Seasonal Variations of Water Quality and Aquatic Macrophytes Survey based on Side Scan Sonar, in a Shallow Coastal Lagoon (Gialova, SW Peloponnesus, Greece)

Papakonstantinou M.[1,2], Papatheodorou G.[2,*], Christodoulou D.[2], Papastergiadou E.[1]

[1] Department of Biology, Section of Plant Biology, University of Patras, 26504 Patras, Greece.

[2] Laboratory of Marine Geology and Physical Oceanography, Department of Geology, University of Patras, 26504 Patras, Greece.

*corresponding author: e-mail: gpapathe@upatras.gr

Abstract

Gialova lagoon is located in the north-west of Pylos city (Prefecture of Messinia, SW Peloponnesus) and is part of the Ecological Network "Natura 2000". The aim of the current research is the assessment of the ecological quality of the lagoon using hydroacoustic technique and the monitoring of abiotic and biotic parameters on seasonal basis. Side scan sonar imagery resulted in 6 different lagoon floor acoustic types which correspond to different percentage of vegetation cover. Samplings of aquatic vegetation were carried out from 9 different sampling stations oriented by the results of the hydroacoustic survey. Macrophytes *Ruppia cirrhosa* and *Cymodocea nodosa* but also chlorophyte *Cladophora glomerata* were recorded in the lagoon floor. Key water quality parameters and primary production (Chlorophyll-a) were monitored seasonally at nine stations. Chl-a and TP seems to be the main responsible parameters for the eutrophic ecological status of the lagoon.

Keywords: Lagoon, side scan sonar, macrophytes.

1. Introduction

Coastal lagoons are important aquatic ecosystems with high ecological value. According to the Directive 92/43/EE, they have been defined as a priority habitat type.

Hydroacoustic methods developed for macrophyte surveys include the use of horizontally-aimed side scanning sonar systems for delineating macrophyte beds (Moreno et al., 1998) and vertically-aimed echo sounders for quantifying vegetation height and density (Sabol et al., 2002). So far, few studies have been done on the influences of epibenthic fauna and flora in acoustic backscatter. Some of them revealed successful results (Papatheodorou et al 2012, Christia et al. 2014), whereas others revealed that acoustic systems failed to discriminate biological assemblages (Hutin et al 2005).

The extremely shallow waters (<1.0 m) of the Gialova lagoon and the monotonous fine-grained sediments covering it's floor, introduce even more difficulties in the hydroacoustic detection and discrimination of the submerged vegetation and the lagoon floor texture.

2. Survey design and methods

The acoustic data were collected during a reconnaissance survey, utilizing an acquisition software of Edgetech 4100P topside recording unit with a dual frequency (100 and 500 kHz) EG&G 272 TD side scan sonar towfish for the seafloor insonification and a Magellan NAV 6500 Global Positioning System (GPS). Triton Map (Triton Imaging Inc.) software was used for the generation of the floor's mosaic, which was performed at 0.5 m resolution. Based on the side scan sonar information and the classification of side scan sonar data in six (6) distinct echo types, nine (9) ground truth sites were selected.

Depth (m) and transparency (Secchi disk) were measured in situ, in order to determine the amount of light reaching the plants. Temperature (°C), salinity (‰), DO (mg/l) and pH were measured with portable multiparameter instrument (YSI 556 MPS).

Surface water samples were collected and preserved at 4 °C for laboratory analysis of nutrient**s** [NH_4-N, NO_2-N, NO_3-N, PO_4-P, Total Phosphorus (TP)] and Chl-a concentrations (APHA, 1989). Water samples were filtered using 0.45 μm pore size filters for the dissolved nutrients analysis and Chl-a pigment extraction took place in the retained material with 90% acetone (APHA, 1989). Dissolved Inorganic Nitrogen (DIN) was calculated as the sum of the inorganic nitrogen forms.

2. Results

2.1. Acoustic mapping of lagoon floor

Side scan sonographs were ascribed to six echo types (ET) of the lagoon floor based on the consideration of their backscatter intensity and homogeneity, their extent and the configuration of their limits.

The side scan sonar survey used to illustrate the presence, spatial distribution, extent and growth of submerged macrophytes in the deepest parts (0.8 -1.0 m) of the lagoon. With the application of this hydroacoustic technique, about 37% of the lagoon substrate/ bottom was systematically mapped.

The ET1, 2, 3 and 4 showed a patchy pattern which is consisted of high reflectivity patches in a low reflectivity background. The patchy pattern was more intense on the types ET1 and ET2 followed by ET3 and ET4. The patches of ET2 show higher reflectivity than those of ET1, 3 and 4. Ground-truthing (sampling) procedure showed that ET1, 2 and 3 represent areas covered by *Ruppia cirrhosa* (dominant species) and *Cymodocea nodosa* with coverage of 76-100%, 51-75% and 26-50%, respectively, of the lagoon's bottom. ET4 presents areas covered mainly by *Ruppia cirrhosa* and occasionally by *Cladophora glomerata* with coverage of 6-25%. ET1, ET2 and ET3 are restricted to relatively small areas close to the communication channel of the lagoon with the Navarino Gulf, covering only the 2.2%, 0.9%, and 3.0% of the studied total area, respectively. ET4 is located mainly at the central part of the lagoon and it covers the 15.4% of the studied area.

