Thalassographica *Vol. 13/ Suppl. 1/ 1990* *29-32*

MULTIVARIATE ANALYSIS OF CHLOROPHYLL-A AND ZOOPLANKTON IN SARONIKOS GULF FROM JANUARY 1984 TO DECEMBER 1985

E.. Papathanassiou, I. Siokou-Frangou, O. Gotsis-Skretas & P. Panayotidis
National Centre for Marine Research, Ag. Kosmas, Hellinikon, Athens 16604, Greece

ABSTRACT: The zooplankton biomass and the chlorophyll-a values were examined at five stations in the Saronikos Gulf (Greece) during the period from June 1984 to December 1985. Multivariate analysis concerning these biological parameters (classification and ordination) at these stations showed that the Elefsis Bay is separated from the rest of the Gulf for both chlorophyll-a and zooplankton, while a relative discrimination was observed for the station near the sewage outfall area, especially for chlorophyll-a.

INTRODUCTION

One of the most studied areas in Greece is the Saronikos Gulf which is situated near the Athens area and is subjected to urban and industrial pollution (Moraitou-Apostolopoulou & Ignatiades, 1977; Moraitou- Apostolopoulou, 1981; Friligos, 1981; 1982; Yannopoulos, 1976, Karydis et al., 1983). The National Centre for Marine Research has started a project to study the phenomenon of the increasing jellyfish population in the Greek waters. This study involved the sampling of several physical, chemical and biological parameters at five stations in Saronikos Gulf representing its different water masses in the gulf (Dugdale and Hopkins, 1975) (Fig 1) and was continuous for two and half years (May 1983-December 1985). On the other hand it will probably proved very interesting to verify the hydrological model, based on the results of biological investigations. The present paper describes the distribution of chlorophyll-a and zooplankton biomass in the area of Saronikos Gulf and makes an attempt to separate the water masses in the gulf and group the stations on the account of chlorophyll-a and zooplankton biomass distribution during a period of 2 years, from January 1984 to December 1985.

MATERIALS AND METHODS

Chlorophyll-a measurements were taken at depths 0, 10, 20 and 50 m. The mean integrated values were used in the statistical analysis. The method that was used for chlorophyll-a measurements, was based on the use of a Turner fluorometer as this has been suggested by Yentsch & Menzel (1963) and subsequently modified by Holm-Hansen *et al.*, (1965). Zooplankton samples were taken by a WP-2 plankton net (200 μm mesh size), which was equipped with a "Hydrobios" flowmeter. The samples were collected by means of double oblique hauls, (50 m to the surface); in stations where the depth was less than 25 meters the double oblique hauls were made from 10 m to the surface due to the profound geomorphological differences of the bottom. The zooplankton biomass was estimated by the dry-weight method (Lovegrove 1966).

The raw data of both chlorophyll-a concentrations and zooplankton biomass were transformed using the transformation $y_{ji} = \log (x_{ji} + 1)$ (Field *et al.*, 1982).

The Bray-Curtis similarity matrix was used for all computations at the multivariate methods (Field *et al.*, 1982).

