BENTHIC MACROFAUNA ASSOCIATED WITH INTERTIDAL *ZOSTERA NOLTEI* BEDS IN ATLANTIC (ARCACHON BAY, FRANCE) AND MEDITERRANEAN ECOSYSTEMS (KNEISS ISLANDS, TUNISIA): COMPARATIVE STUDY

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ABSTRACT

The present study aim to compare between two distinct and distant geographical ecosystems; the Kneiss Islands and Arcachon Bay, which formed by extensive large mudflats with the intertidal *Zostera noltei* beds, hosted a greater diversity of waterbirds and provides socio-economic importance. In order to determine the response of benthic communities' structure and functioning to climate variation, the two eelgrass ecosystems constitute a natural laboratory to infer climate warming. The macrobenthic fauna community of *Zostera* (*Zosterella*) *noltei* beds in Kneiss Islands was studied by sampling 34 stations and 48 stations for Arcachon Bay. A total of 148 taxa were identified in Kneiss Islands and 117 species for Arcachon Bay, but only 23 species are common in the both separate ecosystems. Diversity, abundance and community structure are significantly different between the two study areas, could be explained by differences between Mediterranean and Atlantic climatic conditions and by anthropic factors (e.g. fishing pressure, pollution, nutrient inputs) present in each ecosystem. Multidimensional scaling (n-MDS) analysis identified two distinct geographical station groups on the basis of species and families abundance. Save that, three assemblages were identified between the separated ecosystems on the basis of trophic groups.

Key words: Kneiss Islands, Arcachon Bay, Benthic fauna, *Zostera noltei*, Climate change.

INTRODUCTION

Seagrass meadows are distributed in intertidal and subtidal shores from tropical and temperate areas (Green and Short 2003) and constitutes the important component of coastal ecosystems, with levels of primary production that are among the largest for submerged aquatic communities (HILLMAN *et al*. 1995), supporting rich faunistic communities (WILLIAMS and HECK, 2001). Seagrasses meadows like eelgrass beds forming beds that provide food and refuge for many commercial species and which enhance nutrient cycling, water quality, and sediment dynamics (AIROLDI and BECK, 2007).

Kneiss Islands (Gulf of Gabès, Tunisia) and Arcachon Bay (Atlantic coast, SW France) are two mesotidal bays where seagrass beds colonize the majority of intertidal areas (DO *et al*. 2012; MOSBAHI *et al*. 2015). The both ecosystems have an extensive intertidal mudflats traveled by tidal channels, a semi diurnal and high tide levels, but the hydro-climatic and latitudinal conditions are different.

Kneiss Islands (central Mediterranean) and Arcachon Bay (North-Eastern Atlantic) are two coastal ecosystems sharing many similar features. They both ecosystems extensive large mudflats covered with *Zostera noltei* meadows, alternating with a network of shallow tidal channels (DO *et al*. 2012; MOSBAHI *et al*. 2015). They host a great diversity of water birds species with different ecological requirements, and have consequently been recognized as Important Bird Areas (BIRD LIFE INTERNATIONAL, 2014). Also, the intertidal areas are both of ecological and socio-economic interests, especially for traditional activities (crustaceans fishing, bait digging, tourism,..). The question which arises concerning these two apparent analogous mesotidal ecosystems is: do the structure and functioning of the *Zostera noltei* meadows are comparable or not? So, the main aims of this study are i) to compare the macrobenthic community biodiversity associated with *Zostera noltei* intertidal seagrass beds in Kneiss islands and Arcachon bay; ii) to investigate the structural diversity of the benthic macrofauna based on taxonomic, trophic groups and ecological approaches; iii) to provide a reliable assessment of the general ecological status and 4) to identify the role of the main environmental factors that determine the benthic community structure and functioning.

MATERIALS AND METHODS

Sampling method

Sampling method is similar for the two study areas (Fig. 1). At low tide, the top 20-30 cm of the sediment was collected with a 0.0225 m^2 corer, with four replicates per station. 48 and 34 stations were sampled over spring campaign, respectively in Arcachon bay (2002), when the seagrass bed fully extended over the tidal flats (Blanchet et al., 2004)

and Kneiss islands, sampling was performed between 2013 and 2014. Sediment was sieved through a 1 mm mesh; the remaining fraction was fixed in 4% buffered formalin and stained with Rose Bengal. In the laboratory, macrofauna was sorted, identified to the lowest practical taxonomic level (usually species level) and counted.