ET5 presents small and very sparse distributed areas of high reflectivity confined by distinct and sharp limits. The presence of acoustic shadow zones suggests that the small areas are elevated compared to the surrounding floor. Ground-truthing data revealed that ET5 represents lagoon's bottom with very sparse (1-5%) vegetation (*Ruppia cirrhosa*) covering 3.6% of the survey area. ET6 shows a monotonous low reflectivity pattern that represents smooth and featureless floor consisting of sandy and sandy mud sediments (Bouzos et al., 2002). In total, the lagoon floor is covered by vegetation at 25%, while 75% is not colonized by any kind of aquatic vegetation (ET6).

2.2. Environmental condition of the lagoon

The results of physicochemical parameters of water column showed spatial and temporal variability of all parameters, and the most significant fluctuations were observed in temperature, salinity and in nitrogen and phosphorus concentrations.

In accordance with the standards set by the Organization for Cooperation and Development (OECD) for stagnant water, the trophic status of the lagoon has been established, on the basis of the average and maximum values of parameters: TP, Chl-a and transparency (Secchi depth) (OECD, 1982). On the basis of the average concentration of total phosphorus, it is characterized as hypereutrophic in summer and as eutrophic in spring. As regards the Chl-a, on the basis of the average and maximum values occurred in summer, the lagoon is characterised as eutrophic, while in spring it is characterized as eutrophic, based on the average value, but as mesotrophic, on the basis of the maximum value recorded. Finally, with regard to transparency, in accordance with the average and minimum values, the lagoon is characterized as hypereutrophic in both seasons.

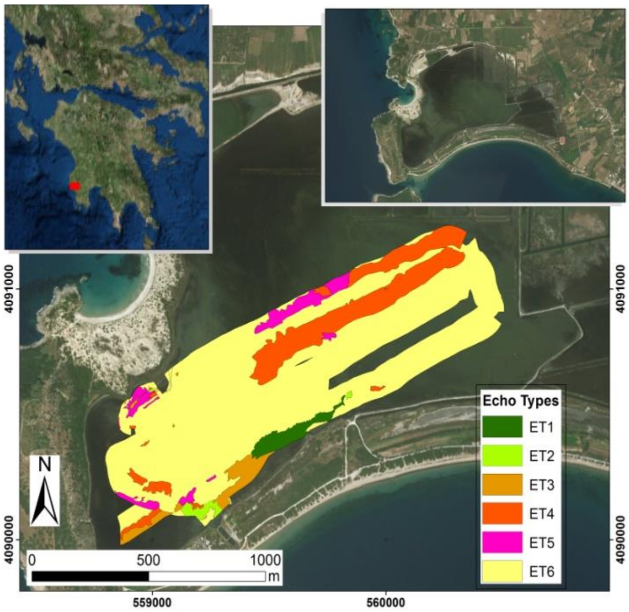

Figure 1. Map showing the spatial distribution of the six Echo Types (ET) in Gialova lagoon.

References

APHA (1989), Standard methods for the examination of water and waste water. In: *American Public Health Association*. 18th Edition. N. York.

Bouzos D., Kontopoulos N., and Avramidis P., (2002), Sedimentological observations in Gialova lagoon (NW Peloponnesus), 6th *Panhellenic Geographical Conference*, 255-262.

Christia C., Papastergiadou E., Papatheodorou G., Geraga M., and Papadakis, E., (2014), Seasonal and spatial variations of water quality, substrate and aquatic macrophytes based on side scan sonar, in an eastern Mediterranean lagoon (Kaiafas, Ionian Sea). *Environmental Earth Science* **71**(8): 3543-3558

Hutin E., Simard Y. and Archambault, P., (2005), Acoustic detection of a scallop bed from a single-beam echosounder in the St. Lawrence. *ICES Journal of Marine Science*, **62**:966-983.

Moreno A, Siljeström P, and Rey J (1998), Benthic phanerogam species recognition in side scan sonar images: Importance of the sensor direction. In: Proceedings of the *4th European Conference on Underwater Acoustics*. Italian National Research Council, Rome, Italy: 173-178. Alippi, A. & G. B. Canelli (eds).

Sabol B.M., Melton R.E., Chamberlain R., Doering P., and Haunert K. (2002), Evaluation of a digital echo sounder system for detection of submerged aquatic vegetation. *Estuaries* **25**:133-141.

Papatheodorou G., Avramidis P., Fakiris E., Christodoulou D., and Kontopoulos N., (2012), Bed diversity in the shallow water environment of Pappas lagoon in Greece. *Int. J. Sediment Research*. **27** (1):1-17.