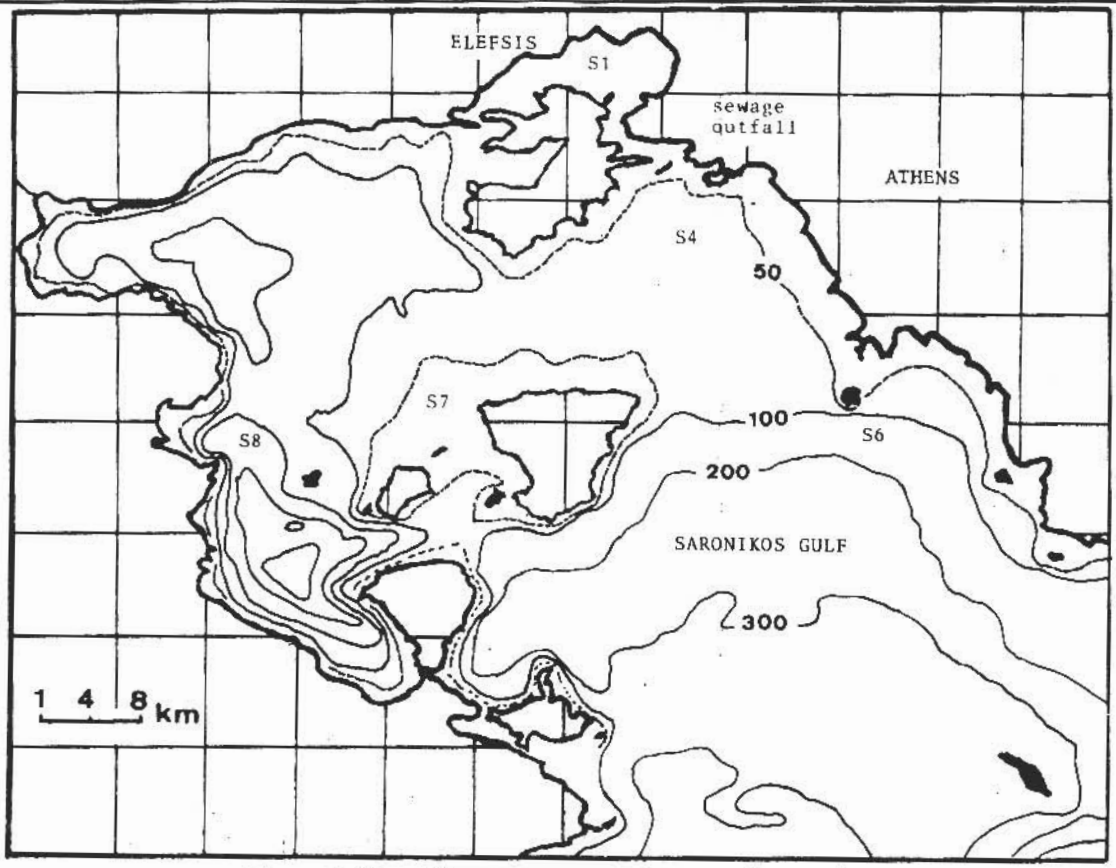

Figure 1. Map of the area, showing the sampling stations

Classification was performed on the similarity matrix using the average linkage clustering technique (Sokal & Sneath, 1963). Ordination methods (multidimensional scaling) were used to evaluate the group separation derived by cluster analysis, following the method described by Field *et al.* (1982) and Clarke & Green (1988).

RESULTS

Classification

The dendrograms showing the station affinities concerning the chlorophyll-a measurements is shown in Fig 2. The stations S4, S6, S7 and S8 are grouped together, while S1 represent another separate group of stations at the level of 47 % similarity. However it is interesting to note the similarity of station S4 with the stations S6, S7 and S8 at the level of 80 % . Concerning the zooplankton biomass the stations can be divded yet again into 2 groups at the level of 42%; one containing the station S1 and the second containing the stations S4, S6, S7 and S8. The similarity of the latter is at the level of 63% and it was assumed that these stations represent only one group (Fig. 2).

Ordination

The results of multidimensional scaling was performed in to two dimensions and gave a stress of 0.00031 for both chlorophyll-a and zooplankton biomass . Both ordination diagrams are presented in Fig. 3 and Fig. 4 . Using this statistical approach it is obvious that for chlorophyll-a the station S1 is separated from the others with a relative similarity of station S4 with the stations S6, S7 and S8. For the zooplankton biomass the ordination diagrams provide the same information as the clustering with the station S1 yet again being far away from the others. The adequacy of the two dimensional representation is also apparent from the small residual variability about the regression line shown in the Shepard diagram (Figs 5,6).

DISCUSSION

Results have given the picture of Saronikos Gulf as far as zooplankton biomass and chlorophyll-a is concerned.

The stations have been diveded into two main groups for chlorophyll-a measurements. General-

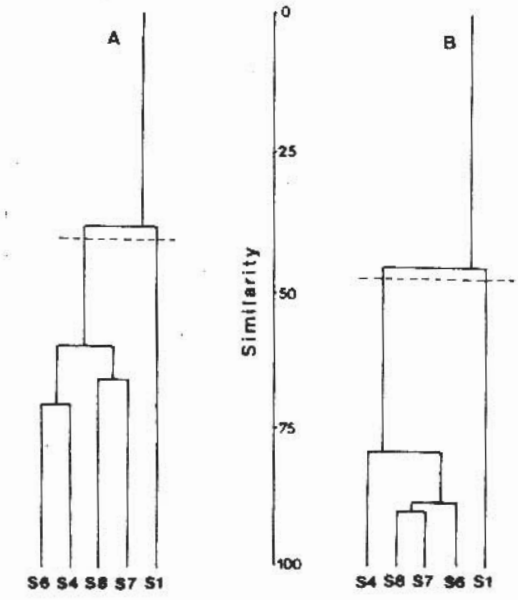

Fig 2. Dendrograms showing the classification in Saronikos Gulf, based on the zooplankton biomass estimation (A) and chlorophyll-a measurements (B).

