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Assessment of surface sediment dynamics and response of benthic macrofauna assemblages in Boughrara Lagoon (SW Mediterranean Sea)

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ABSTRACT

A study was conducted in the spring of 2009, the winters of 2010 and 2013, and in the summer of 2012 at 13 stations in Boughrara Lagoon, Tunisia (southern Mediterranean). The country's largest lagoon, it is considered to be an anthropogenically stressed area, though a major tourist centre—Djerba Island—is located along its northern shores. The lagoon bottoms were studied via analyses of grain size, surface sediment composition, total organic matter (TOM) and through the trophic and functional organisation of benthic macrofauna. The results indicate that the bottoms are composed of fine, medium or coarse sands and that sediment distribution is controlled by water movement. Estimation of TOM content revealed that the studied samples present both normal and imbalanced sediments. The structure and organisation of the lagoon's benthic macrofauna are dominated by select deposit feeders and underwent significant changes during the period 2010–2013.

Subjected for decades to increased pollution due to growing human activities in the surrounding area, Boughrara Lagoon now appears to be impacted by certain environmental/anthropogenic stressors, as indicated by the presence of pollution-tolerant bio-indicator species in the imbalanced area. The response of the lagoon ecosystem to changes in benthic sediment deposition provides a potential assessment tool for similar habitats elsewhere.

1. Introduction

Shallow coastal lagoons are frequently heavily stressed due to anthropogenic interference (Pérez-Ruzafa et al., 2011). This vulnerability may be exacerbated by natural constraints such as confinement and reduced access to the sea, as in the case of Boughrara Lagoon, Tunisia (southern Mediterranean). Sheltered by the Gulf of Gabes to which it is connected by the El Kantra (160 m wide) and the Ajim-Jorf Channels (2.2 km wide), the lagoon has a higher salinity level than the nearby sea (Abdenadher et al., 2012), ranging on average from 42.19 to 53.3 psu (Khedhri et al., 2015) due to evaporative concentration, with evaporation attaining an average of 147.22 mm in 2010 and 126.87 mm in 2013 (Khedhri et al., 2015). In addition, a considerable amount of organic matter is discharged into the lagoon waters in the harbours of Jorf, Ajim, Boughrara and Hassi Jalleba from aquaculture and other activities such as fishing boat traffic. Also, important quantities of phosphogypsum have been discharged for many years, affecting lagoon biodiversity (Ben Brahim et al., 2010; Drira et al., 2010; Rekik et al., 2012) by provoking repeated blooms of harmful dinoflagellates (Abdenadher et al., 2012). To date, monitoring efforts in Boughrara Lagoon have been focused on the deterministic factors of dinoflagellate blooms (Feki et al., 2013) and hydrology (DGPA: Direction Générale de la Pêche et de l'Aquaculture, 2001; Guetat et al., 2012), with no investigation of the ecosystem's general status being undertaken. Due to a lack of general research prior to the widening of the El Kantra Channel (2004–2007), no reports have appeared on sediment dynamics and grain size composition, or on benthic invertebrates known to be good indicators of the health status of ecosystems; inhabiting the sediment-water interface, such fauna are able to integrate any change occurring there (Warwick, 1986; Khattabi and Aleya, 2007; Blanchet et al., 2008; Extence et al., 2013). Marine sediment is, in fact, an essential part of aquatic life and acts as a receptacle for nutrients, heavy metals and pesticides (Köster and Meyer-Reil 2001; Zheng et al., 2014; Zaaboub et al., 2015). Surface sediment grain size and total organic matter (TOM)

