ECOSYSTEM APPROACH AND ECOLOGICAL QUALITY MONITORING IN THE COASTAL WATERS OF RHODES ISLAND (EASTERN MEDITERRANEAN, GREECE)

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ABSTRACT

During the last decades of the 20th century, the coastal environment of Rhodes Island (SE Aegean Sea) went under notable changes on land use. Recreational, industrial and urban activities have been placing pressure on the sustainability of the coastal zone. The implementation of the EU Water Framework Directive (2000/60/EC) gave us the opportunity to have an overall evaluation of the environmental status of the coastal waters of Rhodes Island using the Biological Quality Elements “macroinvertebrates” (zoobenthos) and “macroalgae” (phytobenthos), in correlation with chemical parameters and the Land Use Simplified Index (LUSI).

The zoobenthic communities of Rhodes Island showed an overall good environmental quality status around the island. A slight ecological quality decline was defined only in stations under anthropogenic stress (port, waste water treatment plant, highly touristic areas). This comes in accordance with the higher organic matter found on the sediment for the stations in proximity to Rhodes port and surrounding area. Additionally, the results of the phytobenthic communities monitoring revealed the impact of the waste water treatment plant on the NE coast of Rhodes. The result of the correlation between the LUSI index and the Ecological Quality Status showed that three out of six water bodies of the island are in the “good” class, two in "high” class and one in “moderate” class.

Keywords: WFD, zoobenthos, phytobenthos LUSI, Rhodes Island, Eastern Mediterranean

1. Introduction

During the last decades, the environment of Rhodes has been under major changes and due to its geographical position has been attracting coastal environmental scientific research (Pancucci-Papadopoulou *et al*., 1992). Recreational activities, new industries and human activities on urban and suburban areas of the island have been dramatically increasing since the 1960’s and therefore impacting the coastal zone.

Tourism and the tremendous urban growth, especially on the northern part of the island, have been putting pressures on the coastal zone of Rhodes. New Marinas, the sewage Waste Water Treatment Plants (WWTP) and the new tourist facilities were the major factors that altered the natural environment of the island during the last two decades. The coastal zone of Rhodes becomes densely populated during the touristic season from April till late October when the number of inhabitants is doubled (EL. STAT., 2007). Surface waters are under higher pressure because the demand for waters of good quality is increasing, while at the same time anthropogenic activities lead to the downgrade of the water quality. In some cases, water from WWTP is not completely treated, but released directly into the sea leading to higher organic matter accumulation.

The Water Framework Directive (WFD 2000/60/EC) was set by the European Union in order to protect the coastal environment of all member States (EEC, 2000) and includes for the first time the term “Ecological Quality Status”, meaning that it uses the biological component for the evaluation of the environmental status of an area and does not depend only on the prevailing physicochemical conditions. Thus, zoobenthos, phytobenthos and phytoplankton are used to estimate the ecological quality status of an area since these are more stable in time and space and can provide more accurate and reliable data and conclusions (Borja *et al*., 2009). Macrozoobenthos is agreed to be the most important component of estimating the Ecological Quality Status (Simboura *et al*., 2015). The implementation of the Directive is obligatory for all member countries and are all enforced to achieve Good Ecological Quality Status in their waters by 2015.

2. Materials and methods

Zoobenthic data were obtained from a 10 year sampling period (2003, 2004, 2009) (ELKETHE, 2004, 2009),2010 (Louizidou, 2011) and 2012 (ELKETHE, 2013) in various stations around Rhodes (Figure 1) depending on their proximity to disturbance (Table 1).

Figure 1: Sampling stations on Rhodes Island.

Table 1: Information of the study area

Sampling Station	Disturbance factors
R1	Port
R2	WWTP
RF, R3, RX, R4, R5.	Touristic area
R6	Natura2000 protected area
R8	Port
R9	Electric Power Plant
R10	Fishing ground/touristic area

Soft bottom benthic fauna samples were collected from stations around Rhodes, providing an efficient number of samples to estimate the ecological quality status. Professional boat seines and the R/V ALKYON of the Hydrobiological Station of Rhodes department of the Hellenic Centre for Marine Research were used for the sampling. Samples were collected by a Smith McIntyre grab (surface 0,1 m^2), or a Ponar grab (surface 0,045 m^2) from 20 m depth. All samples were sieved on board on a 1 mm sieve then preserved in 4% formaldehyde, sea water and Rose Bengal until further identification to species level at the laboratory. Qualitative and quantitative data were processed by PRIMER 6 software (Clarke and Gorley, 2006) in order to calculate biological parameters such as H’ (Shannon & Weaver, 1963), Pielou evenness (J’) (Pielou, 1966) and species richness (S). The biological quality elements for the Mediterranean were classified after the intercalibration exercise (GIG, 2013) and the methodologies applied used BENTIX (Simboura & Zenetos, 2002) for zoobenthos. BENTIX Index uses the percentages of three ecological groups of species, grouped according to their sensitivity (GI group) or tolerance to stress (GII and GIII group) and estimates the ecological quality of the study area.

$$BENTIX= [(6x\%GI)+2x(\%GII + \%GIII)]/100$$

Regarding phytobenthos, five sampling locations at the upper infralittoral zone were chosen along the rocky shores of Northern Rhodes and one on the NATURA2000 protected area (SW of the island). Seasonal samplings were carried out for each location (2003, 2006, 2009, 2011 and 2014). Macroalgal samples were collected by free diving from almost horizontal rocky surfaces, 30-50 cm below the lowest water level. 20cm x 20cm quadrats were scraped off at each site (“destructive” sampling). Samples were analyzed by identifying species presence and by estimating their vertically projected coverage. Evaluation of the ecological quality status based on macroalgae was performed by the use of the Ecological Evaluation Index (EEIc) (Orfanidis *et al*., 2011).

