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Pollution effects on plankton composition and spatial distribution, near the sewage outfall of Athens (Saronikos Gulf, Greece)

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This volume is the ninety-sixth issue of the Mediterranean Action Plan Technical Reports Series.

This series contains selected reports resulting from the various activities performed within the framework of the components of the Mediterranean Action Plan: Pollution Monitoring and Research Programme (MED POL), Blue Plan, Priority Actions Programme, Specially Protected Areas and Regional Marine Pollution Emergency Response Centre for the Mediterranean.

Ce volume constitue le quatre-vingt seizième numéro de la série des Rapports techniques du Plan d'action pour la Méditerranée.

Cette série comprend certains rapports élaborés au cours de diverses activités menées dans le cadre des composantes du Plan d'action pour la Méditerranée: Programme de surveillance continue et de recherche en matière de pollution (MED POL), Plan Bleu, Programme d'actions prioritaires, Aires spécialement protégées et Centre régional méditerranéen pour l'intervention d'urgence contre la pollution marine accidentelle.

PREFACE

The United Nations Environment Programme (UNEP) convened an Intergovernmental Meeting on the Protection of the Mediterranean (Barcelona, 28 January - 4 February 1975), which was attended by representatives of 16 States bordering the Mediterranean Sea. The meeting discussed the various measures necessary for the prevention and control of pollution of the Mediterranean Sea, and concluded by adopting an Action Plan consisting of three substantive components:

- Integrated planning of the development and management of the resources of the Mediterranean Basin (management component);

- Co-ordinated programme for research, monitoring, exchange of information and assessment of the state of pollution and protection measures (assessment component);

- Framework convention and related protocols with their technical annexes for the protection of the Mediterranean environment (legal component).

All components of the Action Plan are inter-dependent and provide a framework for comprehensive action to promote both the protection and the continued development of the Mediterranean ecoregion. No component is an end in itself. The Action Plan is intended to assist the Mediterranean Governments in formulating their national policies related to the continuous development and protection of the Mediterranean area and to improve their ability to identify various options for alternative patterns of development and to make choices and appropriate allocations of resources.

The Co-ordinated Mediterranean Research and Monitoring Programme (MED POL) was approved as the assessment (scientific/technical) component of the Action Plan.

The general objectives of its pilot phase (MED POL - Phase I), which evolved through a series of expert and intergovernmental meetings, were:

- to formulate and carry out a co-ordinated pollution monitoring and research programme taking into account the goals of the Mediterranean Action Plan and the capabilities of the Mediterranean research centres to participate in it;

- to assist national research centres in developing their capabilities to participate in the programme;

- to analyse the sources, amounts, levels, pathways, trends and effects of pollutants relevant to the Mediterranean Sea;

- to provide the scientific/technical information needed by the Governments of the Mediterranean States and the EEC for the negotiation and implementation of the Convention for the Protection of the Mediterranean Sea against Pollution and its related protocols;

- to build up consistent time-series of data on the sources, pathways, levels and effects of pollutants in the Mediterranean Sea and thus to contribute to the scientific knowledge of the Mediterranean Sea.

Based on the recommendations made at various expert and intergovernmental meetings, a draft Long-term (1981-1990) Programme for Pollution Monitoring and Research in the Mediterranean (MED POL-Phase II) was formulated by the Secretariat of the Barcelona Convention (UNEP), in co- operation with the United Nations Agencies which were responsible for the technical implementation of MED POL-Phase I, and it was formally approved by the Second Meeting of the Contracting Parties of the Mediterranean Sea against pollution and its related protocols and Intergovernmental Review Meeting of Mediterranean Coastal States of the Action Plan held in Cannes, 2-7 March 1981.

The general long-term objectives of MED POL-Phase II were to further the goals of the Barcelona Convention by assisting the Parties to prevent, abate and combat pollution of the Mediterranean Sea area and to protect and enhance the marine environment of the area. The specific objectives were designed to provide, on a continuous basis, the Parties to the Barcelona Convention and its related protocols with:

- information required for the implementation of the Convention and the protocols;
- indicators and evaluation of the effectiveness of the pollution prevention measures taken under the Convention and the protocols;
- scientific information which may lead to eventual revisions and amendments of the relevant provisions of the Convention and the protocols and for the formulation of additional protocols;
- information which could be used in formulating environmentally sound national, bilateral and multilateral management decisions essential for the continuous socio-economic development of the Mediterranean region on a sustainable basis;
- periodic assessment of the state of pollution of the Mediterranean Sea.

The monitoring of, and research on, pollutants affecting the Mediterranean marine environment reflects primarily the immediate and long-term requirements of the Barcelona Convention and its protocols, but also takes into account factors needed for the understanding of the relationship between the socio-economic development of the region and the pollution of the Mediterranean Sea.

Research and study topics included initially in the MED POL - Phase II were:

- development of sampling and analytical techniques for monitoring the sources and levels of pollutants. Testing and harmonization of these methods at the Mediterranean scale and their formulation as reference methods. Priority will be given to the substance listed in the annexes of the Protocol for the prevention of pollution of the Mediterranean Sea by dumping from ship and aircraft and the Protocol for the protection of the Mediterranean Sea against pollution from land-based sources (activity A);
- development of reporting formats required according to the Dumping, Emergency and Land-Based Sources Protocols (activity B);
- formulation of the scientific rationale for the environmental quality criteria to be used in the development of emission standards, standards of use or guidelines for substaces listed in annexes I and II of the Land-Based Sources Protocol in accordance with Articles 5, 6 and 7 of that Protocol (activity C);

- epidemiological studies related to the confirmation (or eventual revision) of the proposed environmental quality criteria (standards of use) for bathing waters, shellfish-growing waters and edible marine organisms (activity D);

- development of proposals for guidelines and criteria governing the application of the Land-Based Sources Protocol, as requested in Article 7 of that Protocol (activity E);

- research on oceanographic processes, with particular emphasis on surface circulation and vertical transport. Needed for the understanding of the distribution of pollutants through the Mediterranean and for the development of contingency plans for cases of emergency (activity F);

- research on the toxicity, persistence, bioaccumulation, carcinogenicity and mutagenicity of selected substances listed in annexes of the Land-Based Sources Protocol and the Dumping Protocol (activity G);

- research on eutrophication and concomitant plankton blooms. Needed to assess the feasibility of alleviating the consequences and damage from such recurring blooms (activity H);

- study of ecosystem modifications in areas influenced by pollutants, and in areas where ecosystem modifications are caused by large-scale coastal or inland engineering activity (activity I);

- effects of thermal discharges on marine and coastal ecosystems, including the study of associated effects (activity J);

- biogeochemical cycle of specific pollutants, particularly those relevant to human health (mercury, lead, survival of pathogens in the Mediterranean Sea, etc.) (activity K);

- study of pollutant-transfer processes (i) at river/sea and air/sea interface, (ii) by sedimentation and (iii) through the straits linking the Mediterranean with other seas (activity L);

The Contracting Parties at their 6th Ordinary Meeting (Athens, October 1989) agreed to:

(a) Re-orient the research activities within MED POL in order to generate information which will also be useful for the technical implementation of the LBS protocol in addition to supporting monitoring activities;

(b) replace as from 1990 research activities A-L by the following five new research areas:

Research area I - Characterization and measurement

This area will include projects which cover the characterization (identification of chemical or microbiological components) and measurement development and testing of methodologies of specified contaminants;

Research area II - Transport and dispersion

This area will include projects which aim at improving the understanding of the physical, chemical and biological mechanisms that transport potential pollutants from their sources to their ultimate repositories. Typical topics will be atmospheric transport and deposition, water movements and mixing, transport of contaminants by sedimentation and their incorporation in biogeochemical cycles. Priority will be given to the provision of quantitative information ultimately useful for modelling the system and contributing to regional assessments;

Research area III - Effects

This area will include projects relevant to the effects of selected contaminants, listed in Annexes I and II of the LBS and Dumping protocols, to marine organisms, communities and ecosystems or man and human populations. Priority will be given to effects and techniques providing information useful for establishing environmental quality criteria;

Research area IV - Fates/Environmental transformation

This area will include projects studying the fate of contaminants (including microorganisms) in the marine environment such as persistence or survival, degradation, transformation, bioaccumulation etc. but excluding transport and dispersion which is dealt in area II;

Research area V - Prevention and control

This area will include projects dealing with the determination of the factors affecting the efficiency of waste treatment and disposal methods under specific local conditions as well as the development of environmental quality criteria and common measures for pollution abatement;

(c) define target contaminants or toher variables at periodic intervals depending on the progress of implementation of the LBS protocol;

(d) select project proposals on the basis of their intrinsic scientific validity, their Mediterranean specificity, and encourage whenever possible bilateral and multilateral projects among Mediterranean countries from the north and the south of the basin.

As in MED POL - Phase I, the overall co-ordination and guidance for MED POL - Phase II is provided by UNEP as the secretariat of the Mediterranean Action Plan (MAP). Co-operating specialized United Nations Agencies (FAO, UNESCO, WHO, WMO, IAEA, IOC) are responsible for the technical implementation and day-to-day co-ordination of the work of national centres participating in monitoring and research.

The present volume contains the final report of a research project entitled "Pollution effects on plankton composition and spatial distribution, near the sewage outfall of Athens (Saronikos Gulf, Greece)".

POLLUTION EFFECTS ON PLANKTON COMPOSITION AND SPATIAL DISTRIBUTION, NEAR THE SEWAGE OUTFALL OF ATHENS (SARONIKOS GULF, GREECE)

by

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ABSTRACT

The main objective of the present study was to estimate the effect of pollution on the plankton communities, living in the sewage discharge zone or in areas close by in relation to the distance from the outfall.

Nutrients spatial distribution depended mainly on the position of the sewage outfall at Keratsini Bay and the dominating circulation. Phytoplankton biomass followed the same pattern as nutrients, whereas zooplankton abundances did not exhibit their highest values in the most eutrophic areas, due to its sensitivity to pollutant factors. Pollution influenced the pattern of the spatial distribution of zooplankton species but not that of phytoplankton species, showing that planktonic algae and animals have a different responde to pollution.

Statistical analysis (PCA) of all collected data (physical, chemical and biological) for each sampling period revealed a clear differentiation among three areas: (a) Elefsis bay, (b) the area mostly influenced by the sewage outfall (Keratsini bay and the Psittalia area) and (c) the area of inner Saronikos and the western basin, which seemed to be the least influenced by pollution. This persistent differentiation during all sampling periods was related to environmental factors such as temperature, salinity, nutrients, zooplankton species and phytoplankton biomass.

It can be concluded that among the parameters describing the plankton populations of Saronikos Gulf, phytoplankton biomass and zooplankton species distribution can be used as a tool for the investigation of pollution impact on plankton communities.

1. INTRODUCTION

The type of problem typically confronting environmental biologists concerns the effects of environmental factors on species in a biological community.

An impact study determines whether a specified impact causes change in a biological community and if it does, describes the nature of that change. Such a study is best designed when it judges impact effects against previously collected baseline data, and it is best used when the results provide the basis for subsequent monitoring to detect future impacts of the same type. However, one may be able to obtain both before- and after- impact data or only after-impact data. There may or may not be a control area, but to test whether a condition has an effect, samples must be collected both where the condition is present and where the condition is absent, everything else being is the same. An effect can only be demonstrated by comparison with a control (Green, 1979).

Frequently, environmental biologists receive funds to study an impact after its effects have become a problem and no "before-impact" data can be collected. In this case the impact effects are most appropriate to be demonstrated and described from spatial pattern. The main objective of such a study thus could be: To determine the impact effects, if any, of existing point-source pollution by assessing the spatial pattern of species composition in the adjacent area.

Saronikos gulf, one of the most studied Greek gulfs, is of great interest to marine biologists, because the last decades eutrophication and other pollution phenomena have been occurring in its naturally oligotrophic waters as a consequence of urban and industrial disposal. Existing data for the unpolluted areas of the gulf have demonstrated a defined seasonality pattern on the annual cycle of plankton (Pagou, 1994; Siokou-Frangou et al., in press), controlled by the phosphorus and nitrogen availability (Ignatiades, 1969). However, once enrichment (Friligos, 1985) becomes constant, because of continuous drainage of nutrient rich effluents, the trophic potential of the water may become independent of seasonality, thus influencing not only the annual cycle, but also the abundance and distribution of the plankton populations.

Systematic studies on nutrients, phytoplankton and zooplankton populations and their interrelationships in Saronikos gulf are dated back to 1967 and therefore a considerable amount of literature has been collected concerning i.e. effects of sewage on nutrients and phytoplankton (Becacos-Kontos and Friligos, 1973; Friligos, 1985; etc.), phytoplankton annual cycles, species composition and distribution (Ignatiades and Becacos-Kontos, 1970; Ignatiades 1979, 1981, 1984; Karydis and Moschopoulou, 1982; Karydis et al., 1983; etc.), primary production (Becacos-Kontos, 1967, 1981; Ignatiades 1977, 1990; Ignatiades et al., 1987; etc.), and zooplankton ecology and systematics (Yannopoulos, 1976; Moraitou-Apostolopoulou, 1976, 1981; Moraitou-Apostolopoulou and Ignatiades, 1980).

N.C.M.R. is systematically involved in the study of Saronikos gulf, over a decade. Since 1983 (Papathanassiou et al., 1987) the composition and distribution of plankton has been studied, in selected stations of Saronikos Gulf, whereas since 1986 (Catsiki, 1991) a pollution monitoring programme of the area has been undertaken. Also during July 1986-July 1987, the effect of pollution on the zooplankton community of Saronikos Gulf has been studied (Siokou-Frangou et al., 1990), whereas the ministry of Public Works assigned to N.C.M.R. the realization of the project "Monitoring of biological parameters in Saronikos Gulf" for the periods January - December 1987 (Panayotidis, 1988) and April 1989 - March 1990 (Siokou-Frangou, 1991a).

From the above mentioned and other previous ecological studies in the area the differential responses of the plankton communities to pollution according to distance from the sewage outfall and the hydrodynamic profile of the area, have been suggested (Siokou-Frangou, 1993; Pagou et al., 1993; Pagou, 1994).

Elefsis bay is the most industrialized area in Greece. The bay communicates with Saronikos gulf by two narrow sills. Keratsini bay, where the Athens

sewage outfall is discharged, is also a semi-enclosed marine environment, exhibiting the more intense eutrophic characteristics. These are the areas that have been chosen for the realization of this study, since a systematic and detailed study of the spatial pattern of both phyto- and zooplankton populations is lacking.

Consequently the main objective of the present study is to estimate the effect of pollution upon the plankton communities, living in the sewage discharge zone or in areas neighbouring it, in terms of their location with regard to the outfall. A secondary objective is that, this study of the spatial pattern of the plankton populations in the Saronikos gulf may be used as a reference point when the new outfall will be fully operational.

The impact effects were studied according to:

a. The quantitative distribution of the phytoplankton and zooplankton populations.

b. The species composition and distribution in relation to the distance from the outfall.

c. The phytoplankton and zooplankton community structure.

However for an optimal impact study design it must be possible to relate to the impact any demonstrated change unique to the impact area and to separate effects caused by natural environmental variation unrelated to the impact (Green, 1979). In order to achieve that, the spatial distribution of plankton was studied under different seasonal conditions and samples were collected from a network of 18 closely spaced stations (~1 mile apart) in the sewage discharge zone. Also 3 control stations were sampled, so that evidence for impact effects on the plankton community were based on changes in the impact area that did not occur in the control area.

Unfortunately, though systematical studies on nutrients, phytoplankton and zooplankton are dated back to 1967 (Ignatiades 1969, Ignatiades and Becacos-Kontos 1969, Moraitou-Apostolopoulou 1974), the central sewer was built in 1959 and as a consequence there is a lack of before impact data. The problem was partly overcome by the selection of the above mentioned control stations.

2. MATERIALS AND METHODS

2.1 The study area

Saronikos Gulf is an open gulf with broad communication with the Aegean Sea. Thus the water masses of the gulf have a rather frequent and easy renewal when the right driving forces are present (mostly the wind field, but also the hydrodynamics of the water masses play a significant role). On the other hand Elefsis Bay is a semi-enclosed bay communicating with Saronikos Gulf by two narrow sills.

The temperature in all studied areas follows the yearly climatic fluctuations with higher temperatures during summer and minima about February-March. Salinity in Saronikos Gulf is influenced mainly from inflows from Aegean Sea with minima during early summer. The salinities of Elefsis Bay have a different behaviour due to the restricted communication of the water masses of the bay with Saronikos Gulf. Though there is a certain exchange of water masses between the two areas, anoxic conditions during summer do appear at the bottom layers of the Elefsis Bay (Psyllidou-Giouranovits and Pappas, 1988) due to the lack of any particular horizontal and mainly vertical movement. Keratsini bay is the area, where untreated wastes from the metropolitan area of Athens discharged into the sea, near Piraeus Harbour, through a central sewer, built in 1959. This outfall was fully operational during the study period and even now, after the completion of the construction of the new outfall, operates at intervals. As a consequence, the area around the outfall and the land-locked, heavily industrialized Elefsis Bay are excessively rich in nutrients and considered to be the most polluted areas of Saronikos gulf (Friligos, 1981a, 1981b, Psyllidou-Giouranovits et al., 1990).

The stations sampled (Fig. 1) were located at inner Saronikos Gulf (8 stations), Keratsini Bay (4 stations), Elefsis Bay (8 stations) and at the western basin (1 station). The characteristics (coordinates and sea bottom depth) for each sampling station are presented in Table 1.

Sampling took place during 5 seasonal cruises, carried out by the N.C.M.R. oceanographic research vessel "AEGAIO" and the respective dates for each cruise were:

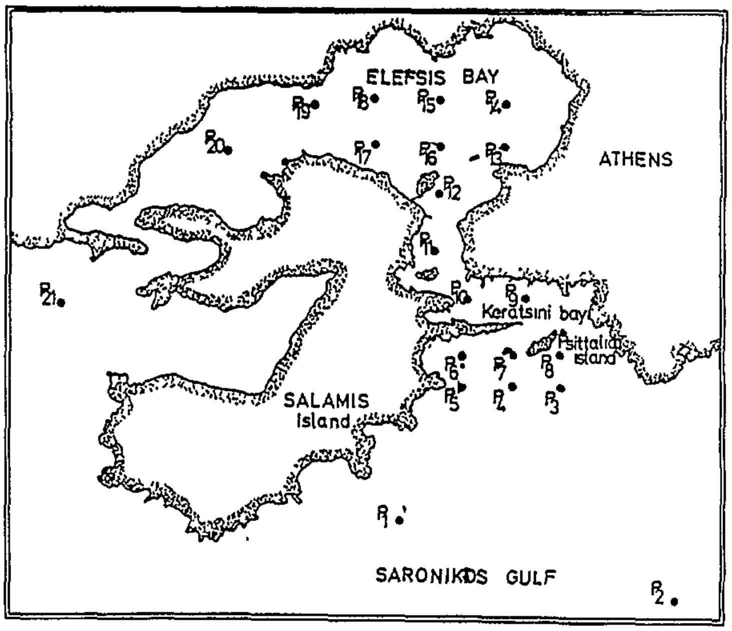


Fig. 1 Location of sampling stations in Saronikos Gulf

Table 1

Sampling stations, depths and coordinates

Station	Depth (m)	Latitude	Longitude
P01	90	37E 53' 20"	23E 31' 70"
P02	73	37E 52' 50"	23E 38' 60"
P03	80	37E 55' 20"	23E 36' 00"
P04	84	37E 55' 20"	23E 34' 77"
P05	74	37E 55' 20"	23E 33' 50"
P06	27	37E 56' 17"	23E 33' 60"
P07	44	37E 56' 10"	23E 34' 80"
P08	54	37E 56' 00"	23E 36' 00"
P09	27	37E 57' 00"	23E 35' 40"
P10	26	37E 57' 20"	23E 34' 00"
P11	18	37E 58' 40"	23E 32' 90"
P12	21	37E 59' 30"	23E 33' 00"
P13	21	38E 00' 40"	23E 34' 50"
P14	18	38E 01' 10"	23E 34' 50"
P15	19	38E 01' 10"	23E 33' 10"
P16	23	38E 00' 30"	23E 33' 10"
P17	27	38E 00' 25"	23E 31' 70"
P18	22	38E 01' 05"	23E 31' 75"
P19	30	38E 01' 00"	23E 29' 50"
P20	29	38E 00' 00"	23E 27' 30"
P21	92	37E 55' 08"	23E 20' 40"

- Cruise 1: 6 - 7 September 1989
- Cruise 2: 7 - 8 December 1989
- Cruise 3: 9 February 1990
- Cruise 4: 13 June 1990
- Cruise 5: 22-23 May 1991

During all cruises water samples for physical, chemical and biological studies were taken from 2m and 10m depths by a rosette Multi-Bottle Array System, model 1015 manufactured by General Oceanics, inc., whereas continuous physical measurements were performed by the use of a CTD unit attached to the rosette sampler.

3. METHODOLOGY

3.1 Physical Parameters

Hydrographic measurements were carried out by the use of a SBE-9 CTD underwater unit manufactured by Sea Bird Electronics, inc. All data were instantaneously acquired, processed, stored and displayed in a computer unit in order to follow the instruments lowering speed and the data quality. The accuracy and the resolution of the various sensors of the instrument are described at Table 2.

Table 2

Sensor specifications of the CTD unit

Sensor	Range	Accuracy	Resolution
Conductivity (Siemens/m)	0 - 7	0.0003	0.00004
Temperature (EC)	-5 - +35	0.004	0.0003
Pressure (hPa)	0 - 3000	0.05% of full scale	0.004% of full scale

Hydrographic data were collected at four cruises during September 1989, February 1990, June 1990 and May 1991. All stations were covered at these cruises and a continuous recording of CTD data was achieved at a lowering speed of the CTD fish-unit at about 50-60 cm/s. All data were processed, corrected and analysed, whereas TS diagrams were drawn for all stations at each cruise, along with plots of salinity, temperature and density (#t) for surface (2m) and 10 meters depths.

3.2 Chemical Parameters

For the determination of dissolved oxygen and nutrients concentrations in sea water, samples were collected from surface (2m) and 10m depths, during all five cruises.

Dissolved oxygen was determined on board, according to Carritt and Carpenter (1966). Water samples for the analysis of nutrients were collected in 100ml polyethylene bottles and kept continuously under deep freeze (-20EC), after the addition of one drop mercuric chloride (HgCl2) 0.04 M as preservative, until analysis in the laboratory was proceeded, were they thawed, filtered through membrane filters (0.45 µm pore size) and analyzed with a Technicon CSM-6 autoanalyser.

Nitrates, nitrites and silicates were analyzed according to Armstrong et al. (1967), phosphates according to Murphy and Riley (1962), as automated by Hager et al. (1968) and ammonia according to Koroleff (1970) as automated by Slawyk and MacIsaak (1972). The running of the samples on the Autoanalyzer and the mathematical treatment of the chart measurements was effected according to Satsmadjis (1978).

