A MULTIVARIATE PROCEDURE FOR THE DISCRIMINATION OF EUTROPHIC LEVELS IN COASTAL MARINE ECOSYSTEMS

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Abstract

A methodological procedure for eutrophication assessment at a spatial scale is proposed using numerical classification. The values of five ecological indices (number of species, Menhinick's, Odum's, Margalef's, Evenness) describing the phytoplankton community structure in Saronicos Gulf, Greece were calculated and their horizontal distributions were developed. The simulated data produced were used for the classification of the trophic state of the subareas of the Gulf. A stepwise description of the methodology is given and the advantages of the procedure in coastal studies are discussed.

Key-words: eutrophication, GIS, phytoplankton, bio-indicators, Aegean Sea

Introduction

A number of studies has already been carried out to quantify eutrophication using parameters describing the eutrophic conditions such as nutrient, chlorophyll-*a* concentrations and phytoplankton cell number [1, 2]; in addition the use of ecological indices has been proposed [3, 4] for assessing water quality. However, most of these studies don't consider the spatial distribution of the parameters examined and as a consequence the trophic conditions in coastal areas cannot be clearly discriminated. The parameters that describe eutrophication show different horizontal distributions and therefore, all the information they incorporate has to be taken into account if a general assessment of the eutrophic level of the coastal water body is required.

In the present work, a methodological procedure is proposed for eutrophication assessment at a spatial scale based on the horizontal distributions of five ecological indices (number of species, Menhinick's, Odum's, Margalef's, Evenness) describing phytoplankton community structure. Methods of digital cartography were applied for the development of five thematic maps and the simulated data from these maps were used for classifying the trophic levels by cluster analysis. A case study was performed in Saronicos Gulf, Greece and the different areas of the Gulf were assessed as far as their trophic levels are concerned using the proposed methodological procedure.

Material and methods

Study area and source of data. The present work is concerned with the inner Saronicos Gulf, Greece a relatively shallow basin (maximum depth 100m) which receives sewage effluents from the metropolitan area of Athens. The sources of data have been described in previous publications [5] as well as the study area and the location of the sampling sites [6]. The mean values for each ecological index during the stratification period (April-September) were calculated and are shown in Table 1. The indices used were [7] the number of species (S), the Menhinick's index [$D_{Mn}=S/\sqrt{N}$], the Odum's index [$D_{Od}=(Sx1000)/N$], the Margalef's index [$D_{Mg}=(S-1)/\ln N$] and the Evenness index [$E=H'/H$], where N stands for the phytoplankton cell number (cells/l), H'for the sample diversity and H'_{max} for the maximum sample diversity.

Table 1 : Mean values for the phytoplankton cell number (N) and the ecological indices (S : number of species, D_{Mn}: Menhinick's index, D_{Od}: Odum's index, D_{Mg}: Margalef's index, E:Evenness index) during the stratification period (April-September) in the sampling station.

Samp. Stations	S	N	D_{Mg}	D_{Mn}	D_{Od}	E
1	25	1484919	1.680	0.025	0.02	0.28
2	24	1635705	1.680	0.030	0.06	0.36
3	14	197644	1.095	0.057	0.40	0.46
4	16	302134	1.230	0.045	0.22	0.43
5	20	444945	1.520	0.042	0.13	0.35
6	14	197968	1.130	0.038	0.10	0.36
7	18	347708	1.380	0.043	0.18	0.34
8	18	449577	1.320	0.037	0.11	0.32
9	15	502245	1.140	0.043	0.27	0.29
10	40	$1.4x10^9$	1.900	0.001	0.01	0.28
11	40	$1.15x10^9$	1.900	0.001	0.01	0.28
12	16	117405	1.300	0.060	0.40	0.47
13	15	84490	1.310	0.080	0.66	0.61
14	14	74087	1.150	0.070	0.37	0.59
15	-	-	-	-	-	-
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	17	1708041	1.340	0.050	0.31	0.49
19	20	214015	1.710	0.080	0.46	0.65
20	14	106238	1.420	0.100	1.05	0.69

Data analysis. The generation of the spatial distributions of the five ecological indices was based on the application of the Inverse Distance Weighted interpolation method [8, 9]. This method was applied on the data of Table 1 with a spatial resolution of 100x100m using the program Arc/Info, version 7.0.2 (ARC/INFO-Environmental Systems Research Institute, Inc). Therefore, the study area was represented by a grid / surface for each one ecological index.

The next step of the methodology developed was the division of the study area into 22 sub-areas, approximately 5x5Km each (Figure 1). For each one of these areas, the median of the simulated values within its boundaries was calculated for each ecological index. Consequently, each area was thereafter characterized by five values representative of the five ecological indices under examination.

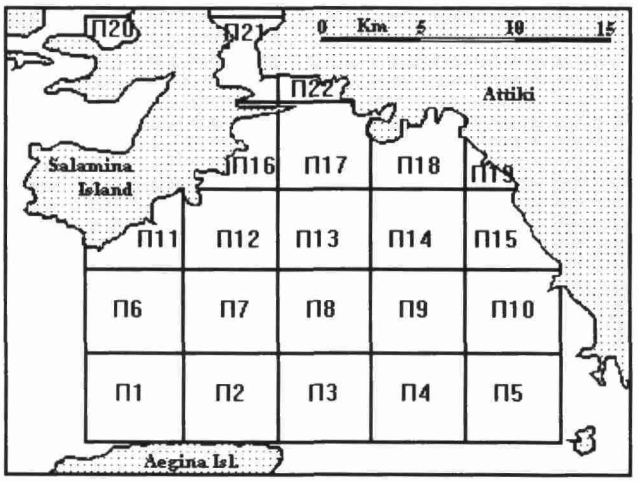

Figure 1 : the 22 areas of Saronicos Gulf

Cluster analysis [10] was applied for the 22 areas and clusters of areas were formed according to the values of the ecological indices. It is noticed here that the Euclidean Distance was used as the dissimilarity index of the analysis [10] and that before the application of the method, standardization of the data was performed [11] due to the different scales that the variables are measured. Subsequently, the non-parametric randomization test (Analysis of Similarities - ANOSIM) was applied for determining whether areas which appear to be in the same clusters, form distinct, significantly different groups [12].

The clusters derived from the ANOSIM method were representative of the existing different eutrophic states in the marine environment and were characterized accordingly as follows. For the areas belonged to each distinct group, the median of their representative values for the phytoplankton cell number (median of the simulated values within their boundaries), was calculated and the obtained values were compared to a eutrophication scale [6] which is given in Table 2. In that way, each distinct group was characterized precisely according to its eutrophic level (eutrophic, upper-mesotrophic, lower-mesotrophic, oligotrophic).

Table 2 : Eutrophication scale based on the phytoplankton cell number (N).

Eutrophication Scale for the phytoplankton cell number (cells/l)			
oligotrophic	lower-mesotrophic	upper-mesotrophic	eutrophic
0	$6x10^3$	$1.5x10^5$	$9.6x10^5$