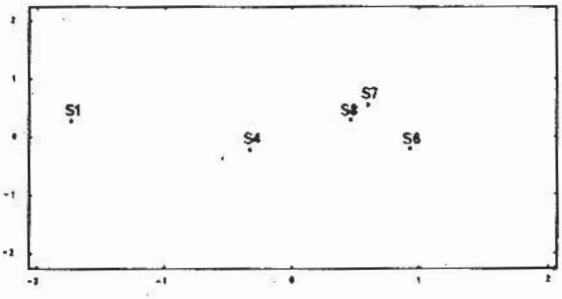

Fig 3. Ordination of the 5 stations based on Chl-a, using multidimensional scaling (MDS).

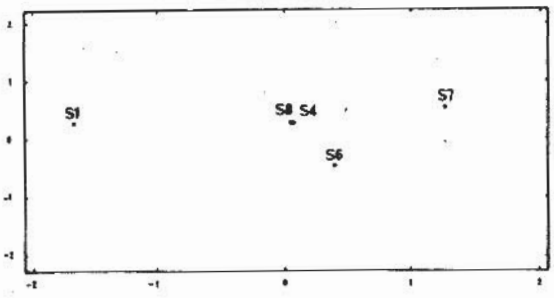

Fig 4. Ordination of the 5 stations based on zooplankton biomass using (MDS)

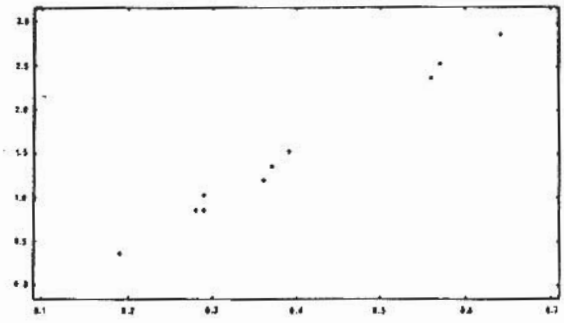

Fig. 5. Shepard diagram of the MDS ordination shown in Fig. 3 (chlorophyll-a).

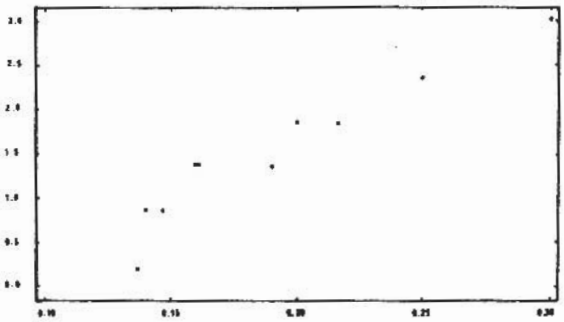

Fig. 6. Shepard diagram of the MDS ordination shown in Fig. 4 (zooplankton biomass).

ly, the stations S4, S6, S7 and S8 can be grouped together. The similarity with station S4 is relative lower and this is probably due to the fact that station S4, being nearer to the sewage outfall of Athens, has unlimited source of nutrients and thus more phytoplankton throughout the year (Karydis *et al.*, 1983; Pagou, 1986).

The dendrogram for zooplankton gave a division of the stations into two main groups the one of which is subdivided into two more. It is interesting to note the good similarity of all the stations with the exception of station S1. This could be accounted on the fact that zooplankton distribution does not depend directly on the sewage effluents.

One of the most striking features is the dissimillarity observed for both chlorophyll-a and zooplankton values at station S1. The very intense variations of both phytoplankton and zooplankton throughout the year (distrophic environment) seemed to be responsible for this observed dissimilarity. These variations should be the outcome of the aggravation of the area from the sewage effluents depending also on the hydrology of Elefsis

Bay (Friligos, 1981; 1982). It is interesting also to note that the division of these stations for chlorophyll-a and to some extend for zooplankton follows the division of water masses in Saronikos gulf confirming the existing hydrological model (Dugdale & Hopkins, 1975).