3.3 Biological Parameters

3.3.1 Phytoplankton

Sea water samples for the study of the phytoplankton biomass and populations were collected during the five oceanographic cruises, previously mentioned at each sampling station from 2 and 10m depths.

Phytoplankton biomass was estimated by the chlorophyll ß concentrations on 1 or 2 litres of sea water, depending on the expected concentrations. Samples for chlorophyll ß determinations were filtered on board through Whatman GF/C Microfiber filters and treated at the laboratory according to the UNESCO/SCOR (1966) method.

The quantitative and qualitative analysis of the phytoplankton populations was proceeded according to Utermohl (1958) in a ZEISS IM or a NIKON Diaphot inverted microscope. Phytoplankton organisms were classified to the level of species, when this was possible and expressed as number of cells per litter (c/l).

Phytoplankton species were classified in the following groups: diatoms, dinoflagellates, coccolithophores, silicoflagellates, "others", and µ-flagellates. The group named as "others" constituted from specimen of Cryptophyceae, Haptophyceae, Chrysophyceae, etc., whose identification was possible, whereas µ-flagellates were unidentified flagellates with cell diameter less than 5 µm.

3.3.2 Zooplankton

Zooplankton samples were collected by horizontal hauls of a WP-2 net (200 µm) near the surface (between 1 and 2m). The volume of the filtered sea-water was measured using a "Hydrobios" flowmeter. Each sample was divided using Folsom splitter in two sub-samples, one for the biomass estimation and the second for the qualitative analysis. The latter was performed in aliquots varying from 1/4 to 1/40, at the species level for copepods and cladocerans, while other zooplankters are referred at the group level. Biomass was estimated by means of dry weight (Omori and Ikeda, 1984).

3.4 Statistical treatment of data

Biological data sets derived from the above mentioned methods, which describe phytoplankton and zooplankton populations, were subsequently subjected to several statistical techniques, in order to summarise information contained in the plankton lists. As Green stated (1979) the statistical analysis is likely to proceed in two stages: (1) reduction of the biological data to fewer variables that are efficient carriers of the information and (2) relating those biological variables to the environmental predictor variables in some explanatory manner. Ordination and clustering methods are most appropriate for the latter case.

3.4.1 Indices

Abundance and biomass distributions are commonly used to determine levels of disturbance or "stress" at given sites. Besides these criteria, some others are also used in order to compare spatial and/or temporal gradient. Those applied at the present data were: the total number of species per sample, dominance and diversity indices distributions.

Dominance indices for each phytoplankton or zooplankton sample, were assessed by the McNaughton (1967) formula, described also by Hulburt (1963).

$$\delta = 100x\frac{N_1+N_2}{N}$$

where ä is the dominance index equal to the percentage of the total standing crop (N) contributed by the two most important species (N_1, N_2).

In addition, a graphical presentation of k-dominance curves for each station based on ranked species cumulative relative abundances (in decreasing order) was examined as a possible procedure to describe spatial patterns of phytoplankton and zooplankton distribution (Warwick, 1986).

Community diversity for plankton populations was estimated according to two very popular and commonly used indices derived from the information theory.

Diversity indices for phytoplankton samples were calculated according to Brillouin's index (Brillouin, 1956; Margalef, 1958) defined as:

$$H = \frac{1}{N}\log_2\frac{N!}{\prod_{i=1}^{s} N_i!}$$

where N is the number of individuals in the whole collection and Nii is the number in the ith species for i=1,2,...,s. The Stirling approximation was used for the calculation of logN!:

$$N! \approx \sqrt{2\pi N}\left(\frac{N}{e}\right)^N$$

The species diversity of the zooplankton population was estimated according to the Shannon-Wiener diversity index (Shannon and Weaver, 1963) as expressed by the formula:

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where pi=Ni/N, and Ni is the number of individuals of the species i, N the total number of individuals and s the total number of species.

3.4.2 Multivariate methods

Though diversity indices are very popular in environmental studies there are strong arguments against their use as derived criterion or predictor variables in such studies, the strongest being that other statistical methods, such as cluster and ordination analysis, retain more information in the biological data while reducing them to a more useful and ecologically meaningful form (Green, 1979).

Classification methods are widely used to indicate the degree of similarity in species composition between stations. If station groupings can be related to pollution, this can provide strong correlative evidence of cause and effect.

In this study, a similarity matrix from surface data (2m) for each sampling period was constructed, using the Bray-Curtis measure of similarity (Bray and Curtis, 1957) on log (1+x) transformed data for phytoplankton and on square root transformed data for zooplankton. The Bray-Curtis similarity index was calculated according to the formula:

$$S(x_j,x_k) = 1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})}$$

where xj, xk are the samples to be compared and yij is the score for the ith species at the jth sample and yik is the score for the ith species in the kth sample.

The produced matrices were then subjected 1) to classification using group average sorting (Sneath and Sokal, 1973) and the relevant dendrograms were derived and 2) non-metric multidimensional scaling (MDS), according to Field et al. (1982) and the relevant MDS plots were derived.

For the above mentioned analyses phytoplankton species subsets were used retaining the 20 most important species at all samples from surface (2m) per sampling period and zooplankton species subsets were constructed from all the identified species and groups.

The previously mentioned k-dominance curves, cluster and MDS analyses were performed using the software package PRIMER developed in Plymouth Marine Laboratory, U.K. (Clarke and Green, 1988).

Finally, a matrix based on Euclidean distances was constructed for each sampling period compiling phytoplankton, zooplankton and environmental data again from surface (2m). Principal Components Analysis (PCA) was applied on these matrices, in order to assess any relations between biological and environmental variables (Legendre and Legendre, 1983).

Phytoplankton and zooplankton data were log (1+x) transformed and the software used for this latter ordination technique was the program STATITCF, developed in the Institut Technique des Cereales et de Fourrages, France.

4. RESULTS

4.1 Physical parameters

4.1.1 September 1989

A typical summer situation both for Saronikos Gulf and Elefsis Bay is apparent during this oceanographic cruise. The well mixed layer over the thermocline has a depth of about 30 meters in Saronikos Gulf and about 20 meters in Elefsis Bay as it can be seen from Figures 2, 5a and 5b.

Salinities are low at the surface layers of Saronikos Gulf (Fig. 3b, 4b) and increase with depth at deeper layers reaching the usual values of the area (38.7-38.9 p.p.t.). In Elefsis Bay salinities are more homogenous over the whole column of water, been about 38.6 p.p.t.

The difference of salinity between the two places is an indication of restricted water exchange between Saronikos Gulf and Elefsis Bay.

Temperature is about 24EC in the well mixed surface layer at both places and decreases with depth reaching about 15EC in Saronikos Gulf deeper layers and 14EC in Elefsis Bay.

4.1.2 February 1990

Winter conditions are quite apparent both in TS diagram (Fig. 6) and in temperature, salinity and density profiles (Fig. 9a, 9b). The whole mass of Saronikos Gulf is well mixed, as it can be seen both from the above mentioned figures, with

temperatures about 14°C and salinities about 38.6 p.p.t. Elefsis bay is also well mixed, with lower temperatures (about 11°C) and lower salinities (about 38.5 p.p.t.) than Saronikos Gulf.

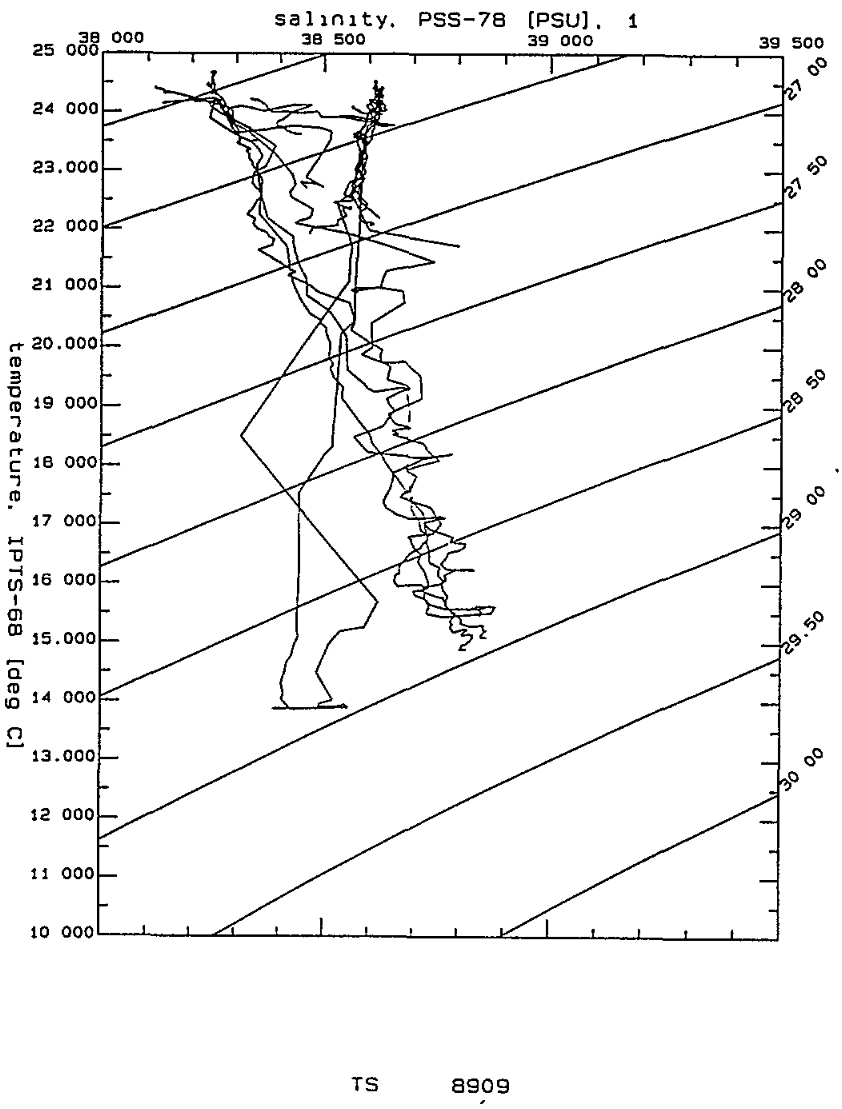


Fig. 2 TS diagram of temperature and salinity of all stations during September 1989

In TS diagram (Fig. 6) the two water masses are quite distinct, Elefsis Bay been colder and less saline than Saronikos Gulf. A temperature front is appearing in Keratsini strait and it seems that there is an outflow from Elefsis Bay towards Saronikos Gulf (Fig. 7a).

Density (σ_t) reaches to relatively high values mainly in Elefsis Bay (up to 29.5, Fig. 6 and Fig. 9b).

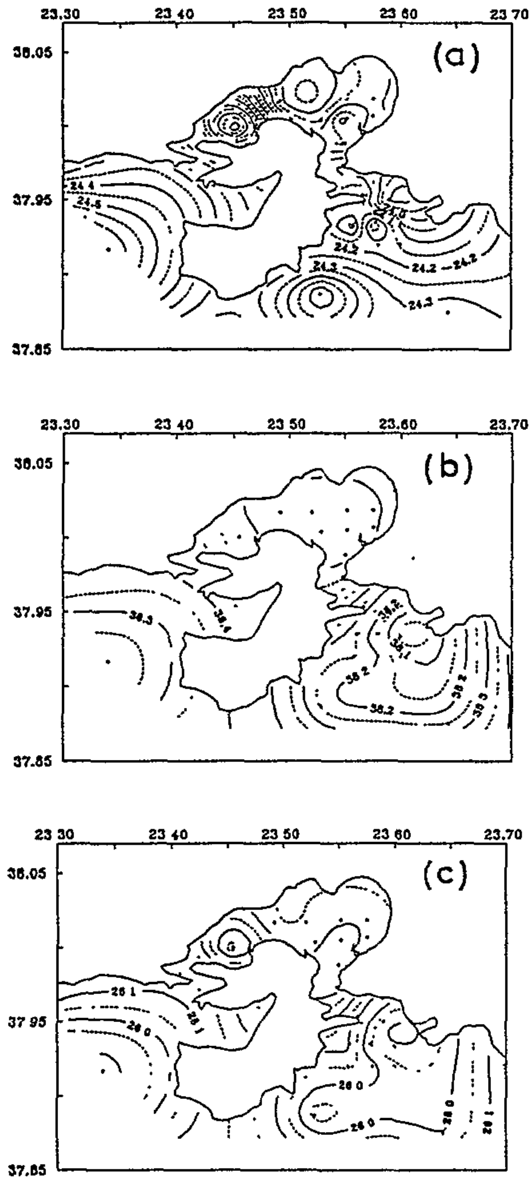


Fig. 3 Surface temperature (a), salinity (b) and density (σ_t, c) of all stations during September 1989

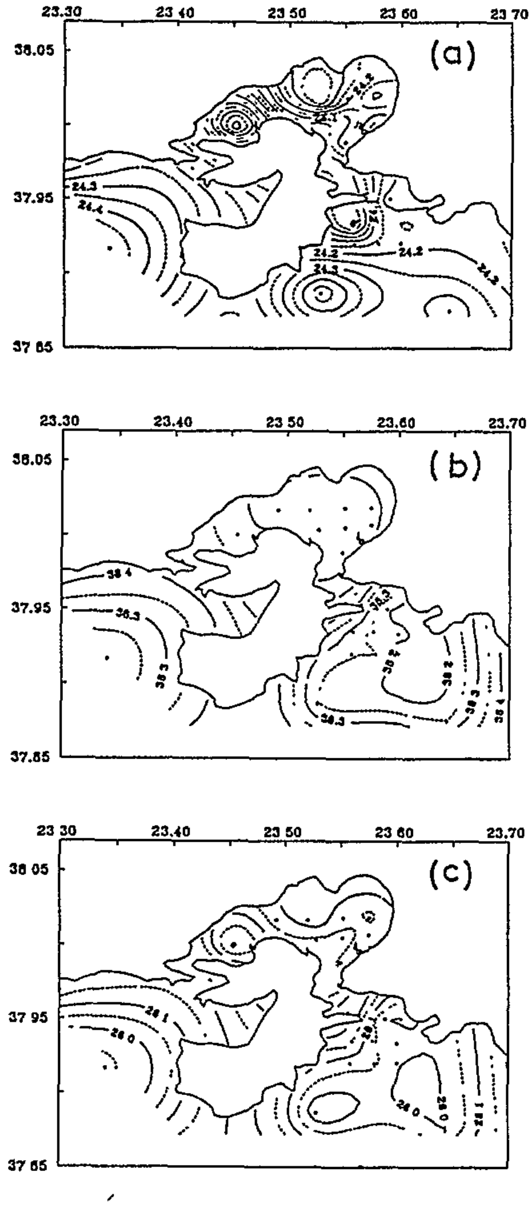


Fig. 4 Temperature (a), salinity (b) and density (σ_t, c) of all stations at 10m depth, during September 1989

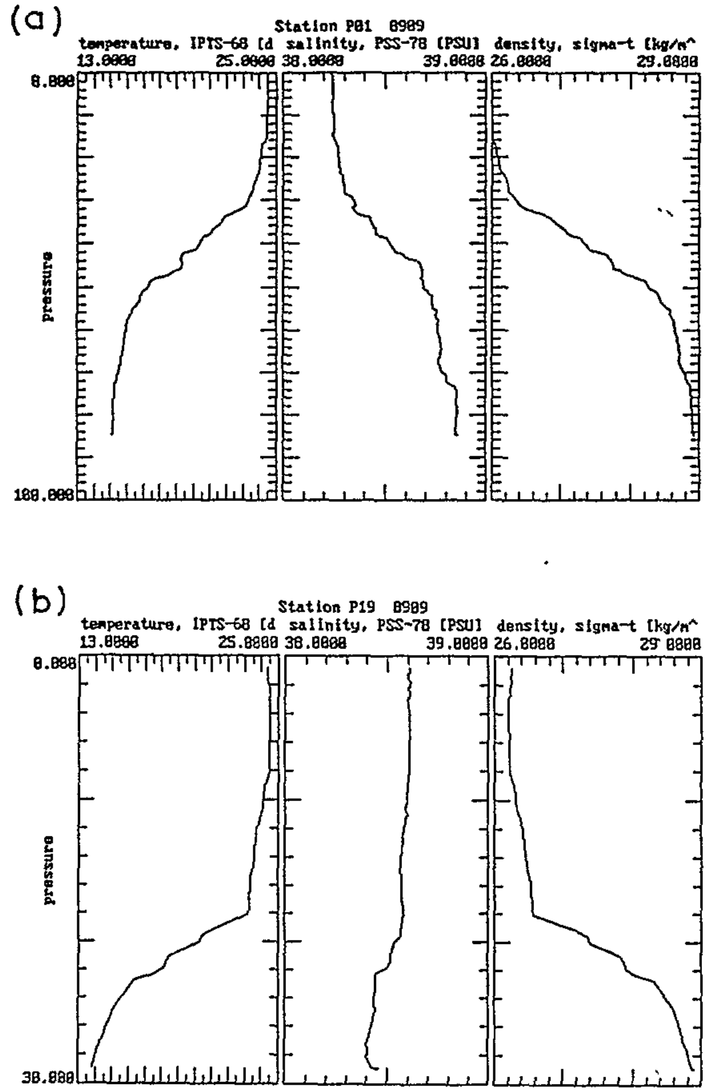


Fig. 5 Temperature, salinity and density (σ_t) profiles for a representative station (a) in Saronikos gulf (st. P01) and (b) another one in Elefsis Bay (st. P19), during September 1989

4.1.3 June 1990

The process of summer warming and increase of temperature is quite clear, the temperature increasing with depth from about 22°C at surface layers to about 14°C at bottom layers both in Saronikos Gulf and in Elefsis Bay (Figs. 10, 13).

Salinity is relatively stable in the whole area (Figs. 11b and 12b). Only in the vicinity of the sewage outfall there are some lower values (about 38.2 p.p.t.), the rest of the values been around 38.7 p.p.t.

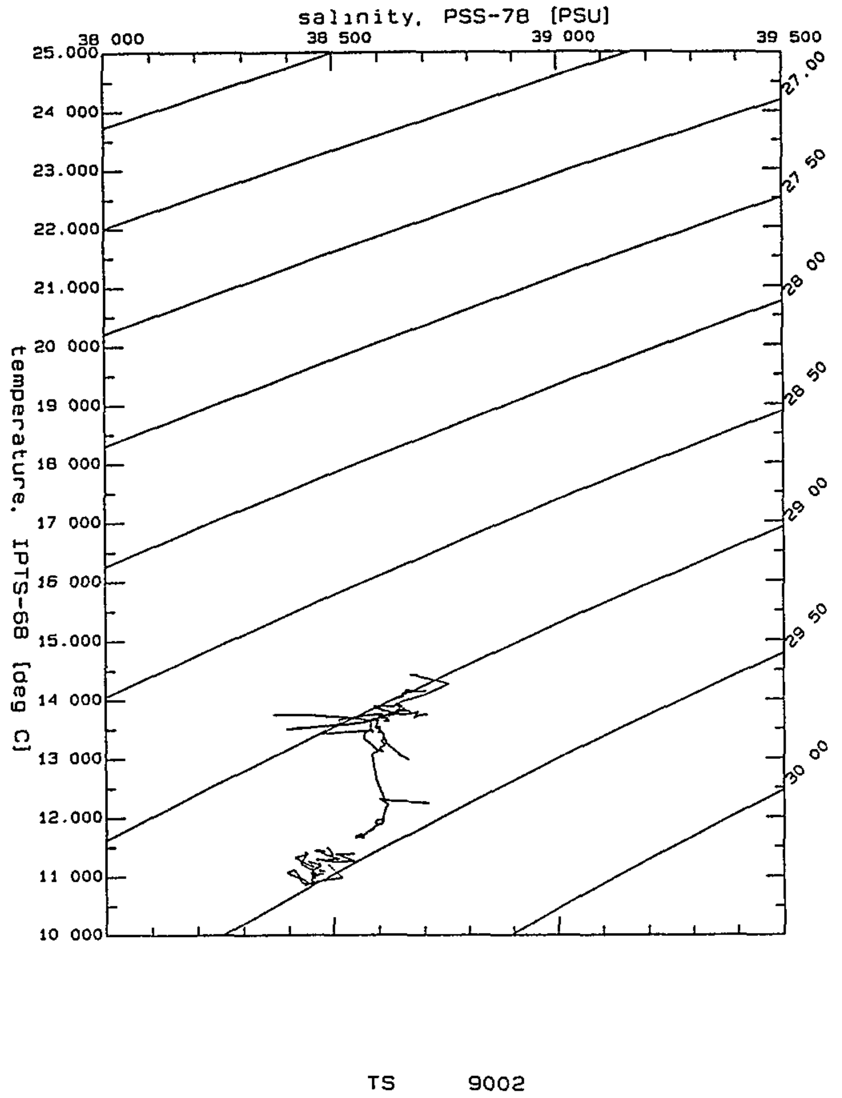


Fig. 6 TS diagram of temperature and salinity of all stations during February 1990

Both from TS diagram (Fig. 10) and from temperature, salinity and density profiles (Figs. 13a and 13b) it seems clear that the water masses of both Saronikos Gulf and Elefsis Bay are rather similar and that Elefsis Bay was well ventilated the period before the cruise.

4.1.4 May 1991

The most striking event during this cruise is the distinct difference of salinity between Saronikos Gulf and Elefsis Bay (Figs. 14, 15b, 16b and 17a, 17b).

Salinities in Saronikos Gulf reach up to 39 p.p.t., whereas inside Elefsis Bay salinities are about 38.3 p.p.t. at surface layers and 38.5 at bottom layers.