Physicochemical and CTD data were collected for the years 2003 – 2009. Granulometry and grain size analysis was performed for sediment samples (Folk, 1954) and organic matter on the sediment was estimated by Loss on Ignition (Nelson & Sommers, 1982). Furthermore LUSI (Land Use Simplified Index) was calculated based on Corine Land Cover 2000 and using GIS software. Rhodes Island was split into 6 water bodies according to the river basins on the Island. For each water body, percentages of land use per category (urban, agricultural and industrial) were calculated, within 1500 m from the coastline, then, scored according to Flo *et al*. (2011) and multiplied by a factor depending on the morphology of the coastline. A prototype five-color scale of LUSI index (Lampou, 2012) was used in order to have a better imprinting of the results.

3. Results

3.1. BENTIX & EEIc

The samples from the eastern sites showed lower diversity values (RΦ, R3, RX, R4, R5, R6), that could be attributed to the increased touristic activities on the area during the summer and to the lower sorting coefficient of the sediment. On the other hand, higher diversity values were measured at the NW sites (R8, R9, R10, R1 and R2). Higher sorting coefficient, higher organic content values and algal meadows, provide more niches for the benthic organisms, increasing diversity. Diversity (H’) showed a slight decline during the period 2003 – 2010 (Fig. 1). BENTIX index showed that the ecological Quality status of Rhodes was Good and High for all stations in 2004, while in 2009, one station was downgraded to Moderate (Ialysos) (fig 2). Subsequently, in 2010 six out of eleven stations (R1, R2, R3, R8, R9 and R10) were characterized as of Moderate Quality Status, with R1, R2, and R10 having the higher organic matter measured in the sediment. Four out of eleven stations (RF, RX, R4 and R6) were classified in Good Quality Status and only R5 as of Hig, probably due to the high Amphipods abundance that was identified at that station (Fig. 2). When it comes to phytobenthos, mean data revealed Good quality status for three stations, High quality for two stations and only the station near the Port of Rhodes showed Moderate quality status (Figure 2).. No differences were noted in regards with time, from 2003 until 2011.

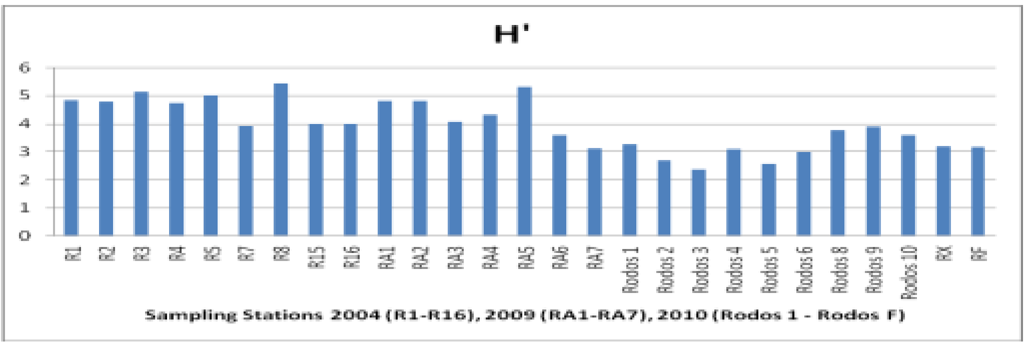

Figure 1: Diversity H’ values for the years 2003 – 2010

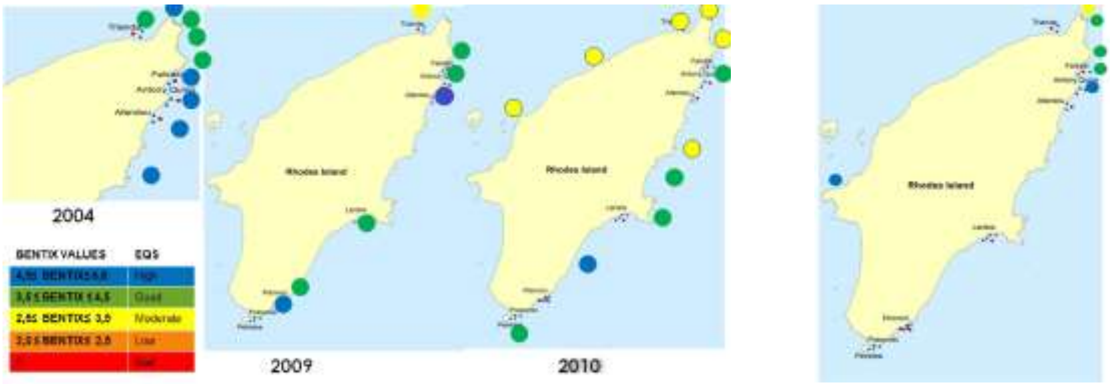

Figure 2: BENTIX results for the years 2004, 2009 and 2010 and mean EEIc values.