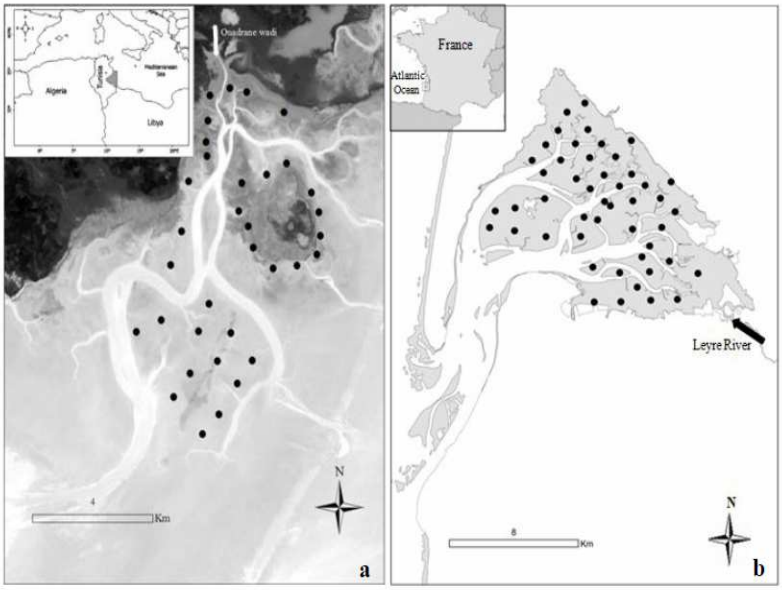

Fig.1. Study sites (a: Kneiss Islands; b: Arcachon Bay) showing the location of the sampling stations

Data analysis

Multivariate analysis was performed to compare macrozoobenthic communities' structure between both areas. Abundances were square root transformed to minimize the influence of the most dominant taxa (for species and families). A non-metric multidimensional scaling method (n-MDS) based on the Bray-Curtis similarity allowed to visually assess differences in macrofaunal assemblages among stations of the studied areas. SIMPER tests determined which species contributed to within-group similarity. These analyses were performed using PRIMER®-v6. A similarity matrix was constructed from the fourth-root transformed abundance data using the Bray-Curtis similarity measure; non-metric multidimensional scaling (n-MDS) ordination was then applied to assess the differences in trophic groups between both ecosystems.

RESULT

In Kneiss Islands, a total of 148 species were identified in 34 stations, which were unequally distributed among sampling stations. The number of species (S) varied between 22 and 64 species per 0.09 m², with a mean of 39. Abundance (A) varied from 9,200 to 36,800 ind.m^{-2} (with a mean abundance of 14,709 ± standard deviation = 900 ind.m^{-2}), equitability (J') from 0.79 to 0.92 (mean = 0.75) and Shannon index (H') from 3.5 to 5.2, with a mean of 4.4 bits ind^{-1} . For Arcachon Bay, 117 species have been identified in 48 stations. The mean number of species was 27.5, ranging from 8 to 49 species per 0.09 m². Abundance ranged between 1,700 and 64,000 ind. m^{-2}, with a mean abundance of 20,553 ± 2,100 ind. m^{-2}. Finally, equitability (J') varied 0.19 to 0.87 (mean= 0.72) and Shannon index (H') from 1.2 to 4.1 with a mean of 2.2 bits ind^{-1}. The average of S, J' and H' were higher in Kneiss Islands than in the Arcachon Bay (one-factor ANOVA; S: F= 24.85; p < 0.01; J': F= 125.7; p < 0.01; H': F= 149.7; p < 0.01). Abundance is similar in Kneiss Islands and Arcachon Bay (ANOVA; F= 3.39; p > 0.05). A total of 23 species were common in both ecosystems, i.e. 125 species had been recorded only in the Kneiss Islands site while 94 species were collected only in Arcachon Bay.

The MDS ordination plot based on species discriminated two different groups, one corresponding to Kneiss Islands and the other to Arcachon Bay (Fig. 2a). Both ecosystems were also clearly separated on the basis of clades (i.e. molluscs, arthropods, annelids,…) (Fig. 2b). Conversely, there were trends of similarity on the basis of trophic groups, three groups of stations were discriminated on based of trophic groups (Fig. 2c).

DISCUSSION

In the present study, a total of 232 taxa were recorded, associated with eelgrass beds, unequally

distributed among the sampling stations. In both sites, annelids and molluscs were the dominant groups. High species diversity and abundance of macrofauna