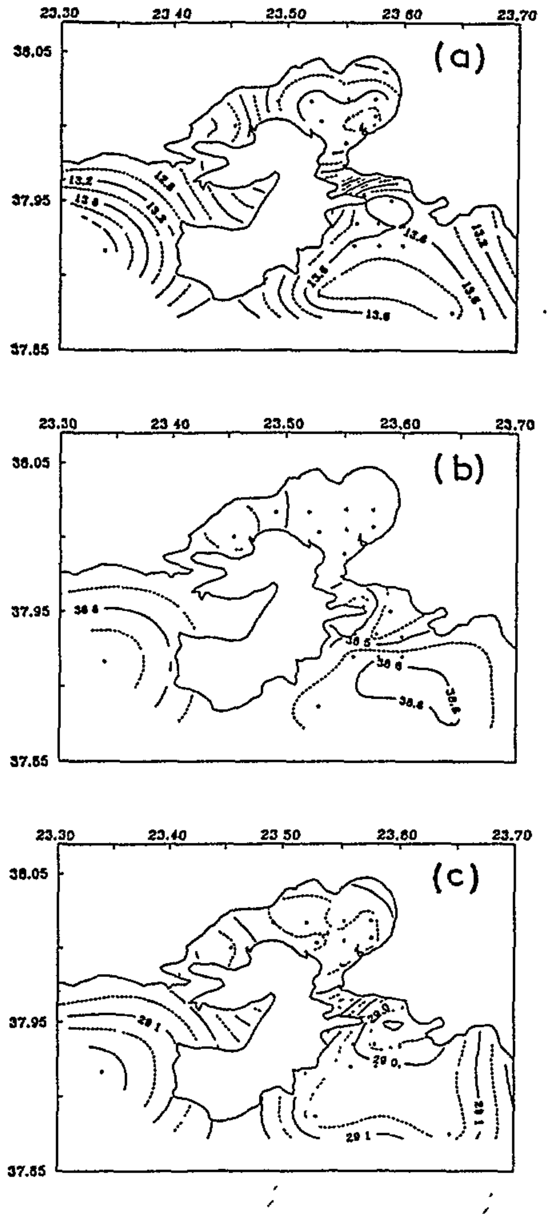


Fig. 7 Surface temperature (a), salinity (b) and density (σ_t, c) of all stations, during February 1990

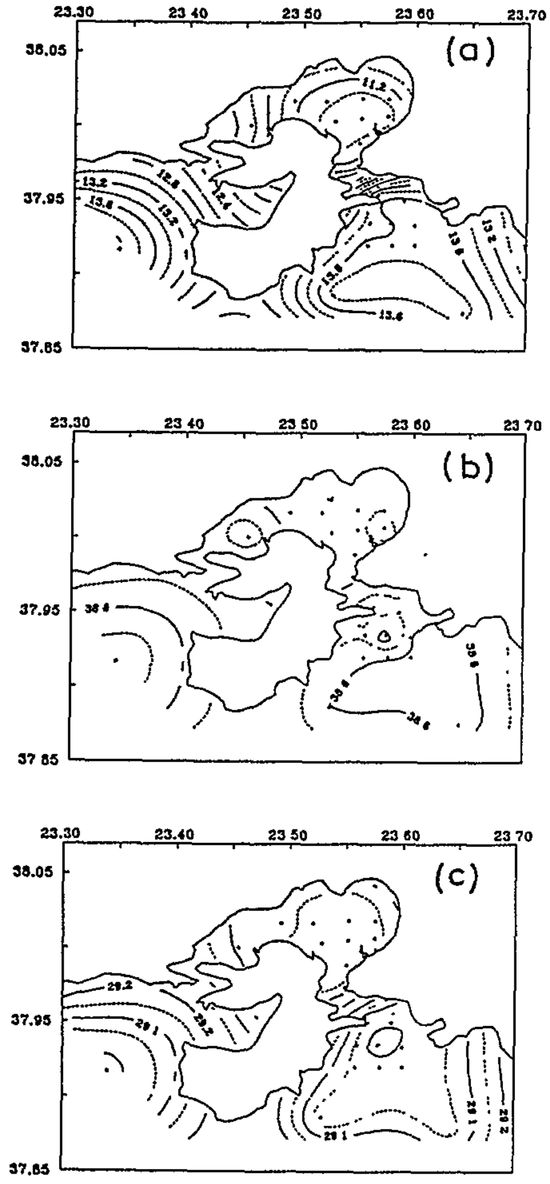


Fig. 8 Temperature (a), salinity (b) and density (σ_t, c) of all stations at 10 meters depth, during February 1990

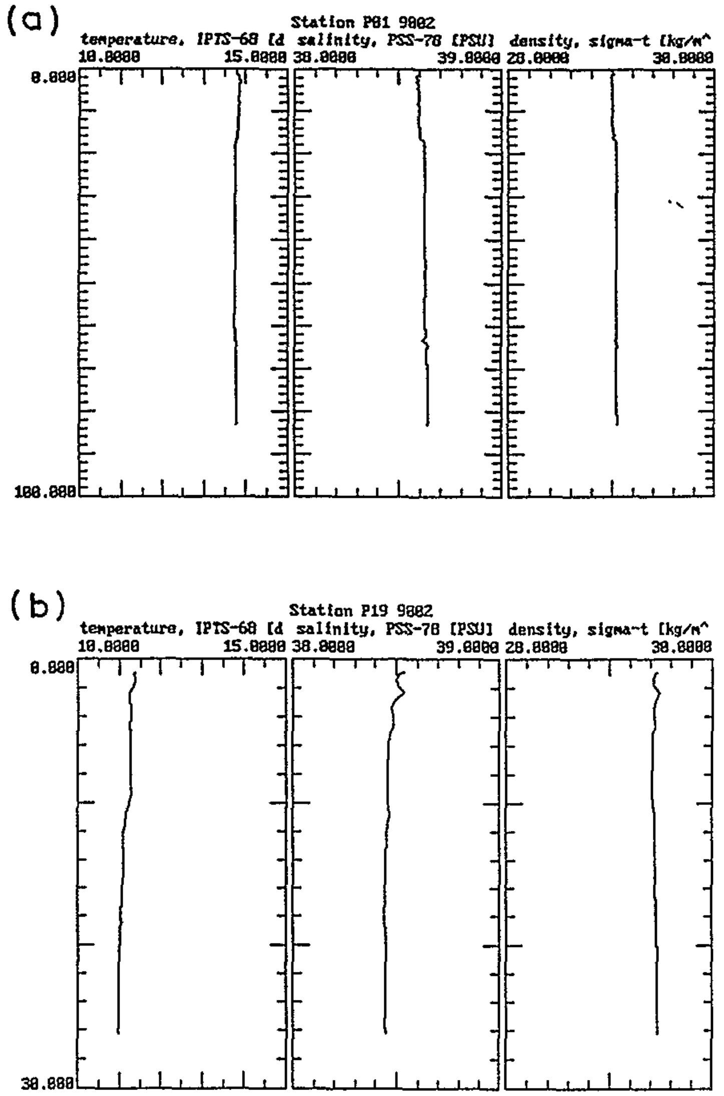


Fig. 9 Temperature, salinity and density (σ_t) profiles for a representative station: (a) in Saronikos gulf (st. P01) and (b) another one in Elefsis bay (st. P19), during February 1990

Surface temperature in Elefsis Bay is higher than Saronikos Gulf due to quicker responde to summer heating procedure (Figs. 15a, 16a, 17a and 17b). At deeper layers Elefsis Bay has low temperature values reaching below 13°C, whereas temperature in Saronikos Gulf reaches 14°C at deeper layers.

5. CHEMICAL PARAMETERS

5.1 Dissolved oxygen

The dissolved oxygen concentrations for the two sampled depths (2m, 10m) that have been measured during the five seasonal cruises from September 1989 till

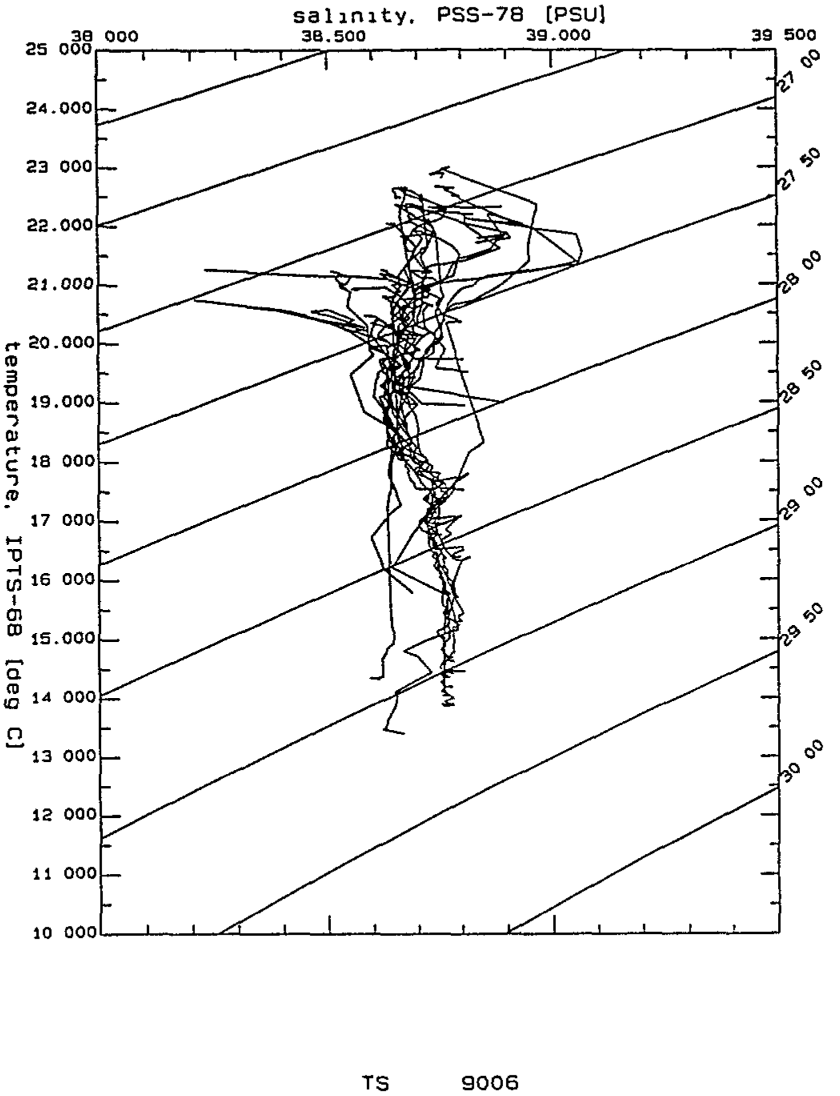


Fig. 10 TS diagram of temperature and salinity of all stations during June 1990

May 1991 are presented at Table 3. The lowest concentration (3.49 ml/l) was recorded at station P20 (depth: 10m, Elefsis bay) during May 1991 and the highest (6.07 ml/l) at station P18 (depth: 2m, Elefsis bay) during the same period. From the results presented at Table 3, it is obvious that during all periods high values of dissolved oxygen concentrations have been recorded and no essential differences were noticed between areas or seasons, whereas seawater was in most cases oversaturated.

5.2 Nutrients

5.2.1 September 1989

Nitrites: The lowest concentration of nitrites (0.03 μg-at/l) was recorded at station P02 (10m) of inner Saronikos, whereas the highest value (0.50 μg-at/l) at station P08 (2m) near the sewage outfall. It is obvious that nitrites fluctuated in a low

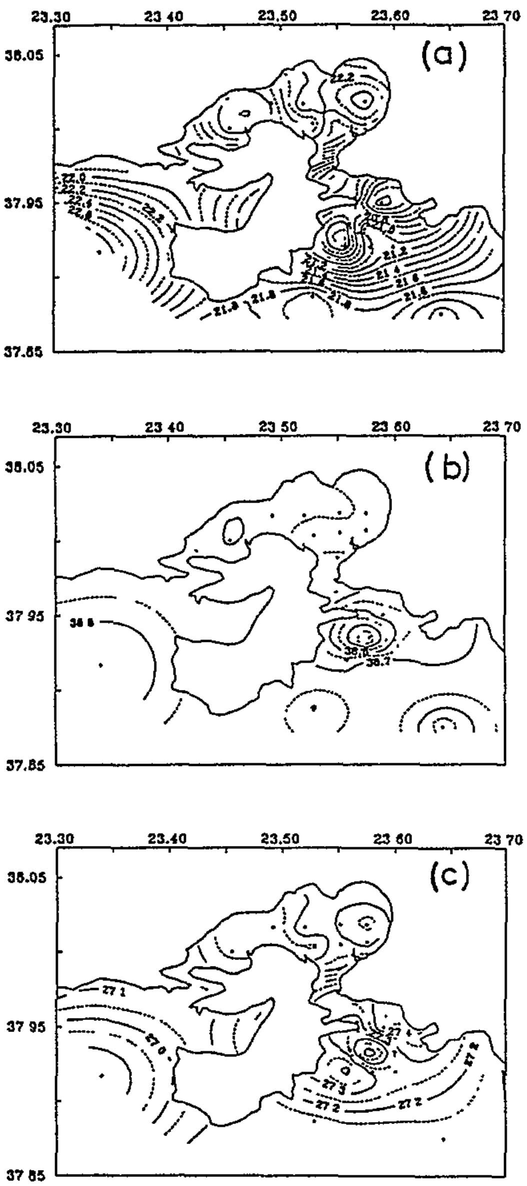


Fig. 11 Surface temperature (a), salinity (b) and density (σ_t, c) of all stations during June 1990

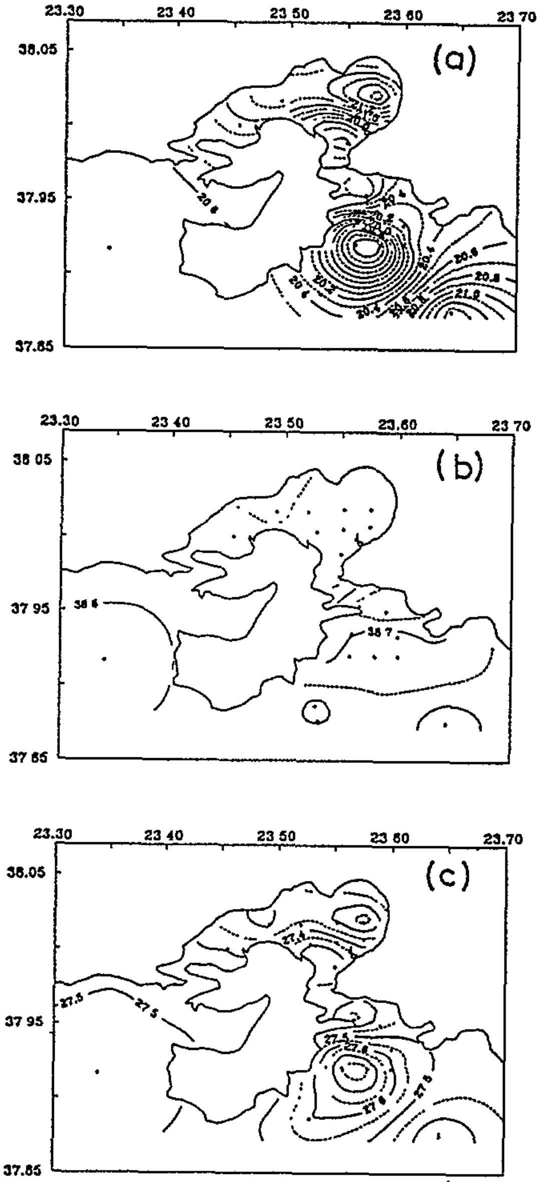


Fig. 12 Temperature (a), salinity (b) and density (σ_t, c) of all stations at 10 meters depth, during June 1990

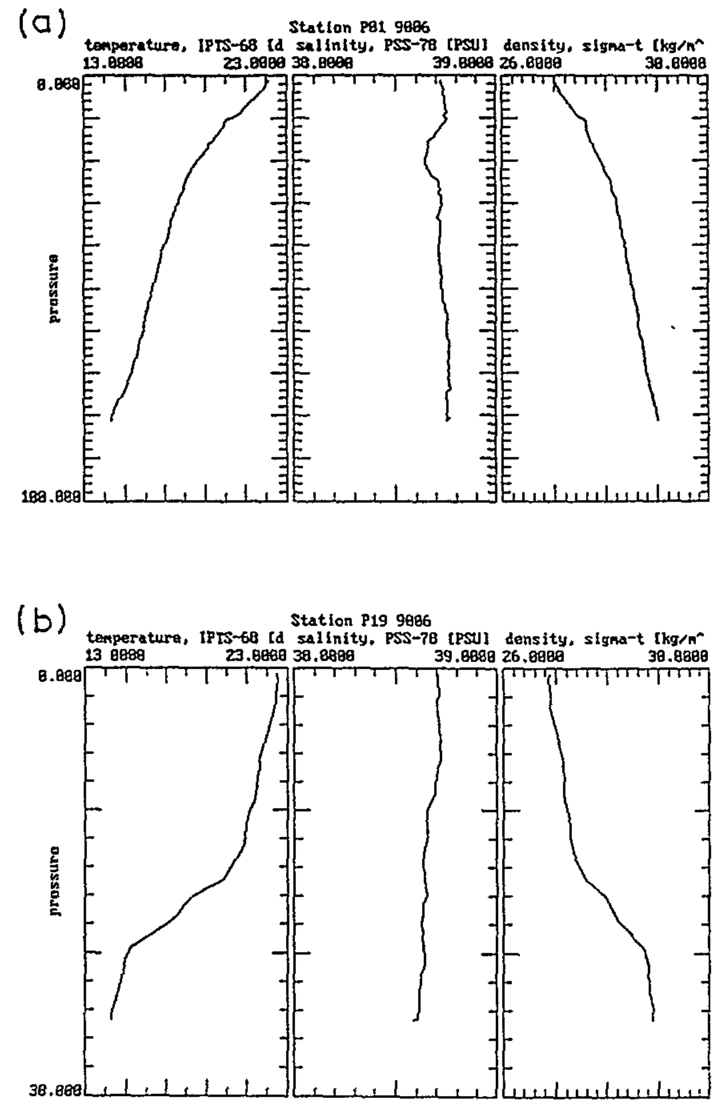


Fig. 13 Temperature, salinity and density (σ_t) profiles for a representative station: (a) in Saronikos gulf (st. P01) and (b) another one in Elefsis bay (st. P19), during June 1990

range. As it can been seen from Figure 18 nitrites concentrations are higher near the sewage outfall at the 2m depth is concerned (Fig. 18a) and are more uniformly distributed at the 10m depth (Fig. 18b).

Nitrates: Concentrations of nitrates exhibited a wider range than nitrites from 0.02 μg-at/l (st. P02, 2m, 10m) in the inner gulf to 1.49 μg-at/l (st. P08, 2m) in the sewage area. From Fig. 19 it is obvious that a similar distribution for both sampling depths has been occurred at this period with higher values at the surface (2m) of the sewage outfall area.

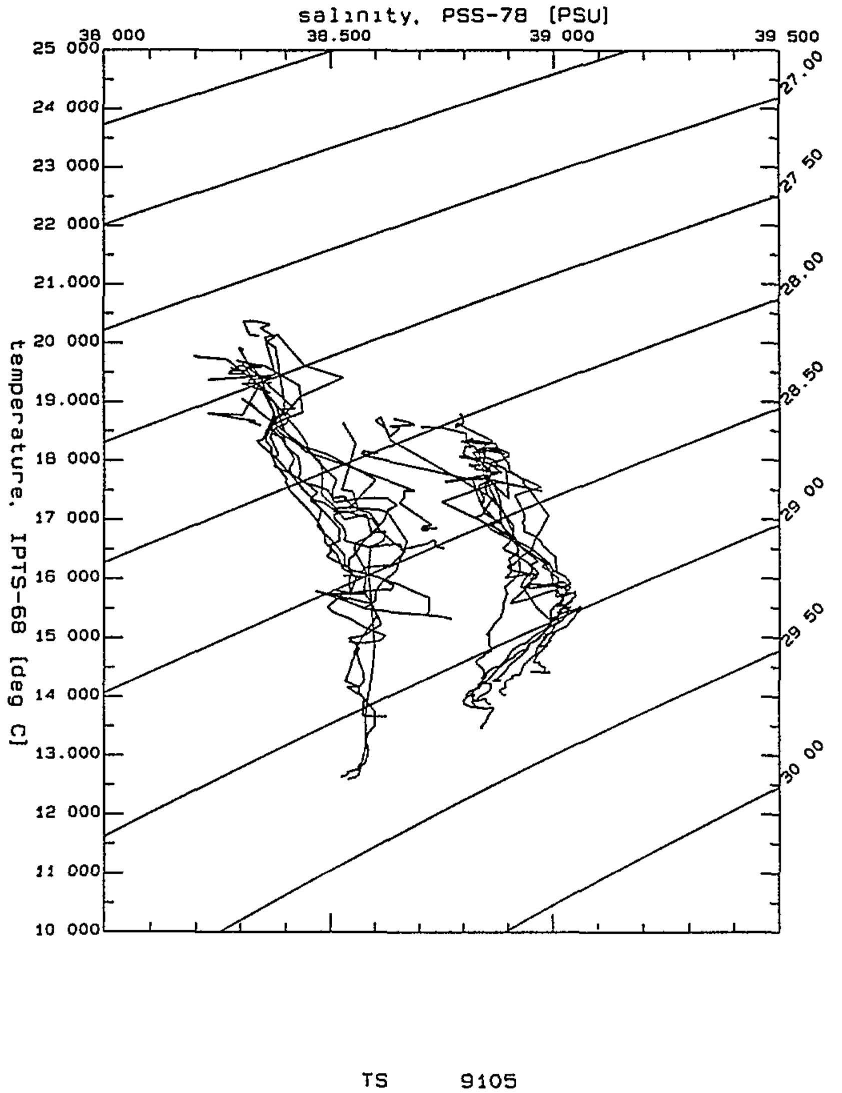


Fig. 14 TS diagram of temperature and salinity of all stations, during May 1991

Ammonium: Concentrations of ammonium reached the value of 4.43 μg-at/l at station P08 (2m), whereas the minimum value of 0.20 μg-at/l was recorded at station P01 (10m). At both sampling depths and especially at 2m very high concentrations of ammonium were recorded at the sewage outfall area (Fig. 20a, b).

Phosphates: The same distribution pattern was detected for phosphates (Fig. 21a, b), as for nitrates and ammonium. The lowest recorded value was 0.04 μg-at/l at station P02 (2m, 10m), station P04 (2m) and station P05 (10m) and the highest value was 1.12 μg-at/l at station P08 (2m).

Silicates: Concentrations of silicates ranged from 0.65 μg-at/l at station P04 (2m) to 7.82 μg-at/l at station P20 (10m). Higher concentrations were recorded at 10m almost at all stations, whereas according to the distribution pattern (Fig. 22a, b), a similar pattern was prevailed for both sampling depths with higher values at the western part of Elefsis bay.

