

## **Marine Geomorphology and environmental status of Elefsis Bay and inner Saronikos Gulf, Greece. A multidisciplinary analysis.**

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### **Introduction**

Saronikos Gulf is located in the Aegean Sea between Attica and eastern Peloponnese Peninsula and is considered as a hot spot site for the particular environmental conditions and sea floor morphology. Through the ages, the coastal areas surrounding the gulf were used for economic and strategic purposes, with the most important of these being the Piraeus port and Elefsis Bay. Both are located on the north eastern part of the gulf and are strongly linked to human activities since the beginning of the ancient greek civilization. The area holds a great geomorphological and environmental interest, due to the human intervention since the ancient times but also due to the various landforms and processes that form its amazing underwater and coastal landscapes. In addition, the industrial activities along the coast of Elefsis Bay in the north east of Saronikos Gulf, affect the ecosystems, leaving traces of human activity that impacts the environmental status of the inner Saronikos Gulf.

Foraminifera are one of the most spread and diverse group of meiofauna. Especially benthic foraminifera are commonly used as bio-indicators of both natural and human-stressed environments and are increasingly used in environmental monitoring in coastal and marginal marine ecosystems (e.g., Dimiza *et al.*, 2016a, b).

### **Objectives**

The main aim of this study is to create bathymetry maps in order to record the coastal and marine geomorphology of the gulf and to show the dynamic evolution of the coastline for the past 11.500 years. In addition, the study of foraminiferal thanatocoenoses in relation with their bathymetric distribution aims to relate the marine landforms with the recent processes and environmental conditions and efficiently describe the environmental profile of the area.

### **Materials and methods**

For the creation of the bathymetry map we used a combination of data collected from field studies and available archive data from the Hellenic Center for Marine Research (HCMR) and the Institute of Geology and Mineral Exploration (IGME). Gis techniques (ArcGis from ESRI) were used to record the bathymetry of the gulf. Concerning the foraminiferal analysis, sediments were collected as small push-cores (mean depth about 10 cm) from box corers onboard the R/V Aegaeo from 12 sampling stations, four in Elefsis Bay and eight in Saronikos Gulf in February 2016, at water depths ranging from 15 to 95 m. Surface sediments (0-1 cm) from each station were collected and were immediately stained with rose Bengal dissolved in 70% ethanol (2g l<sup>-1</sup>) to facilitate the distinction between live and dead foraminifera. Approximately 2g of each sample was washed in the laboratory and sieved over 125µm and 63µm mesh and oven dried. A total of up to 300 not stained (dead) handpicked benthic foraminifera for each sample were obtained using an Otto microsampler. All subsamples were examined under a Leica APO S8 stereoscope, following Cimerman and Langer (1991), Dimiza *et al.* (2016a), Milker *et al.* (2009) and Sgarrella and Moncharmont Zei (1993) for species classification and species relative abundances have been calculated. Proportional Similarity (PS) between the species composition of dead and living foraminiferal associations was calculated using the Renkonen index (Renkonen, 1938).

### **Results – Discussion**

The benthic foraminiferal assemblage structure (*H'* index) and the ecological quality classification tool, Foraminiferal Stress Index (FSI) as plotted in the georeferenced maps indicated an environmental amelioration for Inner Saronikos Gulf; e.g., upgrade of Ecological Quality Status (EcoQS) from moderate to good quality during the investigated time interval 2012-2016. In contrast, the central part of the Elefsis Bay evidenced an on-going poor environment status throughout the monitoring period. As this part of Saronikos Gulf is experiencing severe oxygen depletion due to limited water circulation during summer, further sampling during the summer period is needed to explore any seasonal difference that can be recorded in the foraminiferal assemblages.

A low-diversity assemblage, dominated by stress-tolerant *Ammonia tepida* and *Bulimina* spp., was characteristic of samples from Elefsis Bay. Samples from the western and central part of Saronikos Gulf were the most variable, characterized by a mix of stress-tolerant and more sensitive taxa, especially *Bulimina* spp. and *Nonion fabum*. In contrast, samples from the coast of Salamis and at the eastern sector of the gulf were characterized by a diverse assemblage that mostly included miliolids and small, epiphytic rotaliid taxa, and the dominant species *Haynesina germanica* and *Bulimina aculeata*.

According to the foraminiferal distribution, it appears that north east Elefsis Bay the high levels of *Bulimina* spp. indicate

periods of anoxic events along with eutrophic conditions while western and central Saronikos is more variable with areas affected by stress and low oxygen periods in the south east of Salamis island and less stress environments in the north east of the island. In the shallow shelf environments of the Mediterranean Sea, the main environmental parameters affecting the distribution pattern of the benthic foraminifera are temperature, salinity and substrate type (Basso and Spezzaferri, 2000; Hyams-Kaphzan et al., 2008; Milker et al., 2009; Samir et al., 2003). Several ecological studies have demonstrated that the environmental variables controlling the distribution pattern of benthic foraminiferal assemblages vary with water depth (e.g., De Rijk et al., 2000; Rossi and Horton, 2009), while Milker et al. (2009) showed distinct benthic foraminifera bathymetric zonation linked to substrate, water turbulence and food availability. According to Dimiza et al. (2016a) several environmental conditions impact on the taphonomic processes. The studied assemblages provided us concerning the relation of dead fauna and bathymetry when considering Renkonen index. The calculated PS exhibited high degree of similarity with an average value of  $PS = 67 \pm 6.8$  in Elefsis Bay and intermediate similarity values with an average of  $PS = 31 \pm 5.9$  in the inner Saronikos, suggesting negligible transport processes in the shallower parts of the gulf.

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