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FULL LENGTH ARTICLE

Tolerance of benthic foraminifera to anthropogenic stressors from three sites of the Egyptian coasts

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Abstract Surely the coupling of natural and anthropogenic stressors combined with a lack of regulation resulted in the current threat to a large part of coastal marine biodiversity as well as coastal human societies, particularly in highly populated regions. The distribution pattern of benthic foraminifera as sensitive bio-indicator is utilized to assess human-induced impact on the coastal area, at Alexandria, Port Said and Suez cites of Egypt. Twenty-two benthic foraminiferal genera were identified and complied by principal component analysis into four factors through cluster analysis. Cross correlation of the generic composition, distribution and relative abundance of common genera in the three investigated cores revealed three different coastal environments entities. The categorized environment ranged from light human impact as Alexandria site to heavily impacted by human activities as Port Said and Suez sites. Fauna of Alexandria site reflects an increase in unpolluted water activity revealing high-energy erosive environment. The second entity involves Port Said site, which represents a highly stressed coastal environment, corresponding to high-energy transport conditions influenced by fresh water flush from local Manzala Lake via Bougaz El Gamel outlet while Suez site is influenced by marine hypersaline water coupling with intensified levels of industrial and domestic pollution, attributed to the anthropogenic impact.

Introduction

Benthic foraminifera are good ecosystem monitors due to the comprehensive information on their ecology from different marine environments, which provide many valuable clues to their ecosystems. In addition, they are abundant as they are widely distributed in all marine environments and relatively diverse populations, are durable as their tests are known to exhibit a high fossilization potential (Murray, 1991), and are easy to collect and separate from sediment samples. Benthic foraminifera represent a group of bottom-dwelling single-celled marine organisms, which either prefers to live at the sediment/water interface (epifaunal) or in the sediment (infaunal). Several studies used benthic foraminifera, as environmental variation factors that clearly impacted benthic foraminiferal distribution and frequencies, particularly productivity, bottom water oxygenation, thermo-haline structure of the water body and its bottom-water circulation (e.g. Duplessy et al., 1988; Mackensen et al., 1994; Hemleben et al., 1996; Schmiedl et al., 1998; Bickert and Wefer 1999; Badawi et al., 2005; Hamouda and Awad, 2012; Hamouda et al., 2014 and Badawi, 2015).

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The increasing destruction of natural habitats causes huge impacts to ecosystems across the globe (Roberts and Hawkins, 1999).

In Egypt, Intense coastal development and the inevitable consequence of economic progress, associated with improper management have been affecting the biodiversity of pelagic and benthic communities, followed by possible extinctions. Several studies were focused on coastal water pollution by trace metals, mainly resulting from disposal of industrial wastes, and agricultural runoff into marine water, (e.g. El-Sayed et al., 1979; El-Nady, 1996a,b; El-Rayis et al., 1997; Fahmy et al., 1997; Hamouda et al., 2014). Unlikely, little concern has been paid to the study of benthic foraminifera from the Egyptian coasts (e.g. Said and Kamel, 1954, 1957; Samir and El-Din, 2001).

The present work is devoted to study the coastal ecosystem along three studied sites (two sites along the Egyptian Mediterranean coast and one site from the Gulf of Suez) which presented independent geographic locations and consequently different environmental conditions, concerning mainly, wind intensity, sea-level changes and erosion. The regional comparison between the two sites located along the Mediterranean Sea and one site from Suez Canal indicates a distinct gradient in ecosystem and controlling factors.

Historically speaking, Red Sea and Mediterranean were linked through artificial Suez Canal, (constructed in 1869) and created the first salt-water passage between the Red Sea and Mediterranean allowing the faunal migration through it. Moreover, Egyptian Mediterranean coast recently suffered from severe erosion, in particular after the construction of Aswan High Dam in 1964 (Frihy et al. 1991; Hamouda and Abdel-Salam 2010; Hamouda et al., 2014). Significant coastal changes have been reported due to the reduction in the Nile sediment discharge, which diminished to near zero, combined with natural factors including delta subsidence, sea level rise and strong coastal current processes (Stanley, 1990; Stanley and Warne 1993 and Fanos et al., 1995). The objective of this study is to generate cross correlation of the coastal ecosystem variations along the three selected significant sites in Mediterranean coast and Gulf of Suez, in terms of the temporal distribution of benthic foraminifera to define the specific anthropogenic stressors influencing each ecosystem.