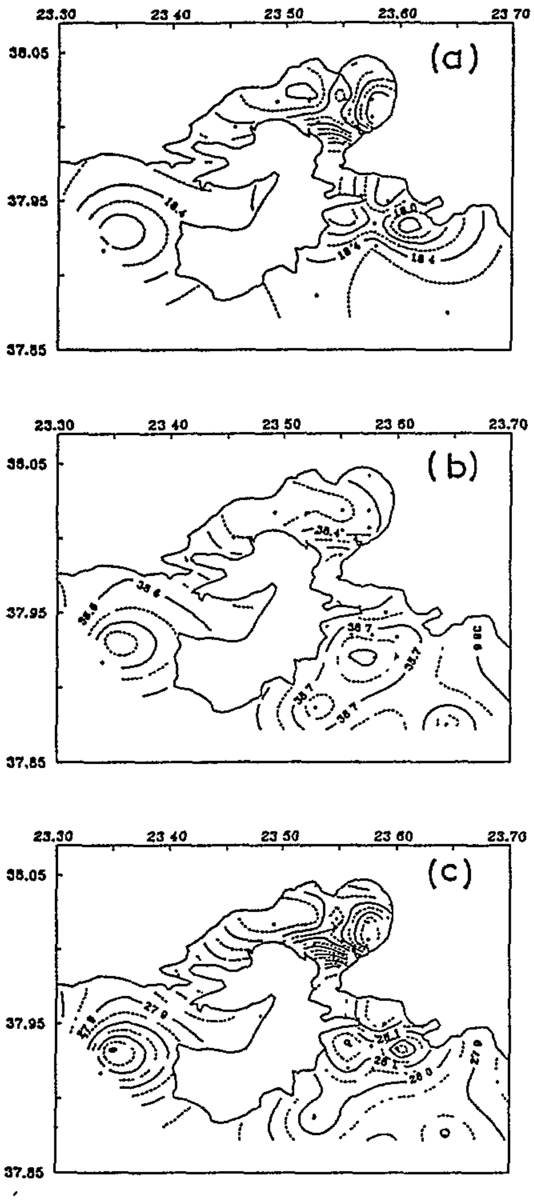


Fig. 15 Surface temperature (a), salinity (b) and density (σ_t, c) of all stations during May 1990

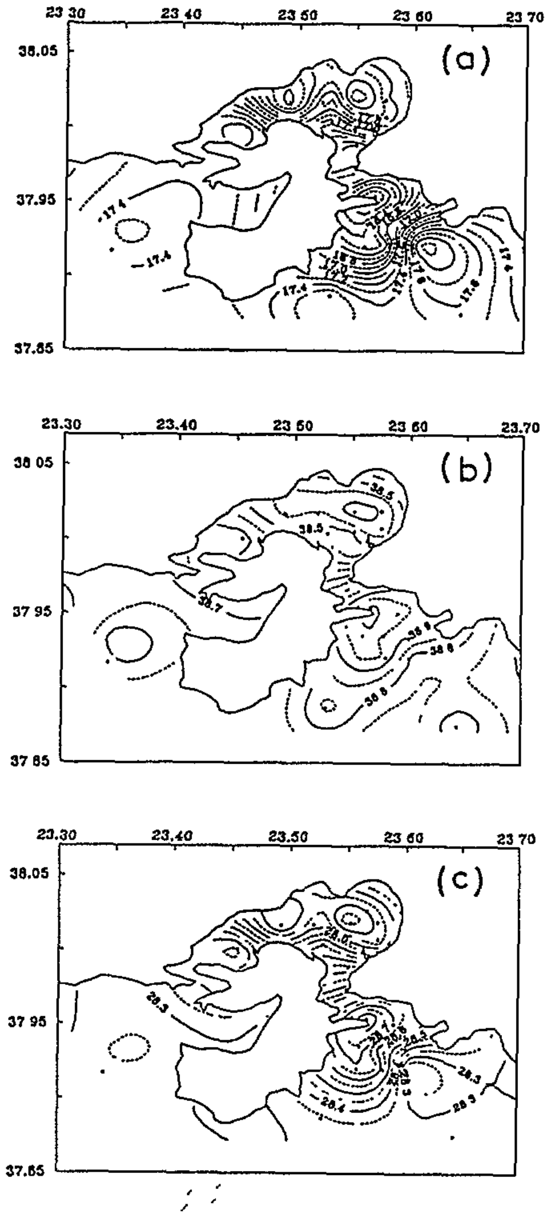


Fig. 16 Temperature (a), salinity (b) and density (σ_t, c) of all stations at 10 meters depth, during May 1990

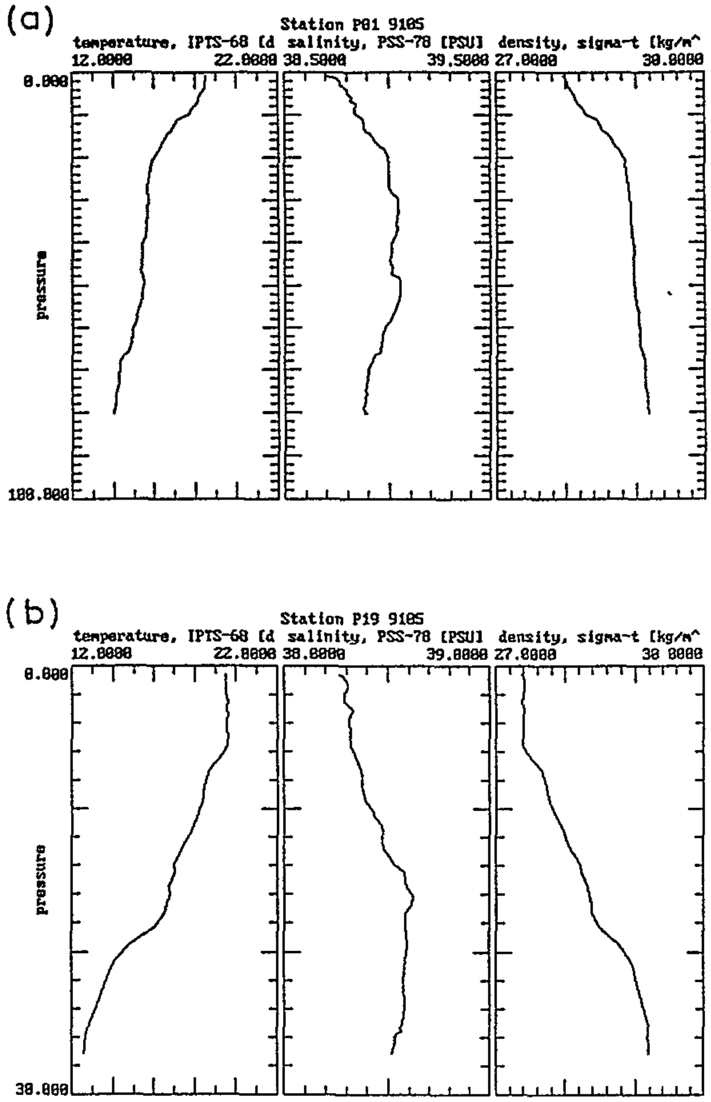


Fig. 17 Temperature, salinity and density (σ_t) profiles for a representative station: (a) in Saronikos gulf (st. P01) and (b) another one in Elefsis bay (st. P19), during May 1991

5.2.2 December 1989

Nitrites: Higher concentrations were recorded at both sampling depths, during this period rather during September 1989, ranging from 0.13 μg-at/l (st. P02, 10m) to 0.78 μg-at/l (st. P09, 2m). The distribution pattern (Fig. 23a, b) showed differences between areas for each depth with increasing concentrations at the sewage outfall area for the 2m and in Elefsis bay for the 10m.

Table 3

Dissolved oxygen concentrations (ml/l) in Saronikos gulf

Cruise	September 1989		December 1989		February 1990		June 1990		May 1991	
Depth Station	2m	10m	2m	10m	2m	10m	2m	10m	2m	10m
P01	4.76	4.58	5.36	5.07	5.69	5.69			5.47	5.47
P02	4.79	4.79	5.17	5.17	5.78	5.58			5.35	5.41
P03	4.41	3.89	5.23	5.21	5.75	5.59	5.26	5.30	5.30	5.58
P04	4.26	4.36	5.06		5.44	5.41	5.35	5.35	5.59	5.60
P05	4.36	4.35	5.07	5.13	5.51	5.46	5.41	5.39	5.57	5.59
P06	5.03	4.93	4.65	4.99	5.41	5.36	4.71	5.02	5.16	5.36
P07	4.63	4.64	4.84	4.88	5.32	5.35	5.35	5.30	5.35	5.48
P08	4.22	4.51	4.93	4.98	5.03	5.02	5.17	5.15	5.24	5.30
P09	4.64	4.74	4.66	4.60	5.21	5.23	4.93	5.26	5.40	4.87
P10	5.03	4.55	5.22	5.18	5.20	5.07	5.35	5.03	4.82	4.66
P11	5.03	4.83	5.54	5.50	5.88	5.98	5.07	4.93	4.61	4.54
P12	5.23	5.02	5.34	5.42	5.94	5.92	4.92	4.16	5.29	3.77
P13	5.07	4.93	5.45	5.36	6.03	5.97	5.07	5.12	5.92	4.06
P14	5.02	4.64	5.42	5.36	5.89	5.99	5.16	5.11	4.23	5.11
P15	4.98	4.02			5.98	5.94			6.02	4.28
P16	5.07	4.60	5.36	5.37	5.92	5.92	4.90	4.78	5.26	4.19
P17	5.21	4.70	5.55	5.42	5.99	5.75	5.36	3.92	6.01	4.04
P18	4.97	4.55	5.39	5.27	5.82	5.88	5.12	4.97	6.07	4.21
P19	5.20	4.93			5.88	5.83	5.40	4.36	6.03	4.85
P20	4.41	3.89	5.50	5.44	5.89	5.82			5.53	3.49
P21	4.80	4.70			5.56	5.89			5.53	5.54

Nitrates: The same distributional pattern was observed for nitrates (Fig. 24a, b) with higher values at the sewage area for the 2m and in Elefsis bay for the 10m, whereas the range of concentrations extended from 0.34 µg-at/l (st. P02, P20, 2m) to 2.73 µg-at/l (st. P18, 10m). Another interesting point is that higher values of nitrates were recorded at 10m than at 2m, especially in Elefsis bay.

Ammonium: A somewhat different picture was present for the ammonium distribution pattern at 10m depth where high concentrations were observed both at the sewage area and the northern part of Elefsis bay, whereas again the highest values for 2m were recorded at the area around the sewage outfall (Fig. 25a, b). Maximum values characterise the surface waters of Keratsini bay and the 10m depth of Elefsis bay, ranging from 0.33 µg-at/l at station P02 (2m) of inner Saronikos to 6.73 µg-at/l at station P06 (2m) near Selinia bay.

Phosphates: Their distribution was quite different from the previously described nutrients, with a little higher concentrations near the sewage at 2m and low values rather uniformly distributed in all other areas and at 10m (Fig. 26a, b) ranging from 0.04 µg-at/l (st. P02, 2m) to 0.97 µg-at/l (st. P09, 10m).

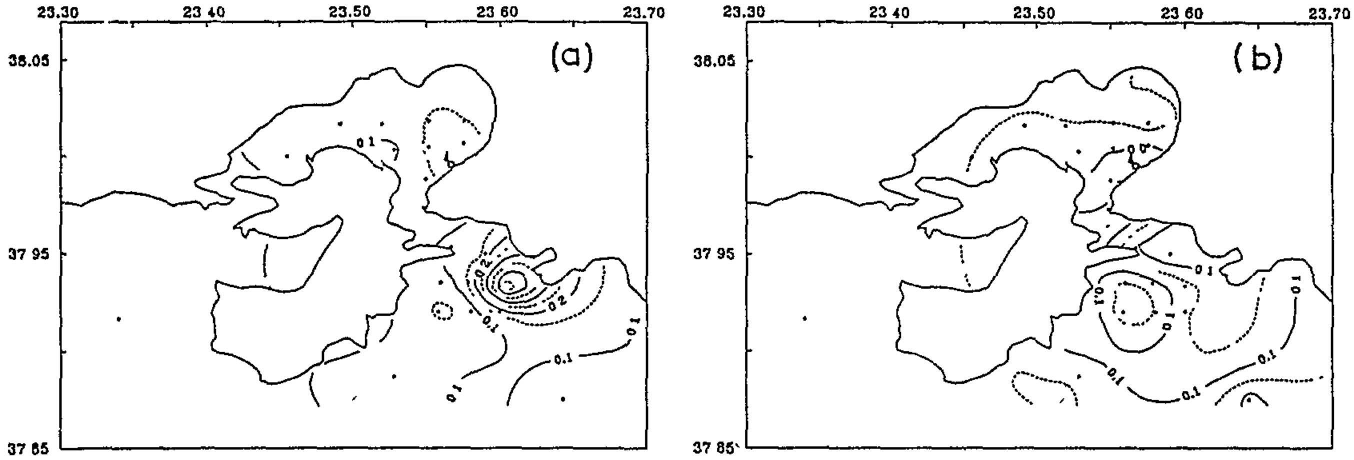


Fig. 18 Nitrite distribution in Saronikos gulf, during September 1989: (a) at 2m depth and (b) at 10m depth

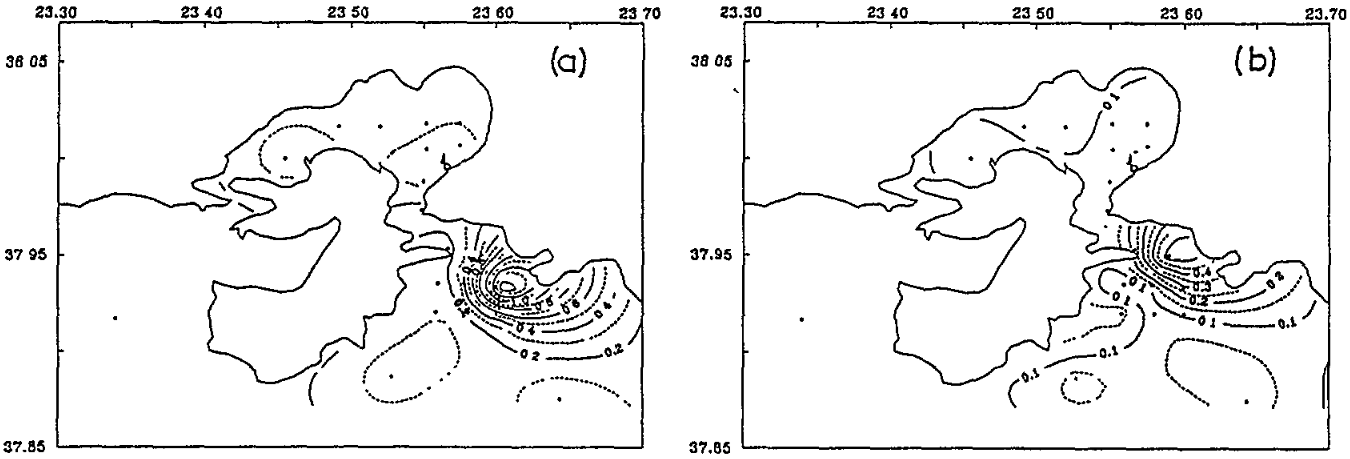


Fig. 19 Nitrate distribution in Saronikos gulf, during September 1989: (a) at 2m depth and (b) at 10m depth

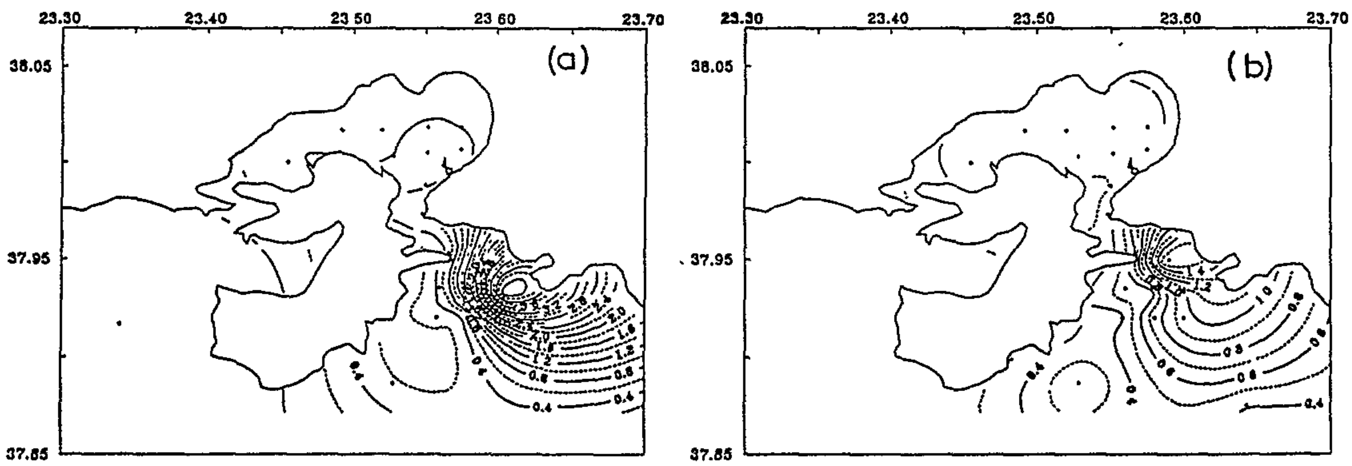


Fig. 20 Ammonium distribution in Saronikos gulf, during September 1989: (a) at 2m depth and (b) at 10m depth

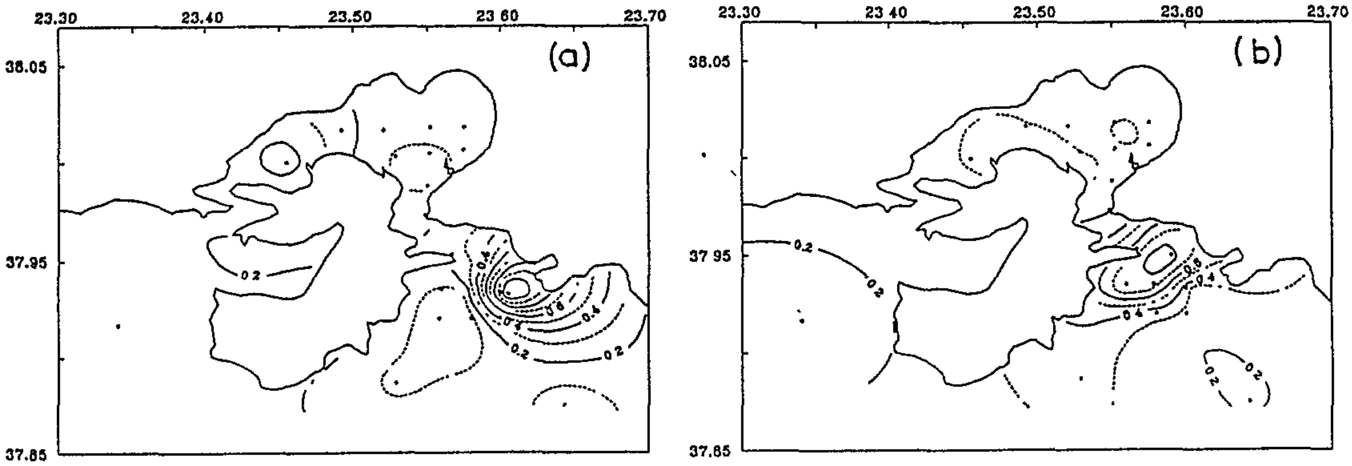


Fig. 21 Phosphates distribution in Saronikos gulf, during September 1989: (a) at 2m depth and (b) at 10m depth

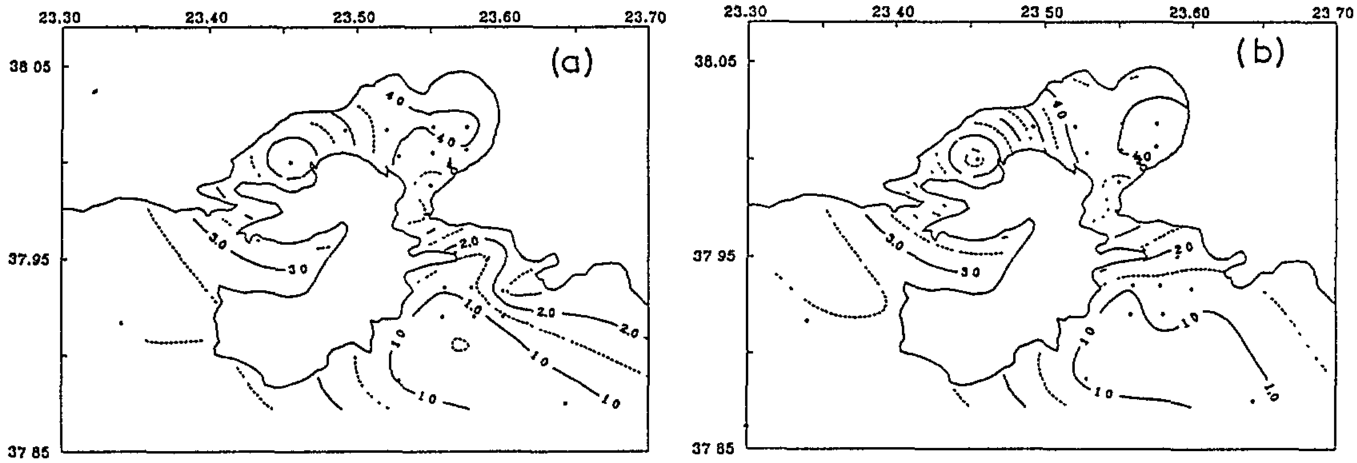


Fig. 22 Silicates distribution in Saronikos gulf, during September 1989: (a) at 2m depth and (b) at 10m depth

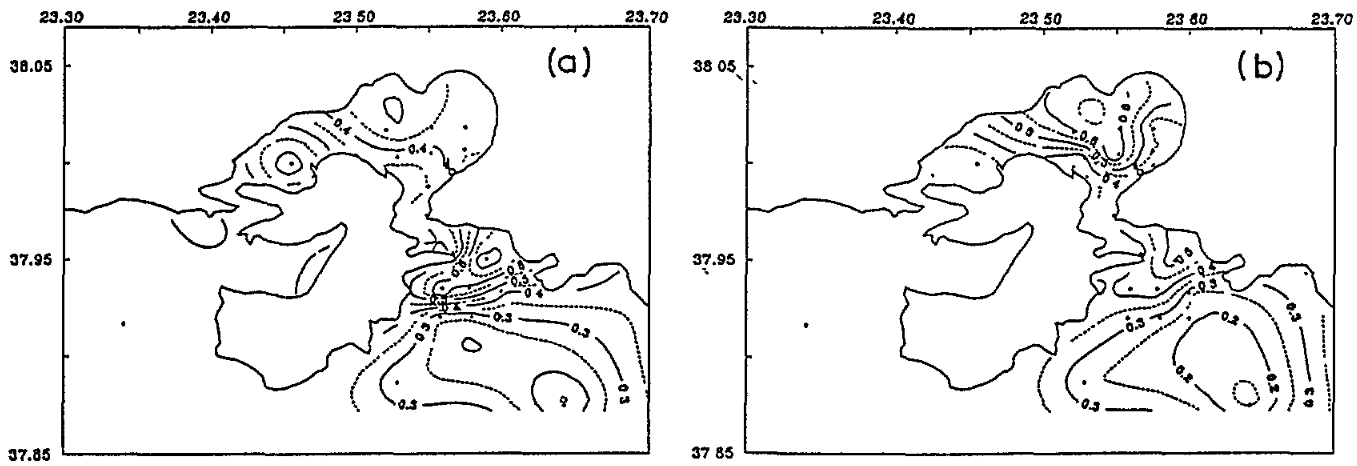


Fig. 23 Nitrites distribution in Saronikos gulf, during December 1989: (a) at 2m depth and (b) at 10m depth

