COASTAL EUTROPHICATION ASSESSMENT: DEVELOPMENT OF A WATER QUALITY CLASSIFICATION SYSTEM USING PHYTOPLANKTON ECOLOGICAL INDICES

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Abstract.

A classification system was developed for water quality assessment in coastal regions. Phytoplankton enumeration/classification data from areas known as eutrophic, mesotrophic and oligotrophic were used for the calculation of five ecological indices. These indices were further processed with descriptive discriminant analysis to optimize the separation of the trophic states. Margalef's, Menhinick's indices and cell number were selected as the most efficient for the separation of the trophic levels, whereas Hill's N0 and Gleason's indices did not show any sensitivity in assessing eutrophication. The discriminant functions obtained from the analysis were used to plot a territorial map, divided into three clearly defined regions, a eutrophic, a mesotrophic and an oligotrophic. The classification scheme was evaluated in a case study from 23 stations spaced out along coastal areas in the Aegean sea, Eastern Mediterranean. Each station was represented with a point in the map and its water quality could be assessed. The classification system developed can be proposed as a methodological tool for coastal water quality assessment in a wide spatial scale.

Key-words: Coastal management, eutrophication, Aegean Sea

Introduction

Many attempts have been reported for the quantitative assessment of coastal eutrophication. The information related to nutrients and chl. á concentrations has been analyzed extensively [1, 2, 3], whereas both univariate and multivariate statistical methods have been applied on phytoplankton ecological indices [4], which seem to be nowadays standard practice in monitoring environmental changes [5] and also in water quality assessments [6].

The evaluation of water quality reported so far assumes the empirical selection of some impacted and unimpacted sites in the area under investigation, that have been used for the development of a local eutrophication scale. This approach in water quality studies shows certain shortcomings: (a) it is strongly affected by the expertise of the researcher about known trends in the investigated area and (b) the effectiveness of the developed eutrophication scale for water quality assessment is limited to the investigated area since it is based on data representing the local conditions.

In the present work a classification system for coastal eutrophication assessment was developed using the multivariate statistical method of discriminant analysis on phytoplankton ecological indices. This classification method was based on a large number of data selected from different regions in the Aegean Sea and its effectiveness was tested in a case study, so it can be proposed as a classification method for water quality assessment in a wide spatial scale.

Methodology

Source of data. Three datasets on phytoplankton enumeration / classification characteristic of the Eastern Mediterranean [2] formed the basis for the development of the classification procedure. The first dataset (22 observations) from two sampling sites S1 and S2 (Fig. 1) came from an area known as eutrophic [2], located in the vicinity of the sewage outfall of the Metropolitan area of Athens, Greece. The data of the second set (80 observations), characterizing mesotrophic conditions [2], were collected from seven stations S3-S9 (Fig. 1) located in the remaining area of the inner Saronicos Gulf. The data of the third set (78 observations) were collected from 5 stations along the N.W. side of the Island of Rhodes (Fig. 1) from an area known as oligotrophic [7].

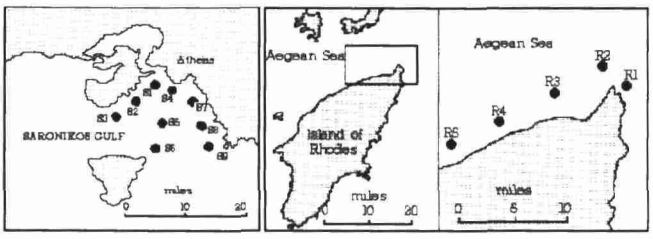

Figure 1. Location of sampling sites in Saronikos Gulf and along the Island of Rhodes (Greece): stations S1 & S2 characterize eutrophic marine environment, stations S3-S9 show mesotrophic character and stations R1-R5 are characteristic of oligotrophy.

Ecological indices. Four ecological indices expressing phytoplankton community diversity were selected for further consideration on the basis of their efficiency to detect eutrophic trends in previous work [4]:

(a) Gleason's index $D = \frac{S}{\ln N}$ [8]

(b) Margalef's index $D = \frac{S - 1}{\ln N}$ [8]

(c) Menhinick's index $D = \frac{S}{\sqrt{N}}$ [8]

(d) Hill's NO = S [8], where S is the number of species and N is the number of individuals in a sample. The cell number has been also used in the analysis as an index of biomass.

Statistical analysis. The multivariate method of discriminant analysis has been used in a descriptive way [9], that is to exhibit optimal separation of the eutrophic, mesotrophic and oligotrophic group, based on certain linear transforms of the measured ecological indices. Prior to the analysis, data were tested for normality and equality of variances (homoscedasticity), since these two assumptions are required for the application of the discriminant analysis [10]. The Kolmogorov-Smirnov test was used to test the goodness-of-fit to the normal distribution and the variance ratio test for the equality of variances [11]. A stepwise variable selection algorithm has been used in order to arrive in a good model; the five diversity indices were included in the dataset, among which a limited number was selected for better group separation. The variable selection criterion applied in the present work was the minimization of Wilk's lambda [12]. Thus at each step, the index that results in the smallest Wilk's lambda for the discriminant function is selected for entry.

After the selection of the indices resulting to the better group separation, the coefficients were estimated for the two discriminant functions so that their values to differ as much as possible between the eutrophic, mesotrophic and oligotrophic groups. Furthermore, a two dimensional territorial map can be drawn, having in its axes the two discriminant functions. The map is divided into three clearly separated regions, a eutrophic, a mesotrophic and an oligotrophic. Based on the discriminant functions, it is possible to calculate the two discriminant scores for each case under consideration, which can be plotted as a point in the territorial map.

Results

Summary statistics of the ecological indices used in the present analysis can be shown in Table 1. A gradual increase in cell number, species number (Hill's N0), Margalef's and Gleason's indices can be observed from oligotrophy to eutrophication, whereas the opposite trend was observed for Menhinick's index. All the datasets have shown homoscedasticity and nor-

Table 1. Summary statistics of the ecological indices used in the discriminant analysis.

Parameter	Indices				
	A Eutrophic waters				
	Gleasons	Margalefs	Menhinicks	Hills N0	Cell number
Range	0 84-2.96	0 76-2 87	0 02-0 11	10-34	53400-519581
Median	1 94	1 86	0 05	24	188334
	B Mesotrophic waters				
	Gleasons	Margalefs	Menhinicks	Hills N0	Cell number
Range	0 51-2 99	0 42-2 90	0 02-0 18	6-33	13600-137272
Median	1 61	1 52	0 09	18	31400
	C Oligotrophic waters				
	Gleasons	Margalefs	Menhinicks	Hills N0	Cell number
Range	0 85-2 59	0 73-2 47	0 10-0 27	7-23	2320-7440
Median	1 40	1 29	0 19	12	4240