Study area

The studied areas include three sites, first site located along the Alexandria coast, at 31.28701°N, 30.0187°E, 15 m water depth, with a core recovery of 79 cm. Second site located Port Said coast, at 31.27858°N, 32.3268°E, 2.5 m water depth, with a core recovery of 80 cm. While the third one is located in Suez coast, at 29.88322°N, 32.60167°E, 15 m water depth, with a core recovery of 60 cm (Fig. 1).

Materials and methods

The recovered sediment cores were sampled at 5 cm intervals with the top 1 cm of each interval split separately for foraminifera study, with 37 sediment samples. For micro paleontological analysis, each sample (3–5) g of sediment was wet sieved through a 63 mm mesh sieve, and oven dried at 40 °C. Subsequently, the samples will be dry-sieved into the fractions < 125 mm and investigated for their benthic foraminiferal content. Benthic foraminifera genera were identified according to Loeblich and Tappan (1988), and counted with the aid of a binocular microscope. The recorded data sets are treated statistically and interpreted relative to environmental parameters to provide an image of the coastal bottom ecosystems in different locations. Relative abundance was calculated to facilitate the comparison of the data sets providing percentage of the most frequent genera with respect to the total numbers of benthic foraminifera in those samples.

Statistical methods (principal component analysis)

Multivariate statistical analyses (R-mode factor analysis and Q-mode cluster analysis) were applied to the statistically significant fractional abundance values. Statistically significant genera were considered as those with abundance $\geqslant 5\%$ even in one sample or 2% in at least 2 samples, (Schmiedl et al., 1998). Q-mode cluster analysis was performed by using Ward's method (Schubö and Ühlinger, 1986) using Euclidean distance as similarity index. Factor analysis is a multivariate statistical technique that is used to compile applied data set to a few main components (factors) that represent the relationship among sets of many interrelated variables.

R-mode factor analysis was carried out on the benthic foraminiferal data set, using the program Statistica, V.5.1 (1996).

Results

The sediments of the three cores consist primarily of gray to pale brown fine grain sediments with high carbonate content. Visually the lithological changes were minor along the studied cores., Alexandria short core is composed of a mixture of shell, shell fragments (mollusks and pelecypods), foraminifera and quartz grains of coarse sands size (typical buff color of Alexandria beach sands). While Port Said short core is composed of silts of gray color mixed with few pelecypod shells and shell fragments (typical of Nile Delta deposits). Port Said core is characterized by 3–6 cm thickness common with Pteropod ooze, pelecypod shell and shell fragments at 53 cm depth from the top of the core. Suez short core is composed of light gray mud mostly clays. There is no variation in the lithology of the core from top to bottom.

Foraminiferal populations mainly consisted of benthic species. Planktonic species were very rare, due to the shallow water in the investigated areas. Totally, 22 benthic foraminiferal genera were recorded in the investigated cores. Significant variations in benthic foraminiferal number and relative abundance have been recorded along the investigated cores, suggesting a geographic gradient of environmental conditions. In General, Benthic foraminiferal fauna primarily composed of porcellaneous and hyaline forms comprising of 73% and 27%, respectively. Alexandria core exhibits the highest dominance of foraminiferal population compared to the Suez one, which is considered moderate. Port Said core sediments are reported very poor in foraminiferal fauna with minor vertical variation. In Alexandria core, the predominant genera are *Quinqueloculina, Triloculina, Amphistegina*, *Elphidium*, *Adelosina* and *Peneroplis*. The benthic foraminiferal number is generally decreased from the core bottom to the surface samples, associated with a rather constant diversity, (Fig. 2). The