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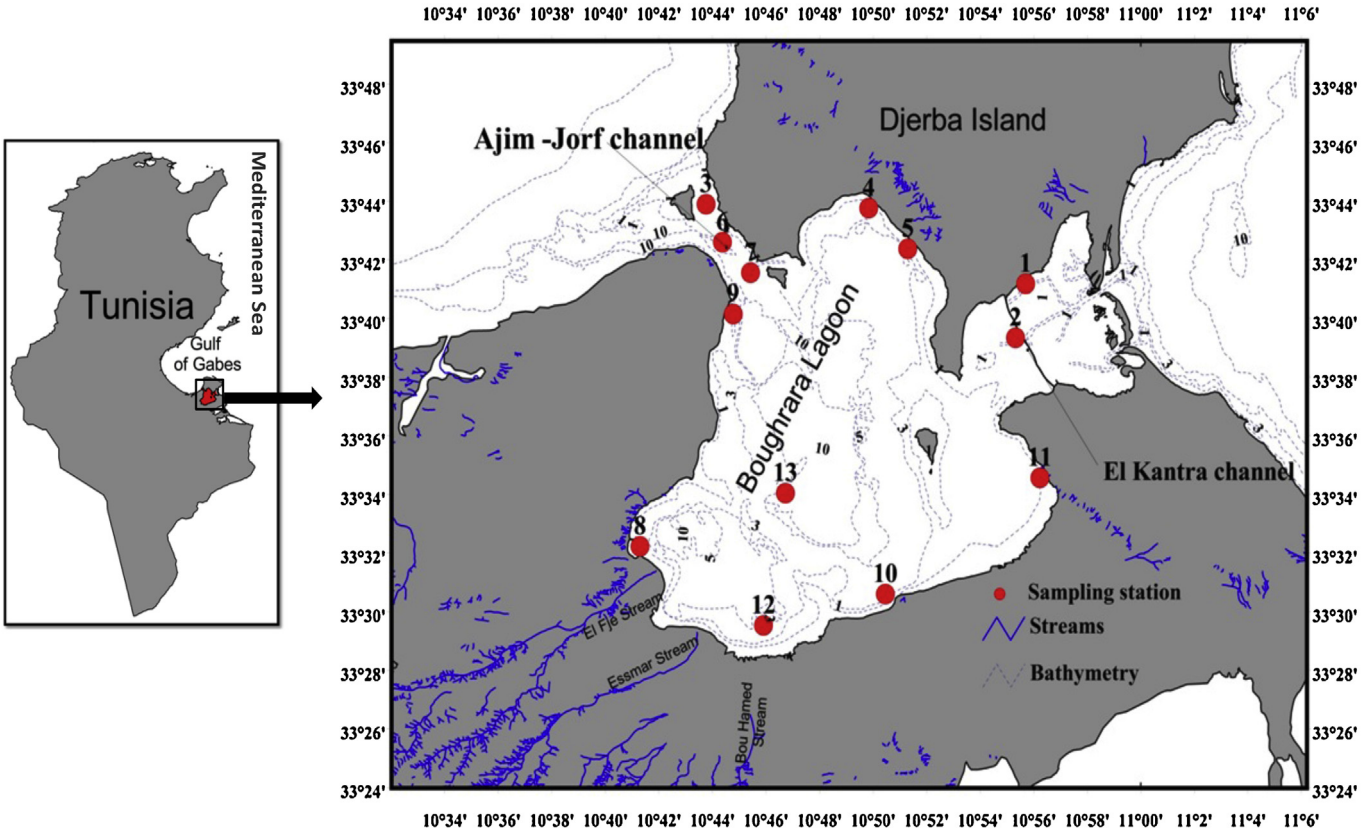

Fig. 1. Study area with location of sampling sites.

are thus considered to be potent tools in studying the structure of ecosystems and in detecting anthropogenic disturbance (Van der Lindena et al., 2016).

With the development of electronic techniques in the recent decades, models and Artificial Neural Network (ANN) (Chau and Wu, 2010; Muttil and Chau, 2007; Xie and Cheng, 2006; Wu et al., 2009) are considered crucial tools in the assessment of water quality and ecosystem health. However, the European Water Directive (WFD) also qualifies benthic invertebrates as potentially powerful indicators to be used in evaluating the ecological quality status (EcoQ) of surface and transitional (lagoons) water bodies (Khedhri et al., 2015; Lavesque et al., 2009). In fact, the sedentary lifestyle of these organisms (Dauvin, 1993; Patrício et al., 2012), their relatively long lifespans (Reiss et al., 2006) and high taxonomic and trophic levels increase their ability to evaluate accidental and chronic variation and to reflect fluctuations in disturbance gradients.

In the present study we analysed the sedimentary and hydrodynamic status of Boughrara Lagoon during the winters of 2010 and 2013, after widening of the El Kantra Channel improved water circulation within the lagoon and increased water exchange with the open sea. The size grading and sediment nature were assessed, and the mode of transport and conditions of surface sediment deposit were identified. Organic matter content was then estimated, along with the potential relationships between benthic macrofauna and sediment fraction distribution in the lagoon.

The present study is a continuation of the works of Khedhri et al. (2014, 2015) in the same lagoon. Here we have reported on the temporal variability of the benthic macrofauna and abiotic parameters during the seasons of 2009–2010 and have cited for the first time the presence of a new species of polychaetes in Tunisia. The novelty in our contribution is in its assessment of potential relationships between macrofauna communities and sediment fraction distribution so as to explain possible links with organic content matter and sediment grain size to create a useful reference for future similar studies.

2. Material and methods

2.1. Study site

Boughrara Lagoon (500 km^2) is located on the south-eastern coast of Tunisia in the governorate of Medenine (between 33°28′N and 33°45′N and 10°40′E and 10°57′E) and is delimited by Djerba Island on the north and by the mainland elsewhere (Fig. 1). The lagoon is connected with the Gulf of Gabes via the Ajim Channel to the north-west and by the El Kantra Channel at a point halfway along the Roman road that connects south-eastern Djerba Island to the mainland. El Kantra Channel, originally a narrow passage 12.5 m wide, was widened to 160 m between 2004 and 2007, thus increasing water exchange with the sea to about 6.9 million m^3 per day, instead of 0.8 million m^3 previously (DGPA, 2001). The lagoon's average depth is approximately 4 m, reaching a maximum of 16 m in the centre. Air temperature appears to play a very important role in Boughrara Lagoon as it has a strong and instant influence on water temperature (Feki et al., 2013).

The study area is characterized by seismic fault lines, especially in a NW-SE direction (Fig. 2). The area presents three main types of terrain: cliffs, coastal mountain range and delta; the basin has an elongation shape of factor 1.48. The climate is dry (average annual precipitation of around 210 mm/year) and sunny with strong easterly winds which transport particles into the sea (Brahim et al., 2014, 2015) and cause severe aeolian erosion. Surface water temperature varies widely with season, with an average of 24.7 °C in summer and 11.2 °C in winter, increasing along a north-south gradient (Feki et al., 2013). Salinity is very high, especially in summer,