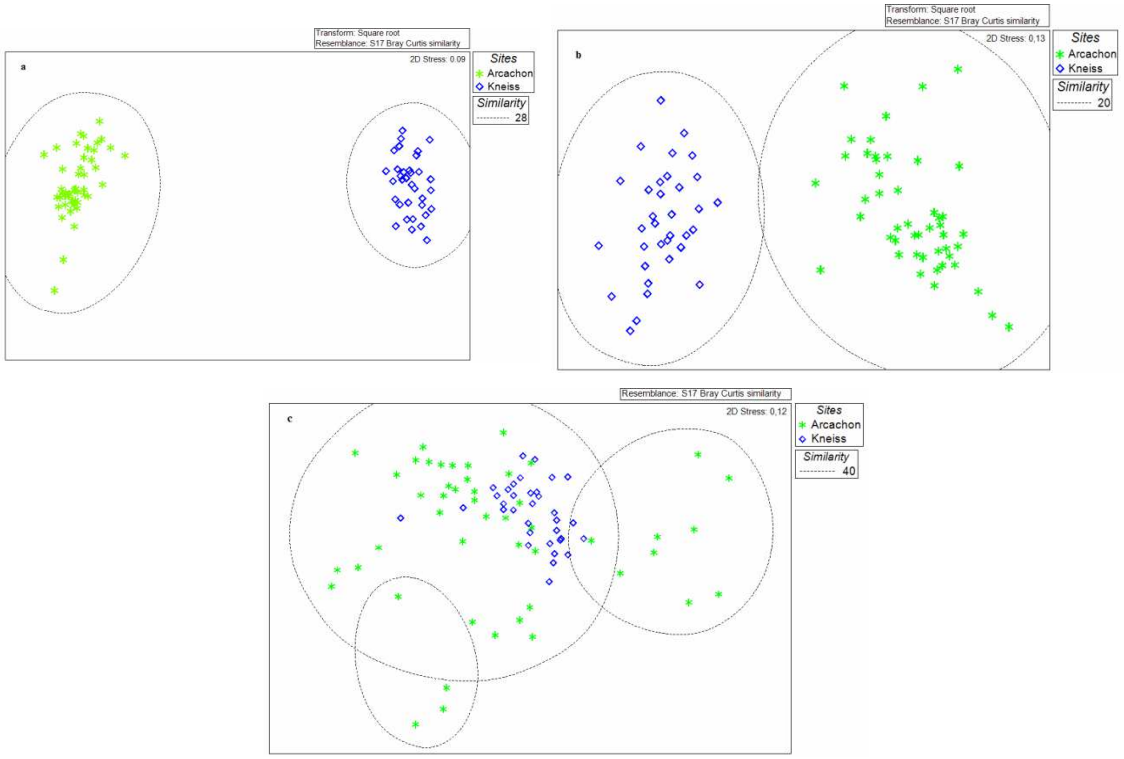

Fig. 2. Non-metric multidimensional scaling (n-MDS) of stations based on the Bray-Curtis similarity matrix for both ecosystems, Kneiss Islands and Arcachon Bay, on the basis of (a) species abundance, (b) family-level groups and (c) trophic groups.

are frequently reported in seagrass habitats (DO *et al*. 2012), compared to unvegetated sediments. *Zostera noltei* meadows increase habitat complexity and provide living space and shelter for a diverse animal community (DUFFY, 2006). In Kneiss Islands, 148 species have been identified and 117 species in Arcachon Bay, these values describing the γ-diversity of each site. 23 species were common in both similar ecosystems, indicating that, these species are still associated with *Zostera noltei* beds. Total number of species in Kneiss Islands site is higher on average than those of Arcachon Bay, even when taken into account the difference in sampling effort. Species-accumulation curve for Kneiss Islands stabilized around an asymptotic value suggesting a good assessment of γ-diversity. Conversely, a lack of asymptote in Arcachon Bay corresponded to an insufficient sampling effort to assess exhaustive diversity (Fig. 3).

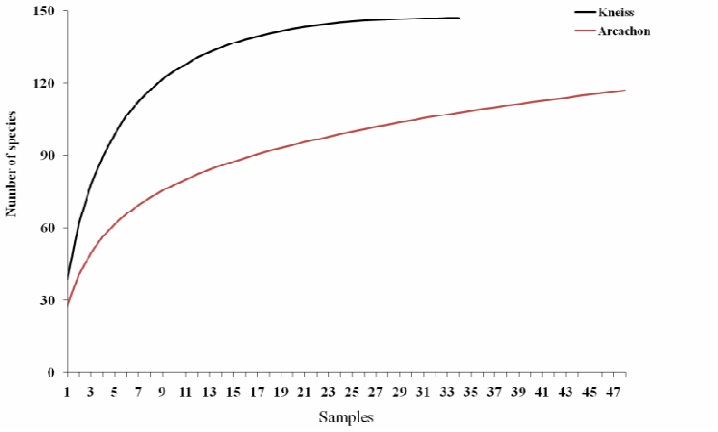

Fig.3. Species accumulation curve for benthic fauna of the Kneiss Islands and Arcachon Bay

The diversity differences between Arcachon Bay and Kneiss Islands is probably a response of human activities (e.g. fishing pressure, port and aquaculture activities, and nutrient inputs), environmental factors (sediments features, salinity) and different climatic conditions. In fact, the Gulf of Gabès is a semi-arid Mediterranean site, characterized by an arid climate (average annual precipitation: ≤ 200 mm year^{-1}) with higher temperature and salinity. Invertebrate's macrofauna in this inshore region is directly under the influence of salty and warm Mediterranean waters reputed for their high intrinsic diversity (COLL *et al*. 2010). General oceanographic conditions in the Mediterranean Basin have been previously described in detail (PINARDI *et al*. 2006). The Mediterranean Sea is of the sub-wet shade climate type. The summer is hot and dry, and the winter is cool and rainy. These general particularities and also some other regional characteristics, such as the fluctuations of floods, temperature and salinity give some specificities to the Mediterranean communities (SALEN-PICARD and ARLHAC, 2002). AFLI et al. (2009) affirmed that environmental conditions, particularly temperature and salinity, play a major role in the structure and the organization of the communities and the exclusion of certain species or groups of species in Mediterranean ecosystems. This explains why a majority of species is in Kneiss Islands only and why a MDS based on taxonomy drastically separated both sea grasses (Kneiss Island and Arcachon Bay).

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