3.2. LUSI index

LUSI index values for the water bodies of Rhodes Island varied from good to poor (Fig. 3). The increased values of LUSI index in the 6th and 5th water bodies could be attributed to the presence of the city and the port of Rhodes and the settlements of large numbers of tourists in summer, respectively. Subsequently, LUSI index showed good correlation with BENTIX index. Specifically, was observed that the BENTIX values were increased as the LUSI values were reduced implying that the biological status was higher in water bodies that did not receive significant human pressures.

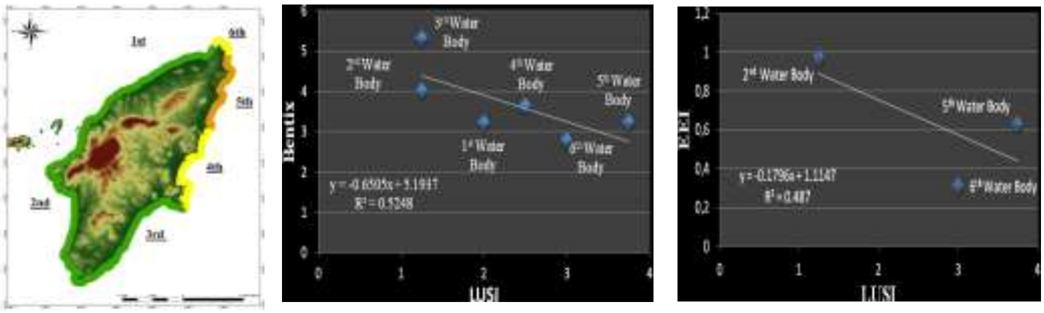

Figure3: LUSI index for the water bodies of Rhodes and correlation with BENTIX and EEIc

3.3. Physicochemical data

Mean temperature for the summer was 24° C and 16,8° C for the winter (www.poseidon.hcmr.gr), while salinity ranged from 39,35 and 39,6 PSU respectively. All sampling stations were sandy (Table 2) and the sorting coefficient was higher for the stations on the NNW, compared to the ones on the SSE of the island. Higher organic matter was 0,075 and measured at R10, followed by R2 (WWTP) with 0,039.

Table 2: Granulometry and Organic matter results

	R1	R2	RΦ	R3	RX	R4	R5	R6	R8	R9	R10
Mean grain Size (μm)	222 Fine Sand	225,7 Fine Sand	169,7 Fine Sand	1622,3 Very Coarse Sand	149,7 Fine Sand	266,6 Medium Sand	91,85 Very Fine Sand	174,7 Fine Sand	119,9 Very Fine Sand	134,4 Fine Sand	280,2 Medium Sand
Sorting coefficien t (μm)	2,051 Poorly Sorted	2,994 Poorly Sorted	1,486 Moderately Well Sorted	1,665 Moderately Sorted	1,653 Moderatel y Sorted	1,671 Moderately Sorted	1,471 Moderately Well Sorted	1,539 Moderately Well Sorted	3,310 Poorly Sorted	5,719 Very Poorly Sorted	6,401 Very Poorly Sorted
LOI	0,027	0,039	0,014	0,014	0,022	0,013	0,013	0,013	0,04	0,036	0,075

4. Discussion

Rhodes environment and coastal zone has been under high pressure since 1990's when the recreational and tourism activities started to grow exponentially. The EU established the WFD in order to estimate the ecological quality Status of the waters of every member state and protect them. The overall ecological quality status of the coastal environment of Rhodes was characterized as of Good Ecological Quality Status. Based on zoobenthos, exceptions included some local stations with specific impacts, in particular, the Port and new Marina of Rhodes, the WWTP, and Ialisos, a very touristic area of Rhodes. These results were also confirmed by the organic matter values on the sediment surface. However, the ecological Quality Status evaluation based on phytobenthos showed an overall Good Quality Status and remained stable over time. Based on zoobenthos results, for the years, 2003 – 2010 and for the stations Rhodes port, Ialysos bay (NW) and Faliraki (NE), only the last one remained at the same ecological quality characterization (Good), while the other two, were slightly downgraded (from Good to Moderate) suggesting a disturbance at the ecosystem over time. Regarding LUSI index, it showed a good correlation with BENTIX index revealing that the local pressures are affecting the coastal environment of the Island.

5. Conclusion

In conclusion, the Ecological Quality Status increases away from the urban area of Rhodes and the overall Ecological Quality of the island is Good with few problematic points. Thus some management actions need to be performed, following the "Management Action Plan for Water Bodies of Greece and Aegean islands (GR14)" (ΕΓΥ, 2015). Further monitoring is necessary to assess if the ecological quality upgrades to a higher quality status.

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