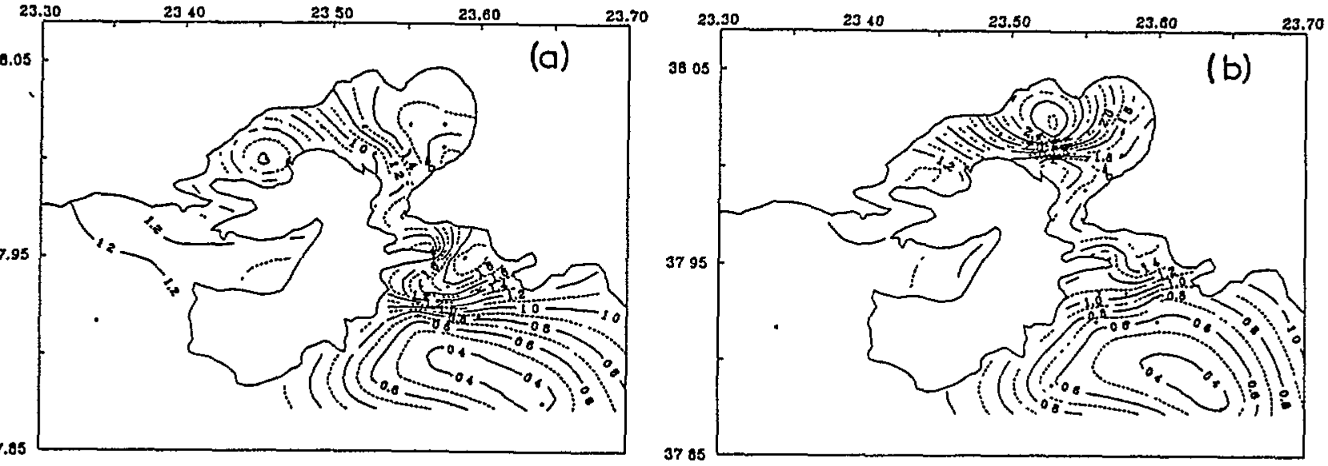


Fig. 24 Nitrates distribution in Saronikos gulf, during December 1989: (a) at 2m depth and (b) at 10m depth

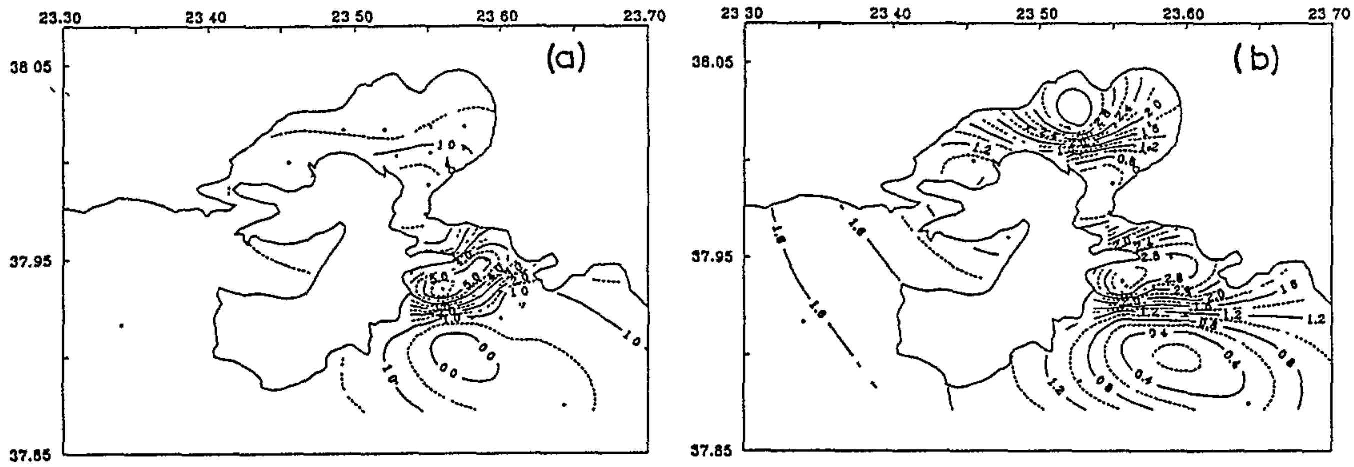


Fig. 25 Ammonium distribution in Saronikos gulf, during December 1989: (a) at 2m depth and (b) at 10m depth

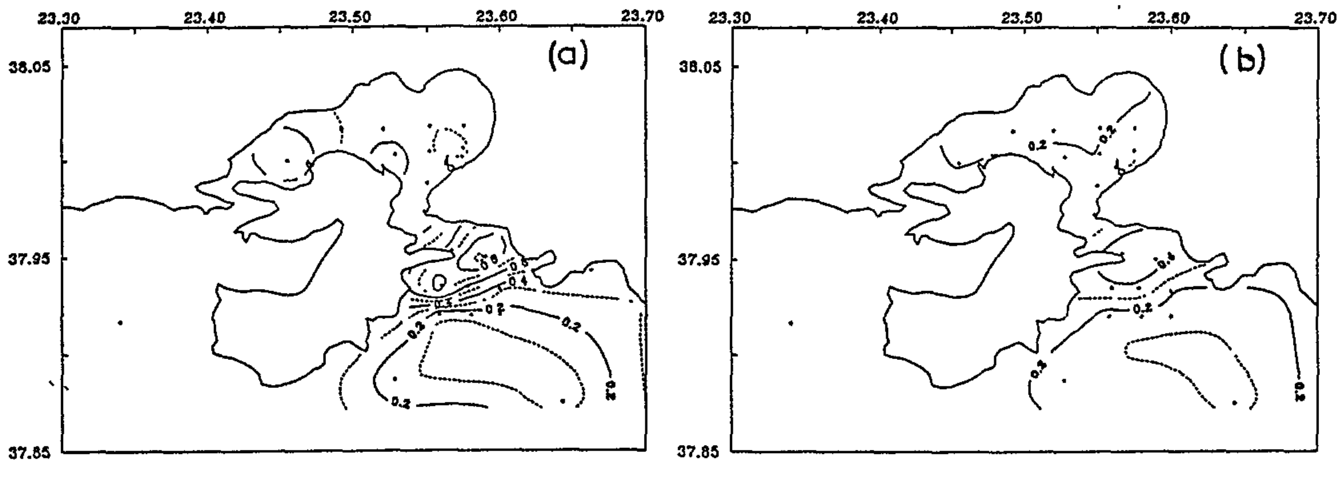


Fig. 26 Phosphates distribution in Saronikos gulf, during December 1989: (a) at 2m depth and (b) at 10m depth

Silicates: As it is obvious from the distribution pattern shown at Fig. 27 though high concentrations of silicates were recorded in Elefsis bay (about 6.0-8.0 µg-at/l) both at 2m (Fig. 27a) and 10m (Fig. 27b) depths the highest value (11.98 µg-at/l) was recorded at the sewage outfall area near Psitallia island at station P07 (2m). The lowest concentrations charactered the inner gulf with a minimum of 1.05 µg-at/l at station P02 (2m and 10m).

5.2.3 February 1990

Nitrites: Very low concentrations (0.03 µg-at/l at station P20-2m, 10m and station P14-10m) were recorded in Elefsis bay compared to those from the inner gulf and Keratsini bay (0.59 µg-at/l at station P09-10m) with similar distributions at all depths over the whole area (Fig. 28a, b).

Nitrates: The distribution pattern and ranges of concentrations for nitrates was also similar at both sampling depths (Fig. 29a, b) with an aggregation of high values in the area around the sewage outfall and a minimum value of 0.06 µg-at/l at station P13 (10m) of Elefsis bay and a maximum of 1.73 µg-at/l at station P09 (10m) at Keratsini bay.

Ammonium: Again high concentrations were aggregated for both depths (2m, 10m) at the sewage area (Fig. 30a, b), whereas the range of concentrations for all areas was between 0.11 µg-at/l at station P16 (10m) and 3.61 µg-at/l at station P09 (2m, 10m).

Phosphates: Very low concentrations were recorded for this salt also in Elefsis bay and considerably higher at the area influenced by the sewage as it can been seen from Fig. 31a and 31b, for both sampling depths. Phosphates concentrations were ranging from 0.08 µg-at/l at stations P15 (2m) and P20 (10m) to 1.21 µg-at/l at station P06 (2m).

Silicates: A more uniform distribution at 2m depth was prevailed than at 10m, where higher values were recorded in Elefsis bay (Fig. 32a, b). Silicates concentrations ranged from 1.14 µg-at/l at station P11 (10m) to 2.71 µg-at/l at stations P17 (10m), P18 (2m) and P19 (10m).

5.2.4 June 1990

Nitrites: Though very low values of nitrites were recorded in all areas, the extremely high concentrations of 2.13 µg-at/l at 2m and 2.11 µg-at/l at 10m of station P16 in Elefsis bay created the picture presented at Fig. 33a and 33b.

Nitrates: Higher concentrations were recorded near the sewage outfall at the 2m, whereas in all areas were kept in low levels (Fig. 34a, b), ranging from 0.06 µg-at/l at station P04 (2m) and P19 (10m) to 0.76 µg-at/l at station P10 (2m).

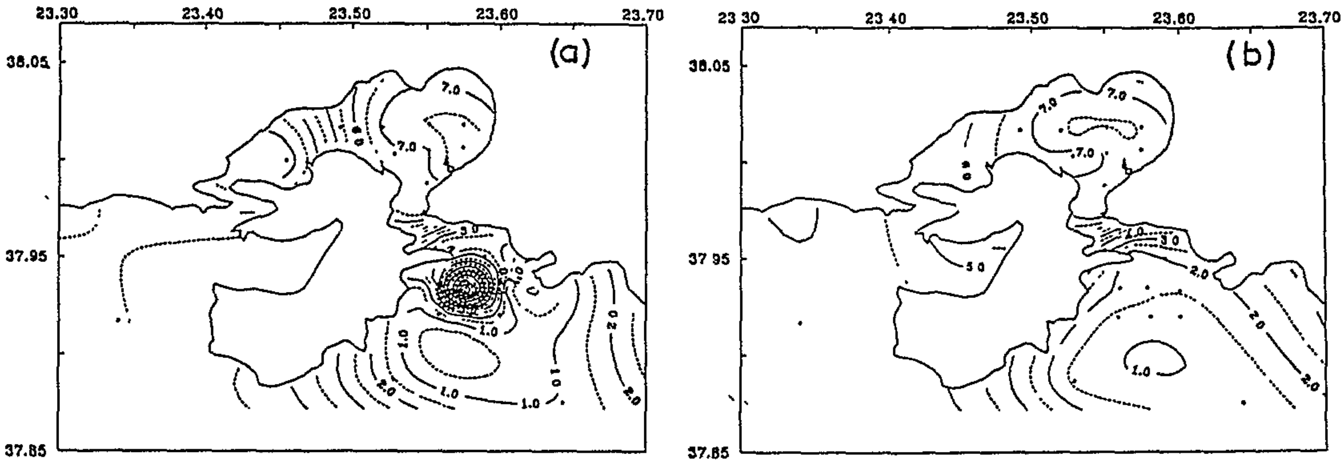


Fig. 27 Silicates distribution in Saronikos gulf, during December 1989: (a) at 2m depth and (b) at 10m depth

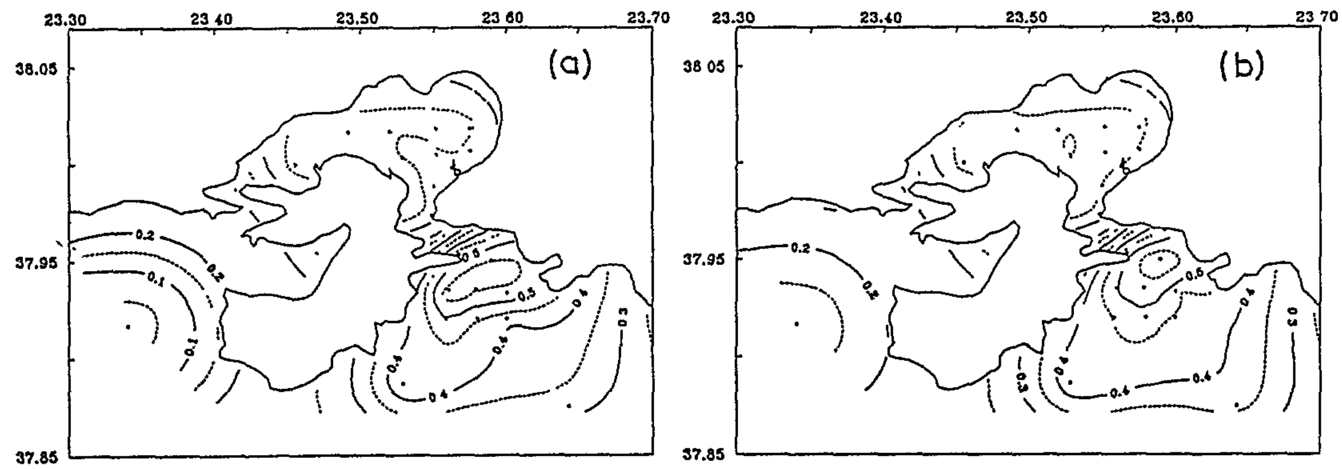


Fig. 28 Nitrites distribution in Saronikos gulf, during February 1990: (a) at 2m depth and (b) at 10m depth

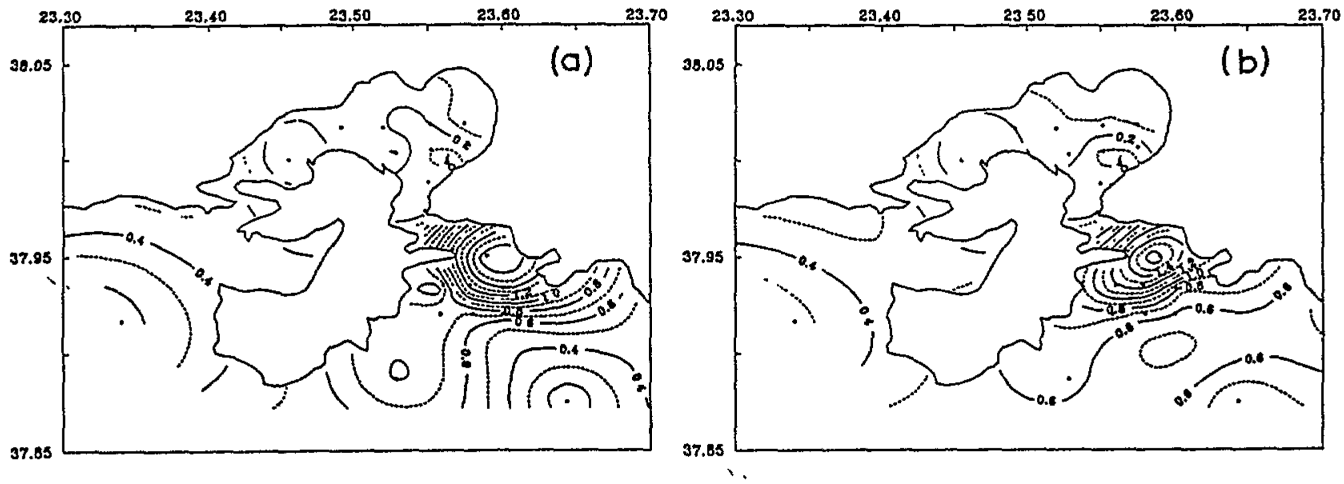


Fig. 29 Nitrates distribution in Saronikos gulf, during February 1990: (a) at 2m depth and (b) at 10m depth

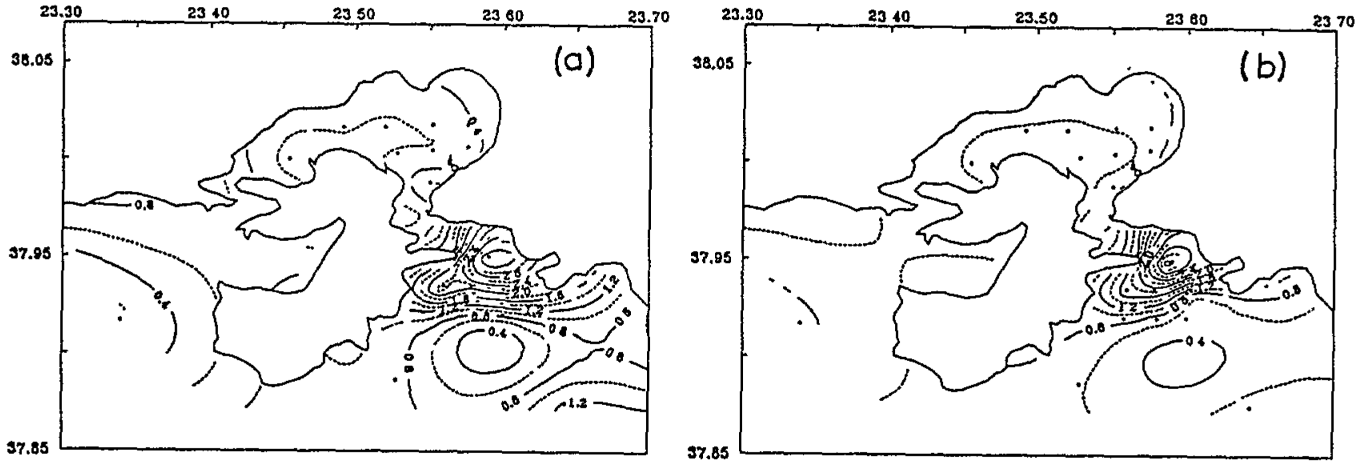


Fig. 30 Ammonium distribution in Saronikos gulf, during February 1990: (a) at 2m depth and (b) at 10m depth

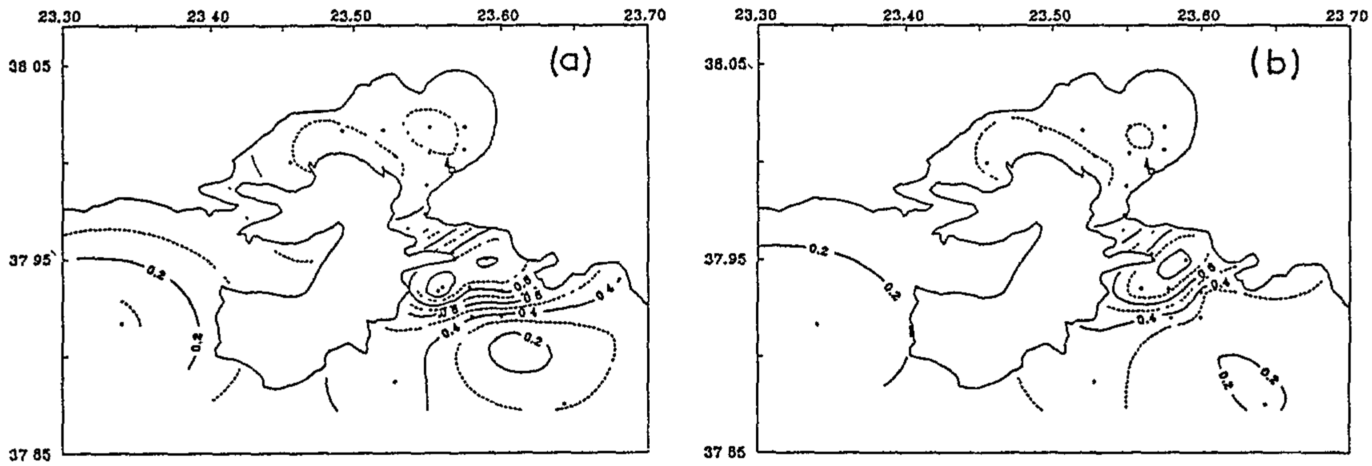


Fig. 31 Phosphates distribution in Saronikos gulf, during February 1990: (a) at 2m depth and (b) at 10m depth

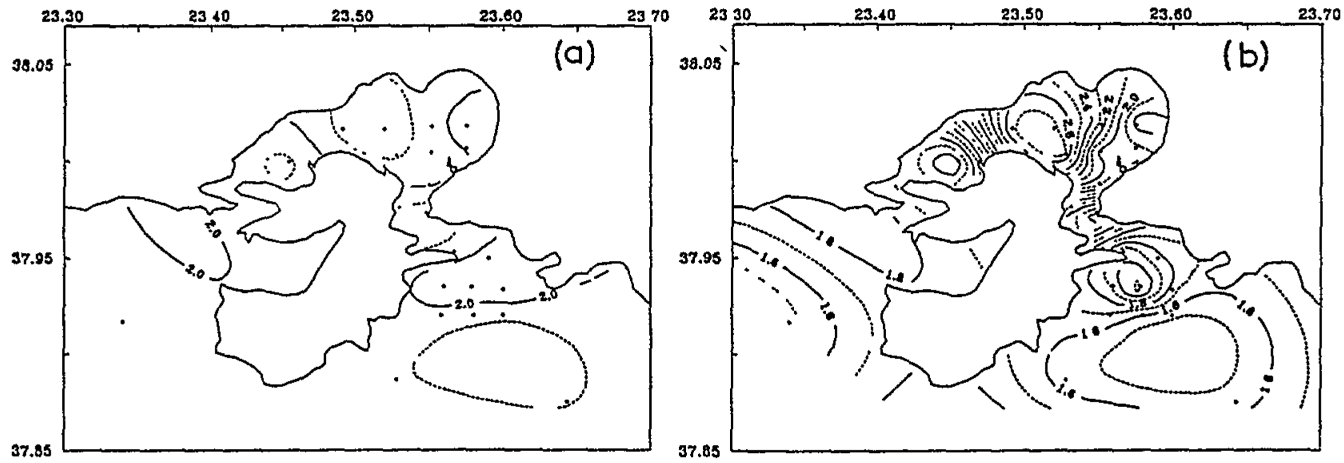


Fig. 32 Silicates distribution in Saronikos gulf, during February 1990: (a) at 2m depth and (b) at 10m depth

Ammonium: During this period, ammonium concentrations were kept low in comparison to those of all previous cruises, ranging from 0.10 µg-at/l at station P03 (10m) to 1.63 µg-at/l at station P08 (2m), with the higher values aggregated again around the sewage outfall as its obvious from Fig. 35.

Phosphates: The influence of the sewage outfall was significant in the concentrations of phosphates, which at this area were very high when compared to all other areas (Fig. 36a, b), ranging from 0.12 µg-at/l at stations P03 (2m), P04 (2m, 10m) and P08 (10m) to 3.23 µg-at/l at station P09 (2m).