The above results have clearly demonstrated that chlorophyll-a and concequently phytoplankton abundance is modified to a higher degree than zooplankton biomass in the areas that are considered to be moderately or highly polluted (Friligos, 1981;1982; Pagou, 1986). On the other hand, the zooplankton biomass, although a valid biological parameter is not probably the best one to estimate differences between stations. It has also to be considered that biomass analysis does not include the species diversity for each station.

These differences in the Saronikos Gulf are limited only for station S1, in Elefsis Bay, where a strong variation exists throught the year (Siokou-Fragou & Anagnostaki, 1985). Further studies in this subject which are carried out in the same area may probably show much more distinct affinities between stations.

ACKNOWLEDGEMENTS

We would like to thank Mrs. K. Anagnostaki for the valuable help she gave us during the course of this study. We are also gratefull to Mr. K. Akepsimaides for helping us in collecting the samples.

REFERENCES

CLARKE K. R. & R. H. GREEN, 1988. Statistical design and analysis for a "biological effects" study. Mar. Ecol. Prog. Ser., 46 : 213-226.

CLIFFORD H. T. & W. STEPHENSON, 1975. An introduction to numerical classification, Academic Press, New York.

DUGDALE R.C. & T. S. HOPKINS, 1975. Description, analysis and conclusions of Saronikos Gulf water masses, S.S.P. 1 up to 11 cruises. Technical Report, 1975, Inst. Ocean. Fish. Research.

FIELD G.J., CLARK K.R. & R.M. WARWICK, 1982. A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8 : 37-52.

FRILIGOS N., 1981. An index of marine pollution in the Saronikos Gulf. Mar. Pollut. Bull., 12 : 96-100.

FRILIGOS N., 1982. Some consequences of the decomposition of organic matter in the Elefsis Bay, an anoxic basin. Mar. Pollut. Bull., 13 : 103-106.

HOLM-HANSEN O., C.J. LORENZEN, R.N. HOLMES & J.D.H. STRICKLAND , 1965. Fluorometric determination of chlorophyll. Cons. Perm. Inter. Explor. Mer 3 : 3 - 15.

KARYDIS M., MOSCHOPOULOU N. & L. IGNATIADES, 1983. Carotenoid/ chlorophyll-a ratio in relation to nutrient distributions. Rapp. Comm. Int. Mer Medit., 28(9) : 69-71.

LOVEGROVE T., 1966. The determination of dry weight of plankton and the effect of various factors on the values obtained. In: Some contemporary studies in Marine Science, 429-467. H. Barnes (ed), George Allen & Unwin, London.

MORAITOU-APOSTOLOPOULOU, M., 1981. The annual cycle of zooplankton in Elefsis Bay (Greece). Rapp. Comm. Int. Mer Medit., 27 : 105-106.

MORAITOU-APOSTOLOPOULOU, M. & L. IGNATIADES, 1977. Pollution effects on the phytoplankton-zooplankton relationships in an inshore environment. Hydrobiologia, 75 : 259-266.

PAGOU K., 1986. The effect of pollution on the phytoplankton species diversity. Rapp. Comm. int. Mer Medit., 30(2) :191.

SIOKOU-FRAGOU I. & K. ANAGNOSTAKI, 1985. Zooplankton. In:"Studies on the Biology and Ecology of jellyfish in Greek waters; "Year Report by E. Papathanassiou *et al.* . National Centre for Marine Research-UNEP, Athens, February 1985, pp. 26-29

SOKAL R.R. & P.H.A. SNEATH,1963. Principles of Numerical Taxonomy. Freeman & Co.,San Fransisco, 359pp.

YANNOPOULOS C., 1976. The annual regeneration of the Elefsis Bay zooplanktonic ecosystem, Saronikos Gulf. Rapp. Comm. Int. Mer Medit., 23 : 109-111.

YENTCH C.S. & D.W. MENZEL, 1963. A method for the determination of phytoplankton chlorophyll and phaeophytin by fluorescence. Deep Sea Res. 10 : 221-231.