sea, favoring the trapping of organic-rich fine sediments inside the lagoon (da Cunha and Wasserman, 2003; De Falco et al., 2004; Como et al., 2007). Increased nutrient inputs to lagoons, leading to high

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primary productivity, and organic matter (OM) accumulation within the system enhance microbial decomposition and oxygen consumption (Nixon, 1982; Bartoli et al., 2009; Viaroli et al., 2004, 2010). The microbial decomposition of OM involves physico-chemical modifications to the medium which are selective for the biota. The main selection factors are low dissolved oxygen (DO) concentrations, leading to reducing conditions and lower pH, and the accumulation of the toxic by-products (ammonia and sulphide) of anaerobic metabolism (Hyland et al., 2005; Magni et al., 2008a; Tagliapietra et al., 2012; Kanaya et al., 2015).

Shallow coastal waters and lagoons are characterized by large seasonal, often unpredictable, variation in physical and chemical variables (Magni et al., 2006; Tagliapietra et al., 2011; Padedda et al., 2012). This may strongly vary the importance of the processes which regulate the macrozoobenthic assemblages from season to season. In coastal lagoons, numerous studies indicated that macrozoobenthic assemblages, mainly composed of opportunistic taxa, undergo marked temporal fluctuations (Tagliapietra et al., 1998; Koutsoubas et al., 2000; Como et al., 2007; Kanaya et al., 2011). However, most studies have not taken into account the variation in macrobenthic assemblages at multiple (e.g. date, season and year) temporal scales. In such cases, the variation in macrozoobenthic assemblages among different sampling occasions is analyzed without separating seasonal differences from those occurring within seasons, the latter representing an import source of variation (Morrisey et al., 1992). In addition, most temporal studies have only considered one particular environment, despite the fact that habitat heterogeneity and changing environmental conditions greatly shape lagoonal benthic communities (Giménez et al., 2006, 2014; Magni et al., 2008b; Como et al., 2012; Zettler et al., 2013). To the best of our knowledge, no study in coastal lagoons has ever analyzed the seasonal variation in macrozoobenthic assemblages over multiple years and in different environments within the same system. Finally, significant data gaps exist in the Southern and Eastern basin of Mediterranean Sea where fewer descriptive studies on the temporal distribution of lagoonal benthic assemblages are available (e.g. Draredja, 2005; Afli et al., 2009; Khedhri et al., 2015). For these reasons, in-depth studies are strongly needed to improve our understanding of ecological responses of coastal lagoons to both CC and human pressure, and to enable the implementation of mitigation and adaptive management policies (Anthony et al., 2009; Tagliapietra et al., 2011). This is even more pressing in less studied regions like those in the Southern–Eastern Mediterranean Sea where, in combination with prospected CC effects (warmer and drier conditions, Christensen et al., 2013), coastal development and human pressure are expected to increase strongly and at a faster rate than in Northern Mediterranean countries (EEA, 1999; Flower and Thompson, 2009; UNEP/MAP-Plan Bleu, 2009; Golini et al., 2015).

To fill these gaps, we investigated the seasonal variation in macrozoobenthic assemblages in two different areas within the Mellah lagoon (Algeria) over a two-year period. These areas are representative of the two main environments characterizing the Mellah lagoon (Zaouali et al., 1985; Guelorget et al., 1989; Draredja, 2007). We used a nested sampling design allowing us to distinguish the seasonal variation from that at smaller (among dates) scale in the two areas. We tested two hypotheses: (1) the macrozoobenthic assemblage change among seasons consistently for two subsequent years and (2) the pattern of seasonal variation differs between areas. This was addressed by analyzing (i) the whole macrobenthic assemblage, (ii) assemblage's univariate measures (i.e., Shannon diversity index, total number of species and total number of individuals); and (iii) the abundance of dominant taxa. This study has been conducted in the frame of a long term cooperative regional effort aimed at contributing new knowledge to the biodiversity and ecology of Southern-Eastern Mediterranean marine and lagoon systems (Magni, 2003; Magni et al., 2004b; Draredja et al., 2006).

2. Materials and methods

2.1. Study area

The Mellah lagoon is located in the northeast of Algeria (8°20′E – 36°54′N), within the El-Kala national park (Fig. 1), a protected natural reserve established since the adherence of Algeria to the Ramsar Convention in 1982. The Mellah lagoon has a surface of 865 ha, a mean water depth of about 3.5 m and communicates with the sea by a long (900 m) and narrow (10–20 m) channel, which has undertaken substantial widening and deepening in 1988 (FAO, 1987) and is periodically dredged due to its recurrent filling with silt. The drainage system of the Mellah lagoon is characterized by three main intermittent streams located in southern sector of the lagoon, whose contribution to the overall nutrient loading is limited to the winter period. Nutrient and phytopigments concentrations in water are relatively low, with annual means of about 2 μM NH_4^+, 1 μM PO_4^{3-}, 4.5 μg l^{-1} Chl-*a* and 11 μg l^{-1} pheopigments, and the tendency to be higher in winter and spring than in summer and autumn (Draredja, 2007). The shores are characterized by extended patches of *Ruppia maritima* meadows, whereas in other sectors of the lagoon bare sediments dominate, with increasing fine fraction and OM contents of surface sediments towards the central and deeper sector of the lagoon (Guelorget et al., 1989; Draredja, 2007). The Mellah lagoon is renowned for its artisanal fishery activities (i.e. *Liza aurata*, *Chelon labrosus*, *Mugil cephalus*, *Sparus aurata*, *Dicentrarchus labrax* and *Anguilla anguilla*), with a yearly fish catch up to about 40 tons (47 kg ha^{-1} $year^{-1}$), as reported for the 1998–2003 period (Chaoui et al., 2006). Wild harvesting of clams (i.e. *Ruditapes decussatus*) and cockles (i.e. *Cerastoderma glaucum*) is also present in the Mellah lagoon.

2.2. Experimental design and laboratory analyses

Samples for the macrozoobenthos were collected for two consecutive years (i.e. 2008 and 2009). Four seasons (i.e. winter

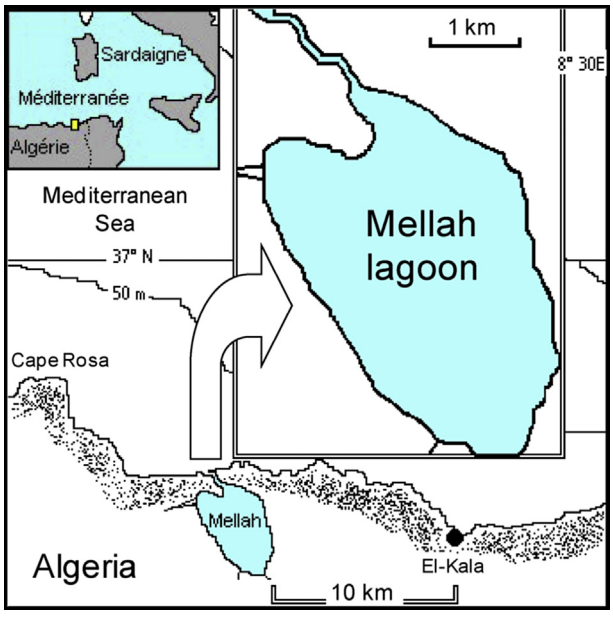

Fig. 1. Location of the Mellah lagoon (northeast Algeria).