Silicates: A different distribution pattern for the silicates exists between the two sampling depths (Fig. 37a, b). At the 2m depth high silicates values were recorded at Selinia bay, near the sewage outfall, whereas at 10m the higher concentrations were in Elefsis bay. The overall range of silicates was fluctuating between 0.56 µg-at/l at station P04 (2m) and 5.19 µg-at/l at station P06 (2m).

5.2.5 May 1991

Nitrites: Very low values rather uniformly distributed were recorded during this period, slightly increased southern of Psitallia island at the depth of 2m (Fig. 38a, b). Nitrites concentrations ranged from 0.01 µg-at/l at station P19 (2m) to 0.24 µg-at/l at station P08 (2m)

Nitrates: At the depth of 2m high values of concentrations were aggregated at the area mostly influenced by the sewage outfall, whereas at the depth of 10m the higher concentrations were recorded in Elefsis bay (Fig. 39a, b). Nitrates concentrations during this period ranged from 0.09 µg-at/l at station P01 (10m) to 1.71 µg-at/l at station P15 (10m).

Ammonium: The concentrations of this salt ranged from 0.13 µg-at/l at station P04 (10m) to 2.14 µg-at/l at station P08 (2m). A uniform distribution pattern was prevailed for the depth of the 10m (Fig. 40b), whereas at 1m again higher concentrations were recorded near the sewage (Fig. 40a).

Phosphates: Not a distinct pattern nor significant differences were detected among depths or areas for phosphates during this period, as it is obvious from Figure 41 (a and b). Concentrations of phosphates ranged from 0.04 µg-at/l at stations P01 (10m) and P05 (10m) to 0.38 µg-at/l at station P07 (2m).

Silicates: The concentrations of silicates ranged between 0.36 µg-at/l at station P02 (10m) and 5.91 µg-at/l at stations P16 (2m) and P20 (10m). A distinct distribution pattern between depths did not existed, whereas there was one between areas, with higher concentrations in Elefsis bay (Fig. 42a, b).

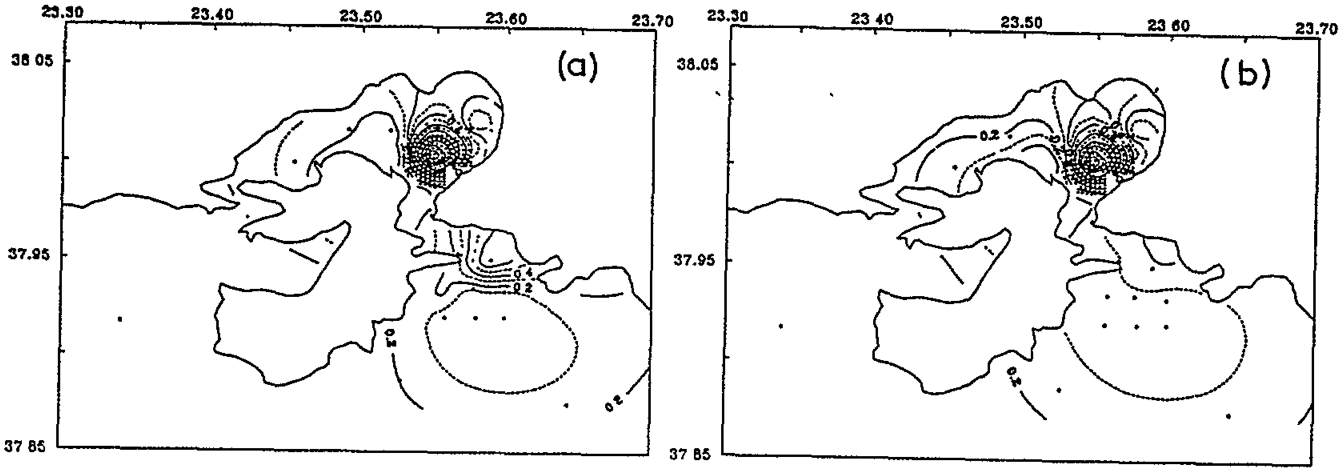


Fig. 33 Nitrites distribution in Saronikos gulf, during June 1990: (a) at 2m depth and (b) at 10m depth

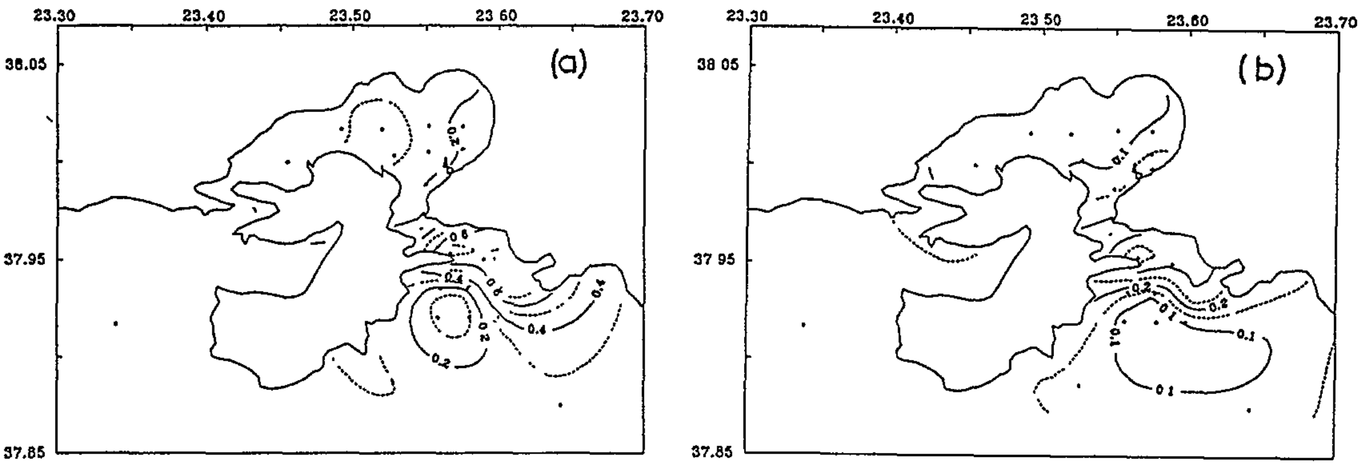


Fig. 34 Nitrates distribution in Saronikos gulf, during June 1990: (a) at 2m depth and (b) at 10m depth

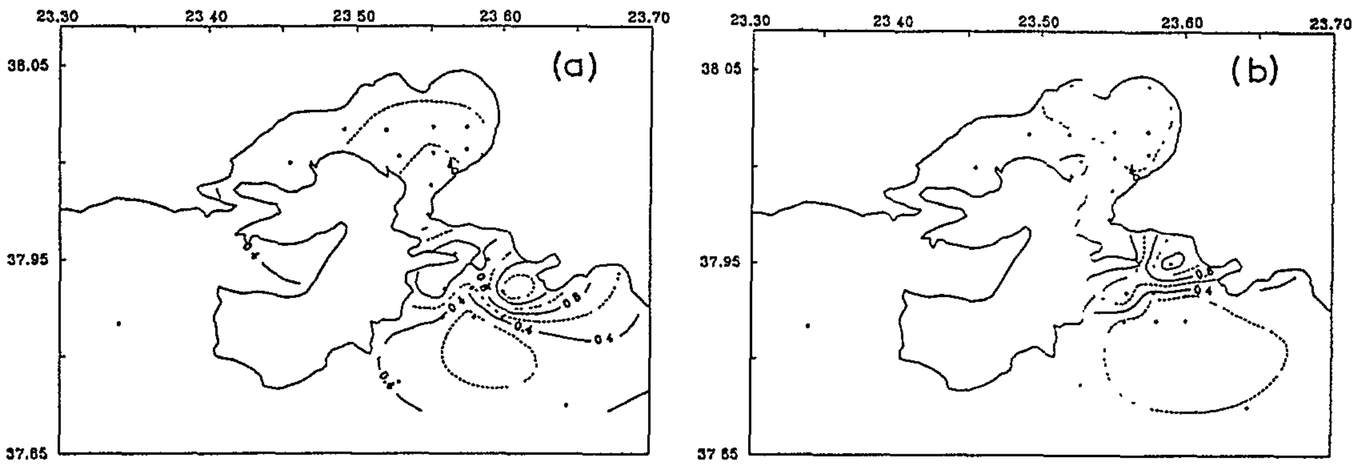


Fig. 35 Ammonium distribution in Saronikos gulf, during June 1990: (a) at 2m depth and (b) at 10m depth

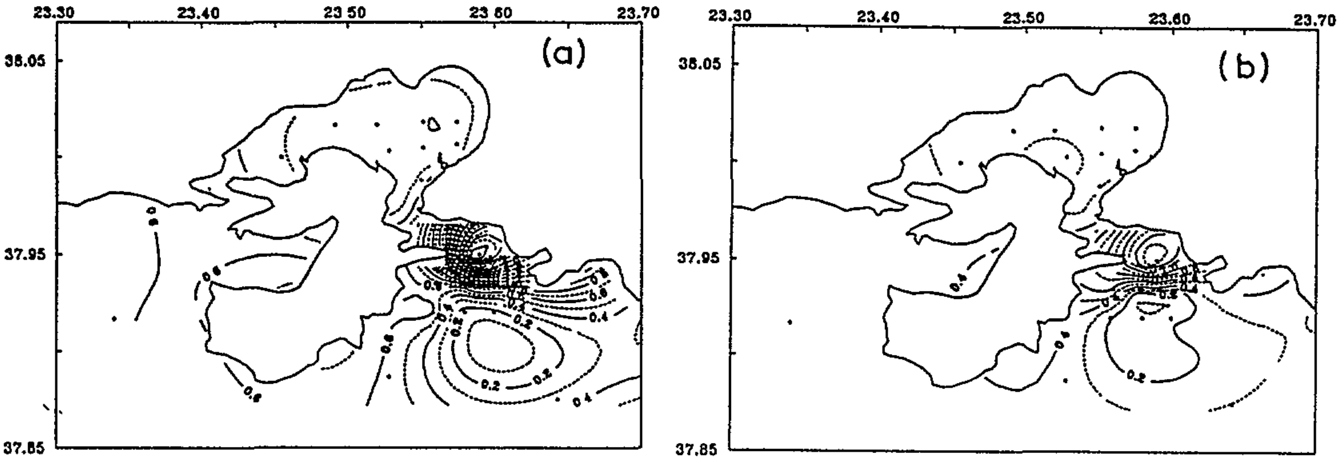


Fig. 36 Phosphates distribution in Saronikos gulf, during June 1990: (a) at 2m depth and (b) at 10m depth

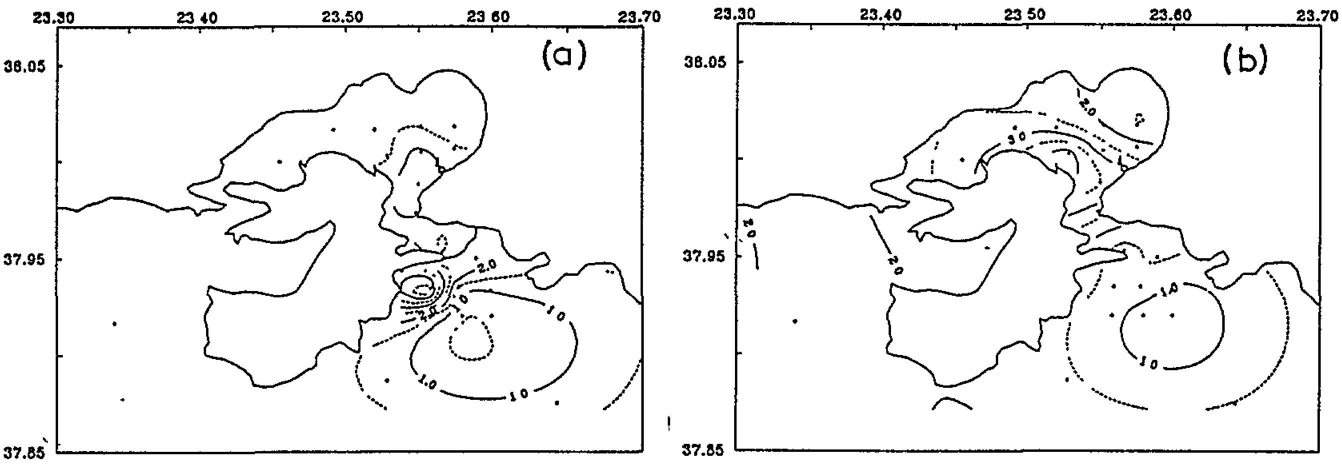


Fig. 37 Silicates distribution in Saronikos gulf, during June 1990: (a) at 2m depth and (b) at 10m depth

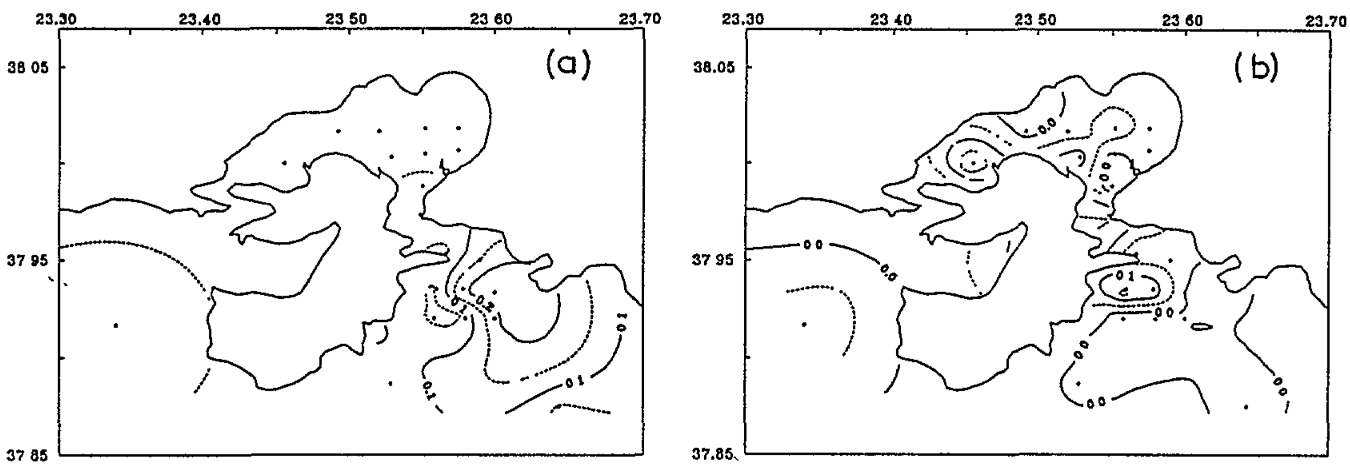


Fig. 38 Nitrites distribution in Saronikos gulf, during May 1991: (a) at 2m depth and (b) at 10m depth

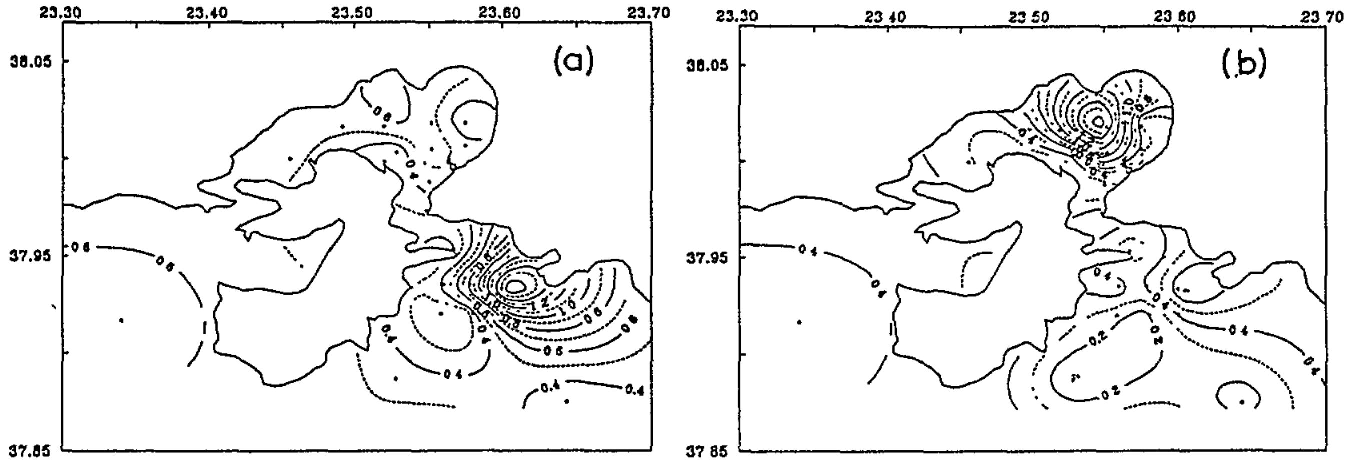


Fig. 39 Nitrates distribution in Saronikos gulf, during May 1991: (a) at 2m depth and (b) at 10m depth

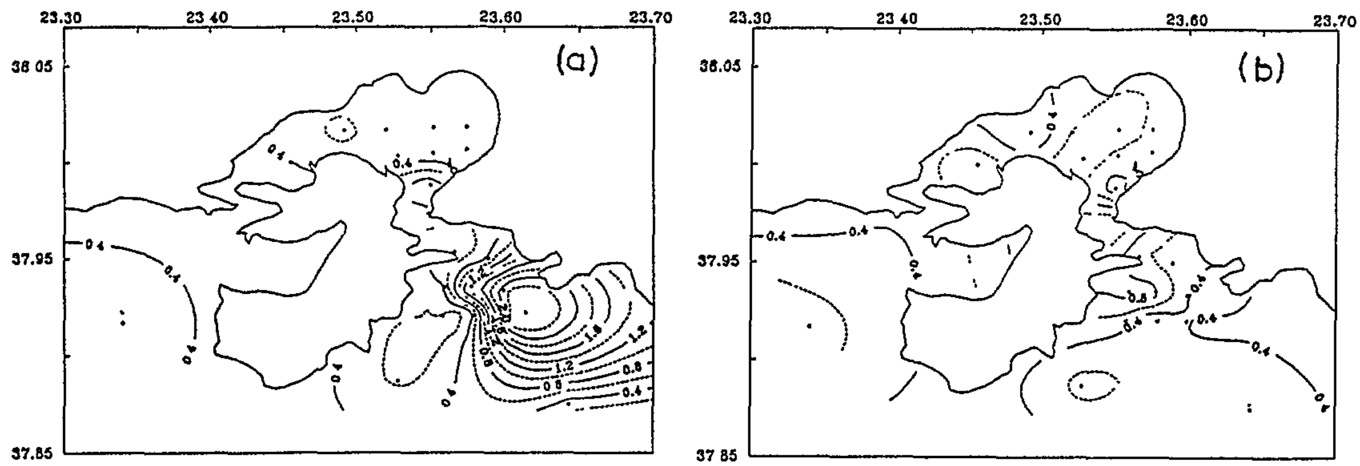


Fig. 40 Ammonium distribution in Saronikos gulf, during May 1991: (a) at 2m depth and (b) at 10m depth

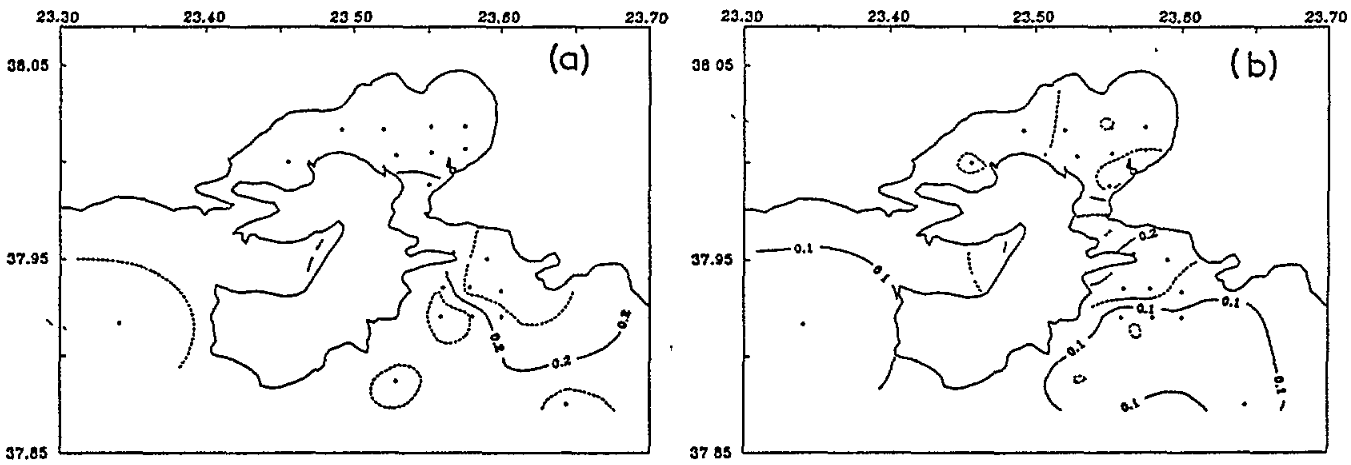


Fig. 41 Phosphates distribution in Saronikos gulf, during May 1991: (a) at 2m depth and (b) at 10m depth

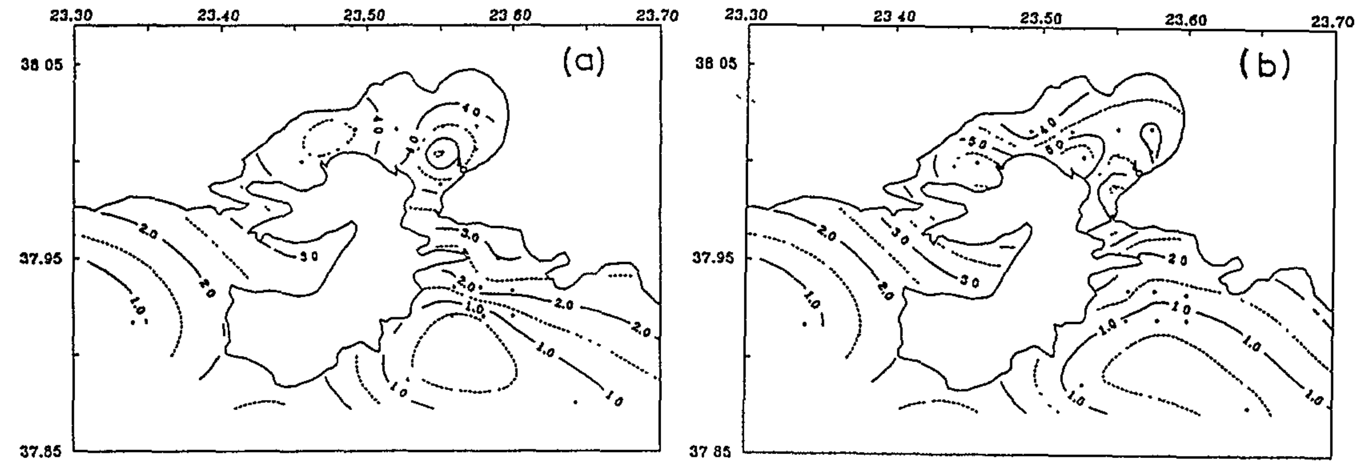


Fig. 42 Silicates distribution in Saronikos gulf, during May 1991: (a) at 2m depth and (b) at 10m depth

6. BIOLOGICAL PARAMETERS

6.1 Phytoplankton

6.1.1 Chlorophyll a

The measurement of chlorophyll a in the sea water, is widely used as a good estimation of biomass for phytoplankton populations. The values of chlorophyll a concentrations in the studied areas of Saronikos gulf, from September 1989 to March 1991 are presented at Table 4, whereas the plots of the distribution of these values for the surface (2m) and the depth of 10m are presented through Figures 43 to 47. The study of this table and figures reveal that except from February 1990, during all other seasons the lowest concentrations of chlorophyll a were recorded at station P21 and the highest were at Keratsini bay (stations P09 or P10).

September 1989: Ranges of chlorophyll a concentrations during September were between 0.17 μg/l at station P21 and 9.56 μg/l at station P10 for the 2m and between 0.22 μg/l at station P21 and 6.05 μg/l at station P10 for the 10m (Table 4). From Fig. 43 (a and b) it is obvious that there is a different distribution pattern between 2m and 10m, because at the 2m level high chlorophyll a concentrations were recorded not only at Keratsini bay but also in Elefsis bay (i.e. st. P16: 7.46 μg/l).

December 1989: During this period were recorded not only the highest values between all sampling periods (Table 4), ranging from 0.34 μg/l at station P21 (10m) to 29.86 μg/l at station P17 (2m), but also a quite different distribution pattern from all other seasons, for both sampling depths with all the extremely high chlorophyll a values aggregated in Elefsis bay (Fig. 44a and b).

<u>Table 4</u>

Chlorophyll <u>a</u> concentrations (µg/l) in Saronikos gulf, during the oceanographic cruises of September 1989, December 1989, February 1990, June 1990 and May 1991

STATION		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Month	Depth (m)																					
September 1989	2	0.20	0.27	2.61	1.22	1.33	4.22	2.07	2.30	2.71	9.56	3.57	4.31	4.33	4.56	2.85	7.46	4.61	4.19	4.67	2.66	0.17
	10	0.28	0.26	1.96	1.27	1.22	3.14	3.15	2.70	3.66	6.05	5.28	4.91	4.44	4.12	3.99	3.57	4.43	4.00	3.57	2.61	0.22
December 1989	2	0.48	0.35	0.37	0.44	0.68	1.15	1.33	0.73	6.61	21.94	11.90	23.33	15.16	10.97	4.75	11.59	29.86	7.79	16.45	11.85	0.50
	10	0.68	0.38	0.59		0.58	0.68	1.23	0.67	3.07	6.28	7.95	8.40	9.11	4.37	5.79	7.27	11.47	5.68	6.03	5.43	0.34
February 1990	2			1.88	1.87	1.47	2.06	1.98	1.86	1.59	2.20	4.12	2.82	2.14	3.40	3.47	2.99	2.99	3.16	2.10		
	10			1.97	1.42	1.71	2.21	1.70	1.76	2.04	1.94	4.29	3.16	2.23	4.84	3.92	2.45	3.30	3.08	3.16		
June 1990	2	0.18	0.13	0.26	0.48	5.08	6.45	0.63	1.49	6.25	11.77	3.85	3.55	3.16	2.56	3.03	2.14	2.85	3.23	2.29		0.07
	10	0.18	0.20	0.46	0.44	1.12	2.44	0.60	0.62	3.44	9.44	3.38	2.35	1.89	4.27	2.69	4.50	2.15	2.61	1.92	3.98	0.10
May 1991	2	0.45	0.26	0.66	0.42	0.55	0.68	4.20	2.19	6.48	2.16	3.15	5.84	5.53	4.52	5.43	4.80	5.67	3.93	4.73	3.64	0.20
	10	0.40	0.80	0.63	0.62	1.34	3.09	1.46	1.50	0.71	1.27	1.23	0.73	2.42	4.93	2.27	1.95	3.14	4.32	0.18	1.39	0.20

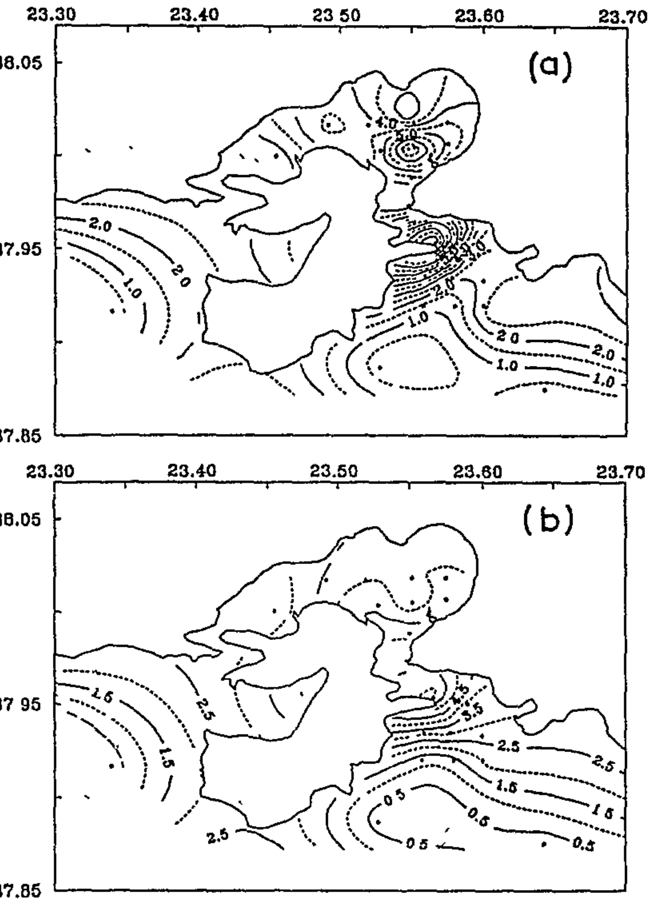


Fig. 43 Chlorophyll a distribution in Saronikos Gulf, during September 1989: a) at 2m depth and b) at 10m depth

February 1990: A more uniform distribution of chlorophyll a values among depths and areas was revealed during February (Fig. 45a and b) and simultaneously during this period the narrowest range of concentrations (Table 4) were recorded among all seasons, ranging from 1.42 μg/l at station P04 (10m) to 4.84 μg/l at station P14 (10m), it must be noted also that this was the lowest recorded maximum for all sampling periods (Table 4).

June 1990: Again the highest concentrations of chlorophyll a were aggregated around the sewage outfall for both depths (2m: Fig. 46a, 10m: Fig. 46b). Concentrations ranged from 0.07 μg/l (st. P21, 2m) to 11.77 μg/l (st. P10, 2m, Table 4).

May 1991: Chlorophyll a concentrations (Table 4) ranged from 0.2 μg/l at station P21 (2m and 10m) to 6.48 μg/l at station P09 (2m). The distribution of chlorophylls was different between depths with higher values around the sewage outfall for the 2m (Fig. 47a) and in Elefsis bay for the 10m (Fig. 47b).

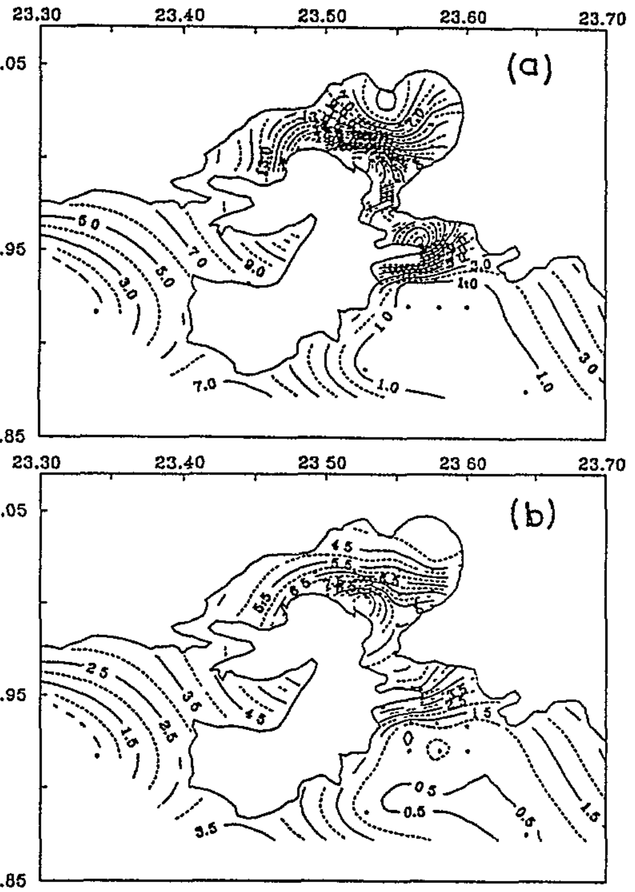


Fig. 44 Chlorophyll a distribution in Saronikos Gulf, during December 1989: a) at 2m depth and b) at 10m depth

6.1.2 Phytoplankton populations

The distribution of total phytoplankton, the phytoplankton groups (diatoms, dinoflagellates, coccolithophores, silicoflagellates, "other groups") along with μ-flagellates concentrations, at the surface layer (depth: 2m) during the five sampling periods from September 1989 to May 1991, are presented through Tables 5, 7, 9, 11, 13 and Figure 48, whereas dominant phytoplankton species are presented through Tables 6, 8, 10, 12, 14 and Figure 49.

September 1989: Total cell concentration of phytoplanktonic groups (not including μ-flagellates) ranged from 35300 c/l (st. P08) to 2968100 c/l (st. P19). Station P19 exhibited the higher cell concentrations for almost all phytoplanktonic groups, except coccolithophores, which had their maximum concentration at station P17 (Table 5). Dinoflagellates dominated in all areas (Fig. 48) during this period, ranging from 12500 c/l (st. P08) to 2374500 c/l (st. P19, Table 5), due to a *Prorocentrum dentatum* bloom. This species ranging from 9600 c/l (st. P08) to 2275900 c/l (st. P19, Table 6) constituted the 64.4% (st. P03) till 95.1% (st. P06, Fig. 49) of the phytoplankton population, with the exception of stations P08 and P21,

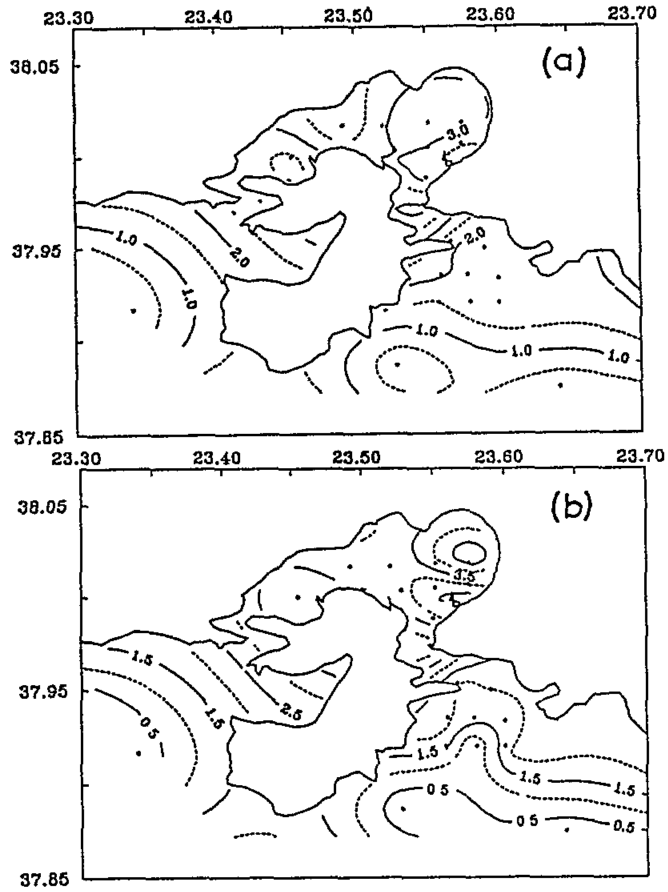


Fig. 45 Chlorophyll a distribution in Saronikos Gulf, during February 1990: a) at 2m depth and b) at 10m depth

where did not exceeded the 27.2% and 17.2% of the population respectively. Diatoms had a significant representation at stations P03, P19 and P20 (Fig. 48), reaching the 486400 c/l at station P19, whereas coccolithophores and "other groups" ranged in lower concentrations and silicoflagellates had not been accounted (Table 5). As it is obvious from Table 5 and Figure 48, μ-flagellates exhibited higher concentrations not only from all other groups but also from their totally summed densities and ranged from 344400 c/l (st. P05) to 9081600 c/l (st. P19), with exceptionally high concentrations also in stations P03 (7418500 c/l) and P21 (5208200 c/l).

December 1989: Very low values of total phytoplankton concentrations were recorded during December throughout stations P01 to P08 and P21 (Fig. 48) with a minimum of 10900 c/l at station P21 and a maximum of 125000 c/l at station P02 (Table 7), whereas concentrations at Keratsini and Elefsis bay (stations P09 to P20) ranged from 232200 c/l (st. P09) to 2024400 c/l (st. P19, Table 7). The recorded high phytoplankton abundances at these areas were attributed to the predominance of dinoflagellates again (Figs 48, 49), which reached a concentration of 1969600 c/l at station P19 (Table 7). Diatoms were not recorded at stations P01, P08, P12 and P14 and ranged at all other stations from 200 c/l (st. P04, P05) to 58800 c/l (st. P02),

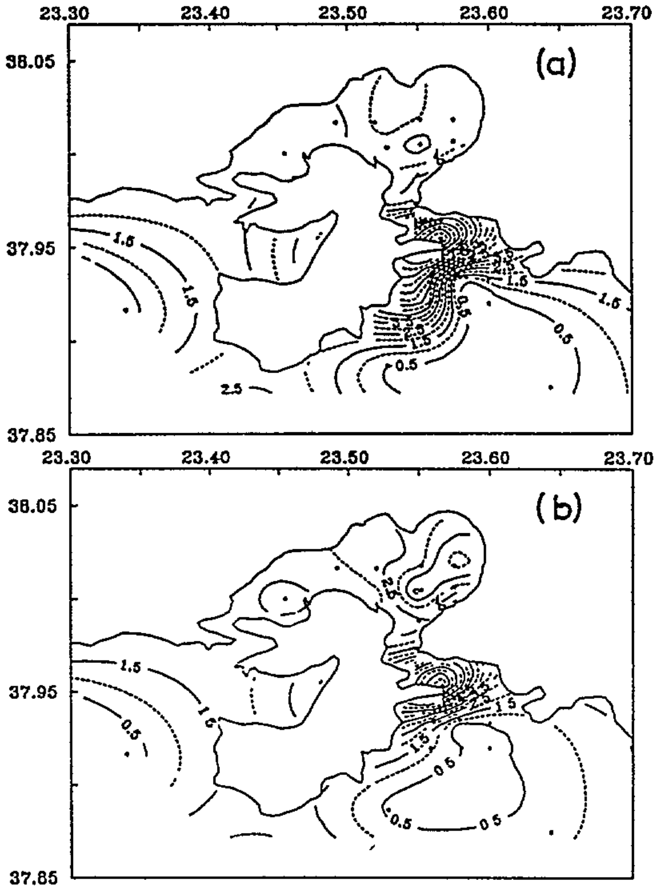


Fig. 46 Chlorophyll a distribution in Saronikos Gulf, during June 1990: a) at 2m depth and b) at 10m depth

coccolithophores and "others" exhibited similar concentrations ranging from 1000 c/l (st. P21) to 51000 c/l (st. P18) and from 600 c/l (st. P10, P14) to 61200 c/l (st. P15), respectively, whereas silicoflagellates were recorded only at station P10 (200 c/l, Table 7). The predominance of dinoflagellates throughout stations P09 to P20 was attributed to *Gyrodinium aureolum*, which reached 1913200 c/l at station P19 (Table 8) and constituted from 82.4 % (st. P15) up to 98.4 % (st. P12) of the total phytoplankton, whereas at stations P01 to P08 and P21 more important role had *Coccolithus huxleyi*, *Cryptomonas sp.* and *Chilomonas marina* (Fig. 49). The concentrations of μ-flagellates ranged from 131000 c/l (st. P05) to 8215600 c/l (st. P15, Table 7), but except from stations P02, P03, P15, P19, P20, P21, there were kept in rather low levels (Table 7, Fig. 48).

February 1990: During September and December not only the widest ranges of total phytoplankton and μ-flagellates concentrations were recorded, but also the highest maxima. On the contrary, during February the narrowest ranges and the lowest values of phytoplankton and μ-flagellates were recorded (Table 9). Total cell concentrations of phytoplankton groups (without μ-flagellates) ranged from 5200 c/l at station P08 to 43700 c/l at station P14, whereas μ-flagellates, whose fluctuations

were not as steep as during the previous months, ranged from 302400 c/l at station P21 to 1008000 c/l at station P15. Between all other groups, diatoms at this time were more important than dinoflagellates ranging from 1000 c/l at station P13 to 11900 c/l at station P06 and from 400 c/l at stations P05, P07, P18, P21 to 4800 c/l at station P11 respectively, whereas dinoflagellates were not recorded at stations P06 and P08. However the dominant group was coccolithophores almost in all stations, except from stations P01, P02 and P21, where "others" were more important (Fig. 48). Coccolithophores ranged from 1800 c/l at station P01 to 30000 at station P14 and "other groups" ranged from 100 c/l at station P05 to 19600 c/l at station P02. Silicoflagellates were recorded only at stations P08 (100 c/l) and P03, P09 (200 c/l). The distribution of dominant species was different between stations located in inner Saronikos gulf and these in Elefsis bay (Table 10, Fig. 49). *Coccolithus huxleyi* had a strong appearance in Elefsis bay (st. P11 to P20) consisting the 43.5% (st. P11) up to 76.4% (st. P19) of the total population, whereas in other areas did not exceeded the 35.1 % of the population. Stations least influenced by the sewage outfall (as st. P01, P02, P21) were characterized by the predominance of *Cryptomonas sp.* (49.2% - 61.4%), whereas stations in the vicinity of Psitallia island and at Keratsini bay appeared to have a more even distribution of dominant species such as *Coccolithus pelagicus* (3.2% - 26.9%), *Leptocylindrus danicus* (0.6% - 23.0%), *Skeletonema costatum* (1.9% - 29.9%) and *Thalassiosira rotula* (3.4% - 15.4%).

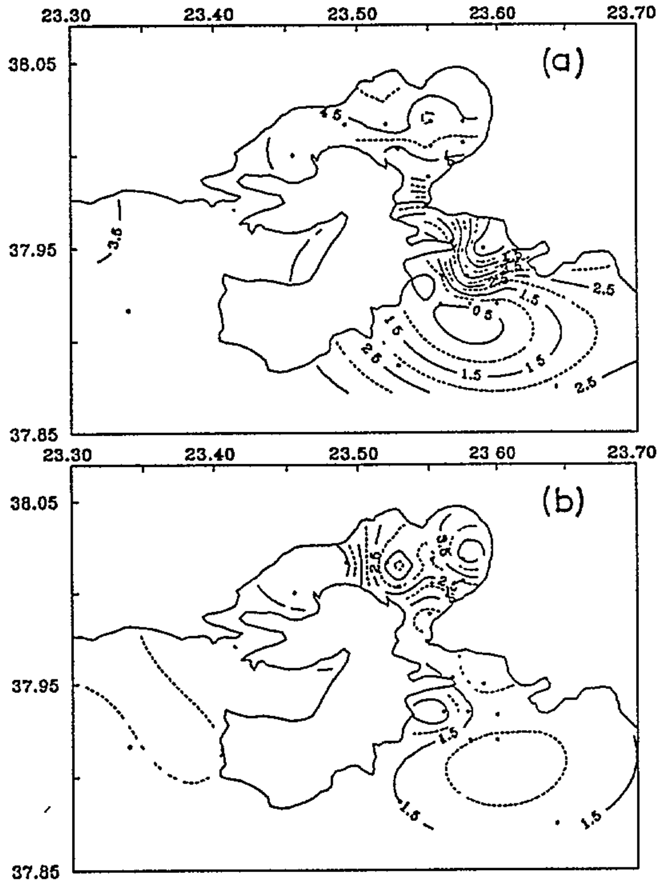


Fig. 47 Chlorophyll a distribution in Saronikos Gulf, during May 1991: a) at 2m depth and b) at 10m depth

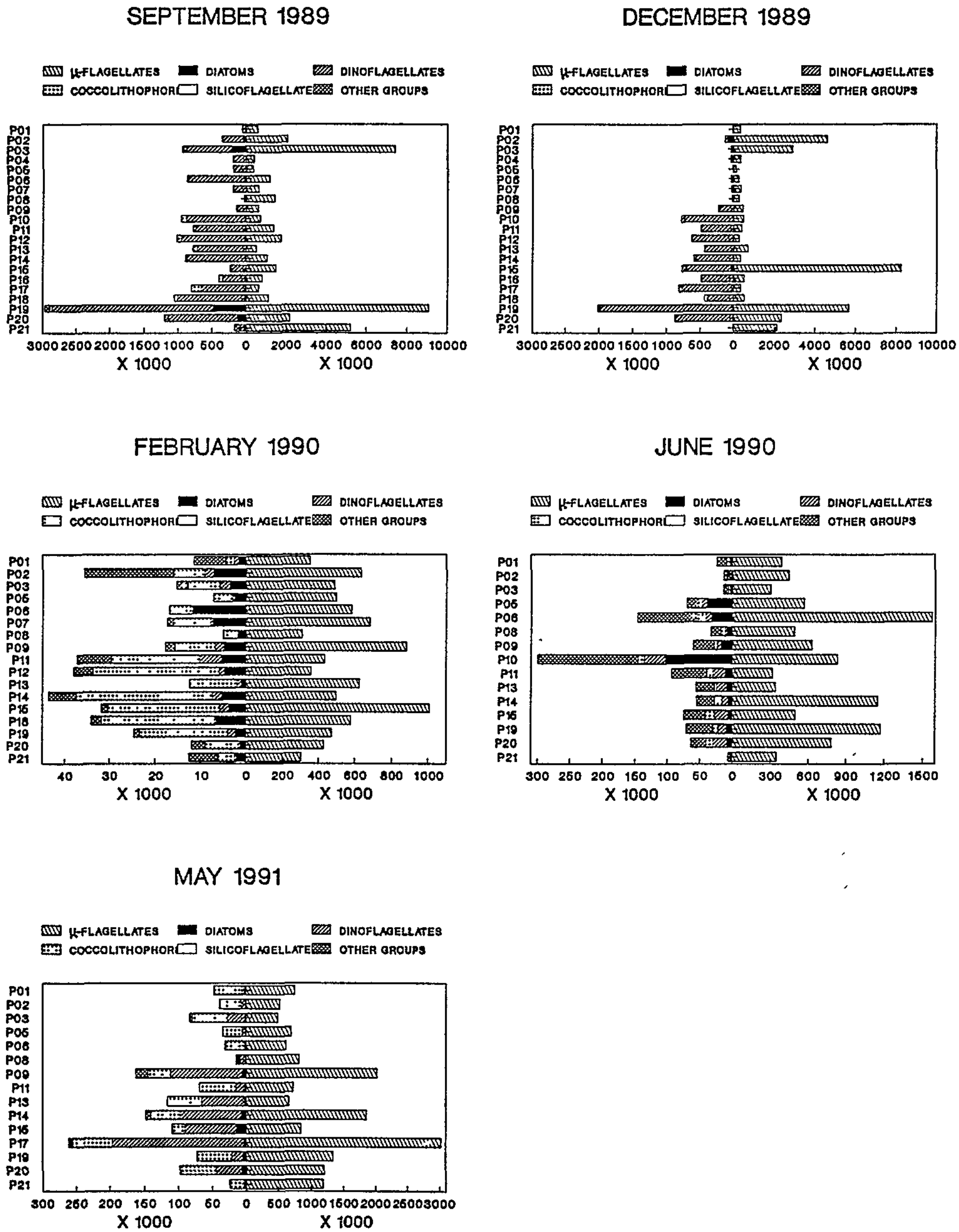


Fig. 48 Phytoplankton groups' and μ-flagellates concentrations (c/l), during the five sampling periods in Saronikos Gulf

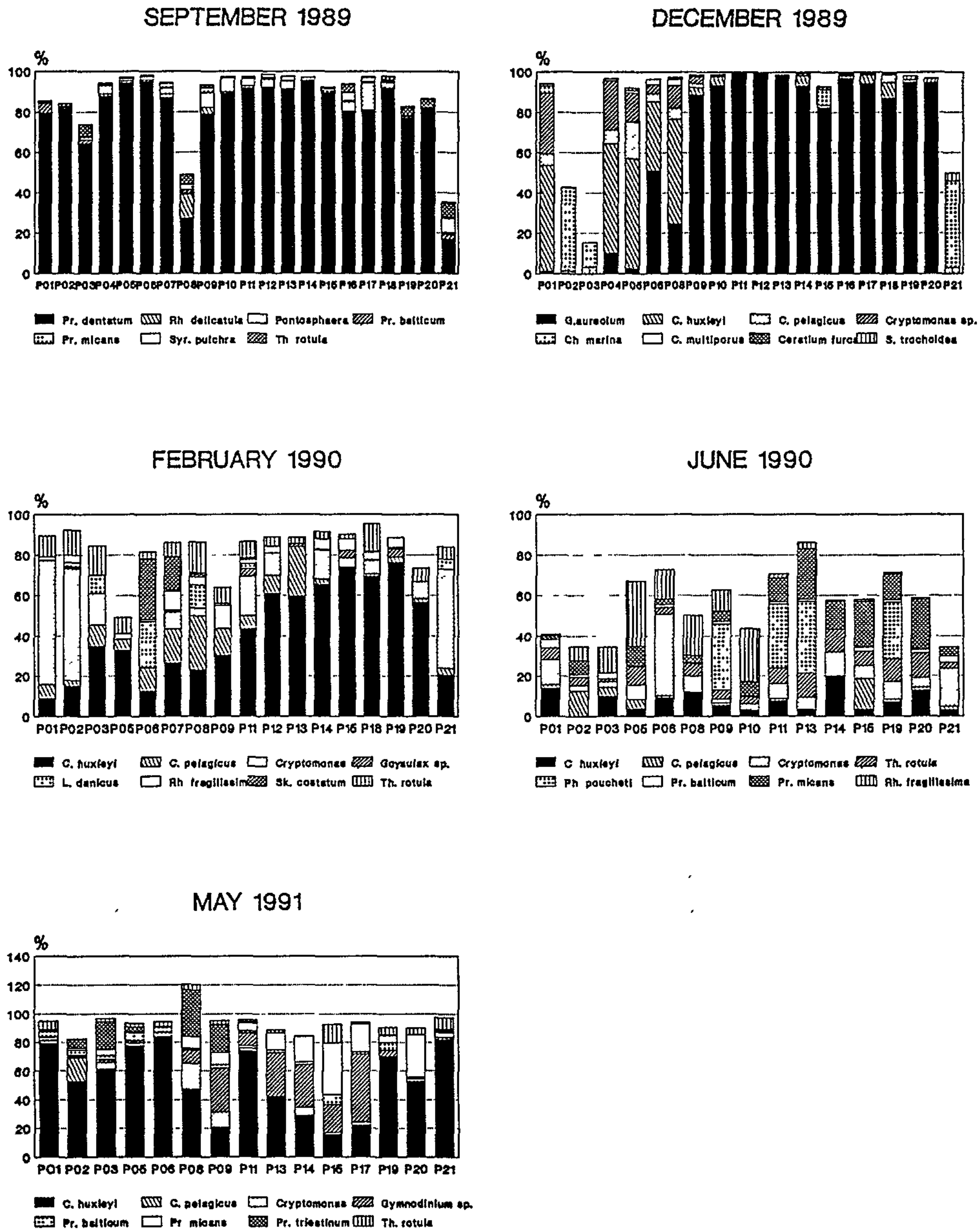


Fig. 49 Dominant phytoplankton species percentages (%), during the five sampling periods in Saronikos Gulf

Table 5

Distribution of phytoplankton groups (c/l), their total concentrations (c/l, not including µ-flagellates) and µ-flagellates (c/l) during September 1989

STATION GROUPS	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Diatoms	2400	44600	219400	4300	4400	11800	4600	9200	7000	19000	14000	5000	3000	3400	4700	17400	8400	25200	486400	127100	34600
Dinoflagellates	55900	296400	651600	176500	186600	840400	190500	12500	126200	863800	727800	952800	724000	866200	220000	328100	656800	981800	2374500	1016400	39000
Coccolithophores	4400	3600	6400	16300	4400	18400	6800	8200	16500	70200	36400	67200	58600	21800	5900	55600	138000	51200	38800	3600	6400
Silicoflagellates																					
Other Groups	1200	12000	58600	1000	600	3400	3200	5400	3200	2400	4800	1600	1400	6400	8600	2600	3000	2600	68400	56200	95200
TOTAL	63900	356600	936000	198100	196000	874000	205100	35300	152900	955400	783000	1026600	787000	897800	239200	403700	806200	1060800	2968100	1203300	175200
µ-flagellates	572100	2053100	7418500	400700	344400	1164200	625400	1422400	589700	702000	1373400	1738800	491400	1047600	1477100	786200	612400	1105700	9081600	2194600	5208200

Table 6

Distribution of dominant phytoplankton species concentrations (c/l) during September 1989

SPECIES	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Chaetoceros affine	0	6400	43200	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	128400	1600	200
Coccolithus huxleyi	0	0	0	1800	800	1400	600	0	600	3200	400	2400	2400	3000	0	9000	9200	200	0	0	0
Coccolithus pelagicus	0	200	0	1000	200	800	600	7800	2600	1800	5000	6400	7800	3400	1200	9400	3000	10200	1200	400	2000
Leptocylindrus danicus	0	16600	3200	200	1200	800	200	0	0	1200	200	0	200	0	0	0	0	0	40800	23000	2800
Nitzschia closterium	200	1600	1600	0	0	0	0	0	0	0	200	0	0	200	0	200	0	0	58400	30200	2200
Phaeocystis poucheti	0	12000	26000	0	0	0	0	5000	0	0	0	0	0	4000	7000	0	0	0	40000	28000	10600
Pontosphaera sp.	0	0	0	8600	2000	15200	5400	200	11200	64400	28000	40000	32000	1800	0	18600	108600	24400	0	0	0
Prorocentrum balticum	3000	2800	16000	1600	600	1600	1200	600	200	400	1400	800	1400	800	1400	800	2200	2000	2800	800	3600
Prorocentrum dentatum	50600	290500	602400	173900	184800	831600	178700	9600	121000	853200	718200	945000	718200	853200	213400	325100	650200	973400	2275900	984800	30200
Prorocentrum micans	400	100	13800	0	0	2800	4200	800	3400	2800	1600	1000	200	3800	1600	1000	1200	2600	25600	1000	1600
Rhizosolenia delicatula	400	0	0	2000	2000	6200	3600	4200	4600	6400	8400	2000	600	0	0	0	1600	2200	0	0	0
Syracosphaera pulchra	200	1600	800	200	800	0	0	200	400	600	1400	15200	13800	10600	2400	16400	16800	9200	10400	2400	1200
Thalassiosira rotula	200	4600	56800	800	600	2000	800	1600	1800	2600	3200	1200	2000	3000	1800	17200	6000	22800	132400	54400	14000

Table 7

Distribution of phytoplankton groups (c/l), their total concentrations (c/l, not including µ-flagellates) and µ-flagellates (c/l) during December 1989

STATION SPECIES	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Diatoms	0	58800	19300	200	200	400	12400	0	400	1200	1700	0	3700	0	38800	900	300	800	12800	9500	2700
Dinoflagellates	1000	11400	5000	4100	1500	23600	5000	9400	209000	741400	485000	631700	431100	558800	662400	476300	776100	379900	1969600	858100	1800
Coccolithophores	10400	3200	4000	22200	12400	18800	18200	20000	14400	39400	8200	5400	4200	38600	14400	11000	41000	51000	13600	3500	1000
Silicoflagellates	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0
Other Groups	5800	51600	13000	8600	2400	2000	800	3800	8400	600	2600	1200	1800	600	61200	2000	1000	1900	28400	13700	5400
TOTAL	17200	125000	41300	35100	16500	44800	36400	33200	232200	782800	497500	638300	440800	598000	776800	490200	818400	433600	2024400	884800	10900
M-flagellates	321300	4631300	2905000	352800	131000	226800	352800	253500	440000	462000	393100	267500	688800	318600	8215600	507600	336000	516600	5664700	2363400	2124700

Table 8

Distribution of dominant phytoplankton species concentrations (c/l) during December 1989

STATION SPECIES	P01	P02	P03	P04	P05	P06	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Ceratium furca	0	0	0	0	0	0	400	2200	2800	400	2800	1400	1600	1200	400	2600	1000	3600	2200	0
Chaetoceros affine	0	800	400	0	0	0	0	0	0	0	0	0	0	9200	0	0	0	5600	3000	0
Chilomonas marina	600	51600	5000	0	0	0	0	800	0	0	0	0	0	60000	0	0	0	26800	3600	4700
Coccolithus huxleyi	9000	0	0	19000	9000	15400	17200	8200	34200	3000	2200	600	30600	0	5800	34400	32800	0	0	0
Coccolithus multiporus	200	0	0	400	200	1200	1000	0	1600	2400	0	1200	800	0	200	2800	800	0	0	0
Coccolithus pelagicus	1000	2400	1600	2400	3000	1800	1800	4800	3600	2600	2800	2400	6400	8400	5000	2600	17200	10800	2600	300
Cryptomonas sp.	5200	0	0	8600	2400	2000	3800	7600	600	2600	1200	1800	600	0	2000	1000	1800	0	0	0
Gymnodinium sp. (10-20 µm)	0	4800	400	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	1000
Gyrodinium aureolum	200	0	0	3600	400	22800	8200	206000	730800	483800	628100	428400	556200	640000	475000	772800	378000	1913200	831600	0
Leptocylindrus danicus	0	6400	2200	0	0	0	0	0	0	0	0	0	0	3200	0	100	0	2800	0	0
Nitzschia delicatissima	0	6400	1600	0	0	0	0	200	0	600	0	800	0	1200	0	0	0	0	300	100
Phaeocystis pouchetii	0	0	8000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10000	0
Scripsiella trochoidea	0	400	0	0	200	0	0	0	0	0	0	100	0	10000	0	0	0	33600	18200	400
Thalassionema nitzschioides	0	12800	5800	0	200	0	0	0	0	400	0	0	0	9200	0	0	0	2000	1800	900
Thalassiosira rotula	0	25200	3400	0	0	0	0	0	0	0	0	100	0	10800	400	0	0	1600	600	1100

<u>Table 9</u>

Distribution of phytoplankton groups (c/l), their total concentrations (c/l, not including µ-flagellates) and µ-flagellates (c/l) during February 1990

STATION / SPECIES	P01	P02	P03	P05	P06	P07	P08	P09	P11	P12	P13	P14	P15	P18	P19	P20	P21
Diatoms	1600	7200	3600	2600	11900	7400	1900	5000	5400	4800	1000	5400	3800	6600	2400	1200	2200
Dinoflagellates	1000	2000	2200	400	0	400	0	1800	4800	1200	1000	2000	2000	400	1600	600	400
Coccolithophores	1800	6800	7000	4200	5000	8200	3000	8800	19400	27600	10400	30000	24600	24800	19400	7200	3600
Silicoflagellates	0	0	200	0	0	0	100	200	0	0	0	0	0	0	0	0	0
Other Groups	7000	19600	2400	100	0	1400	200	2000	7600	4400	0	6300	1400	2200	1200	3000	6400
TOTAL	11400	35600	15400	7300	17400	17400	5200	17800	37200	38000	12400	43700	31800	34000	24600	12000	12600
µ- flagellates	355300	633200	487200	495600	581500	680400	308700	884500	432000	357400	623700	495600	1008000	576500	470400	426100	302400

<u>Table 10</u>

Distribution of dominant phytoplankton species concentrations (c/l) during February 1990

STATION / SPECIES	P01	P02	P03	P05	P06	P07	P08	P09	P11	P12	P13	P14	P15	P18	P19	P20	P21
Coccolithus huxleyi	1000	5400	5400	2400	2200	4600	1200	5400	16200	23200	7400	28600	23400	23600	18800	6800	2600
Coccolithus pelagicus	800	1000	1600	400	2000	3000	1400	2400	2400	3400	3000	1200	800	400	600	200	400
Cryptomonas sp.	7000	19600	2400	0	0	1400	200	2000	7200	4200	0	6200	1400	2200	0	1000	6200
Gonyaulax sp.	0	400	0	0	0	0	0	0	1400	0	200	200	1200	0	1000	0	0
Leptocylindrus danicus	0	800	1400	0	4000	200	600	0	800	0	0	0	0	200	200	0	600
Rhizosolenia fragilissima	200	1200	0	200	200	1600	200	200	800	1200	0	2200	1800	1200	1200	0	0
Skeletonema costatum	0	0	0	0	5200	3000	100	0	300	0	0	0	0	200	0	0	0
Thalassiosira rotula	1200	4400	2200	600	600	1200	800	1400	3000	1800	400	1600	800	4600	0	800	800

June 1990: With the exception of station P10 (299200 c/l) total cell concentrations of phytoplankton groups, not including µ-flagellates, were kept low during this period also, ranging from 3200 c/l (st. P21) to 146000 c/l (st. P06). Rather low concentrations characterized the populations of µ-flagellates ranging from 302400 c/l (st. P03) to 1575000 c/l (st. P06, Table 11). Diatoms were more important than dinoflagellates at stations in inner Saronikos and Keratsini bay (st. P01 through P10), whereas in Elefsis bay the opposite situation was observed. However, "others" was the dominant group throughout all areas (Table 11, Fig. 48). Minima for all groups were recorded at station P21, whereas maxima were recorded at station P10 of Keratsini bay, with the exception of coccolithophores with maximum concentration at station P06. So diatoms ranged from 1100 c/l to 103600 c/l, dinoflagellates from 1100 c/l to 32300 c/l, coccolithophores from 1000 c/l to 15200 c/l, "others" from 3200 c/l to 154100 c/l and silicoflagellates were recorded only at station P02 (100 c/l). Dominant species distribution was quite even throughout all stations (Table 12, Fig. 49) with a more strong appearance of *Phaeocystis poucheti* (28.2% - 35.6%) and *Prorocentrum micans* (11.7 % - 25.4 %) in Elefsis bay, whereas stations located in inner Saronikos and Keratsini bay (stations P02 to P10) were characterized by the predominance of *Rhizosolenia fragilissima* (6.9% - 32.0%).

May 1991: µ-flagellates fluctuated in higher ranges than those of the total concentrations of all other groups (Table 13, Fig. 48). So µ-flagellates ranged from 494800 c/l (st. P03) to 3024000 c/l (st. P17) and total cells from 14800 c/l (st. P08) to 260400 c/l (st. P17). Diatoms ranged from 800 c/l (st. P02) to 14600 c/l (st. P15), dinoflagellates, which dominated in Elefsis bay, from 800 c/l (st. P21) to 193600 c/l (st. P17), coccolithophores, which were relatively more important at stations of inner Saronikos, from 2800 c/l (st. P08) to 58400 c/l (st. P17) and "others" from 200 c/l (st. P13) to 17000 c/l (st. P09). Silicoflagellates were not recorded. Among the dominant species (Table 14, Fig. 49) the predominance of *Coccolithus huxleyi* throughout all areas (17.6% at st. P08 - 84.2% at st. P06) was interesting, whereas *Prorocentrum triestinum* had a strong appearance at stations in the vicinity of the sewage outfall and *Gymnodinium sp*. in Elefsis bay.

6.1.3 Similarities among stations

September 1989: According to the hierarchical clustering based on the 20 most important phytoplankton species two groups were distinguished at the 60% similarity level, whereas station P01 was not included in either of the groups. The first group consisted from the easternmost stations of inner Saronikos P02, P03, P08, stations P14 and P15 of eastern Elefsis bay, P19, P20 of western Elefsis bay and P21 of the western basin. The second group was constructed from stations P04, P05, P06, P07, which were located west of Psittalia island and stations P09, P10, P11, P12, P13, P16, P17, P18 located at Keratsini bay, the Channel and central Elefsis bay (Fig. 50). Ordination analysis and the derived MDS plot confirmed the above described picture (stress=0.102).

December 1989: The study of the dendrogram (Fig. 51) revealed that stations were again separated in two groups at the 35% similarity level this time. The first group had similarities with the one from the September data set analysis,

Table 11

Distribution of phytoplankton groups (c/l), their total concentrations (c/l, not including μ-flagellates) and μ-flagellates (c/l) during June 1990

STATION SPECIES	P01	P02	P03	P05	P06	P08	P09	P10	P11	P13	P14	P15	P19	P20	P21
Diatoms	1800	2400	2000	39900	32800	9000	18000	103600	11000	8600	6600	7000	9600	7900	1100
Dinoflagellates	1800	2900	1400	7600	8200	2200	5000	32300	19300	15200	9200	20400	12000	21800	1100
Coccolithophores	5800	2800	3400	6000	15200	6400	5600	9200	8700	3000	11200	14200	7600	10200	1000
Silicoflagellates	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Groups	14600	6200	7200	17200	89800	15400	32400	154100	54800	29400	29000	33600	41800	24000	3200
TOTAL	24000	14400	14000	70700	146000	33000	61000	299200	93800	56200	56000	75200	71000	63900	6400
μ-flagellates	387500	440000	302400	562800	1575000	488000	630000	831600	317500	340200	1149100	495600	1171800	784400	348000

Table 12

Distribution of dominant phytoplankton species concentrations (c/l) during June 1990

STATION SPECIES	P01	P02	P03	P05	P06	P08	P09	P10	P11	P13	P14	P15	P19	P20	P21
Coccolithus huxleyi	3400	0	1400	2600	13400	4000	3200	9000	7000	1800	11200	2400	5000	8200	200
Coccolithus pelagicus	400	1800	600	3400	1600	0	800	0	1000	0	0	11400	1000	1000	100
Cryptomonas sp.	3000	400	400	5000	59200	2600	1200	9000	7000	3400	6600	4800	6200	3000	1200
Leptocylindrus danicus	0	600	0	600	0	0	0	3800	0	0	0	0	0	0	600
Phaeocystis poucheti	0	0	0	0	0	0	20000	0	30000	20000	0	0	20000	0	0
Prorocentrum balticum	1000	200	400	400	2200	200	800	1800	1000	600	200	1400	1000	1200	200
Prorocentrum micans	400	1000	0	6800	3600	1200	3200	21200	11000	14000	7600	17200	9000	16200	300
Rhizosolenia fragilissima	200	1000	1800	22600	21200	6600	6200	78800	1900	1800	200	800	400	0	0
Thalassiosira rotula	1400	600	200	6400	5000	2000	2800	10200	7200	6800	6400	5600	8000	7800	200

Table 13

Distribution of phytoplankton groups (c/l), their total concentrations (c/l, not including µ-flagellates) and µ-flagellates (c/l) during May 1991

STATION SPECIES	P01	P02	P03	P05	P06	P08	P09	P11	P13	P14	P15	P17	P19	P20	P21
Diatoms	3400	800	2000	1200	1200	1000	4600	1600	2200	7000	14600	3000	3800	4600	2000
Dinoflagellates	3600	6600	25400	4800	1900	8400	107000	13800	63500	90000	75800	193600	17400	39900	800
Coccolithophores	39400	30600	51800	28400	27000	2800	33600	52400	50000	43000	17800	58400	50600	52200	21100
Silicoflagellates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Groups	1400	1600	3800	1000	1000	2600	17000	1000	200	7800	1400	5400	600	1400	1200
TOTAL	47800	39600	83000	35400	31100	14800	162200	68800	115900	147800	109600	260400	72400	98100	25100
µ-flagellates	756000	522300	494800	702000	619900	823200	2026100	734400	659800	1864800	856800	3024000	1345700	1210000	1184400

Table 14

Distribution of dominant phytoplankton species concentrations (c/l) during May 1991

STATION SPECIES	P01	P02	P03	P05	P06	P08	P09	P11	P13	P14	P15	P17	P19	P20	P21
Coccolithus huxleyi	38000	21000	51200	27600	26200	2600	33400	50800	48600	43000	17800	58000	50200	52000	20600
Coccolithus pelagicus	1000	6400	0	0	800	0	200	1600	200	0	0	0	200	0	400
Cryptomonas sp.	1000	400	3600	600	200	2600	17000	1000	200	7800	1200	5400	600	1400	800
Gymnodinium sp. (10-20 µm)	0	400	1800	600	0	1400	50200	6200	35200	44600	21000	122800	3000	200	0
Prorocentrum balticum	1800	1400	2200	1800	1000	200	3800	1200	2200	2400	1000	5400	4000	1400	400
Prorocentrum micans	100	600	3400	400	0	1200	14000	3600	14000	26200	39600	49400	3400	28800	200
Prorocentrum triestinum	600	2400	16200	1200	200	4800	31800	600	400	200	0	1600	400	200	0
Thalassiosira rotula	2800	400	1800	800	1000	600	4000	1200	2000	6000	14200	2600	3800	4600	2000

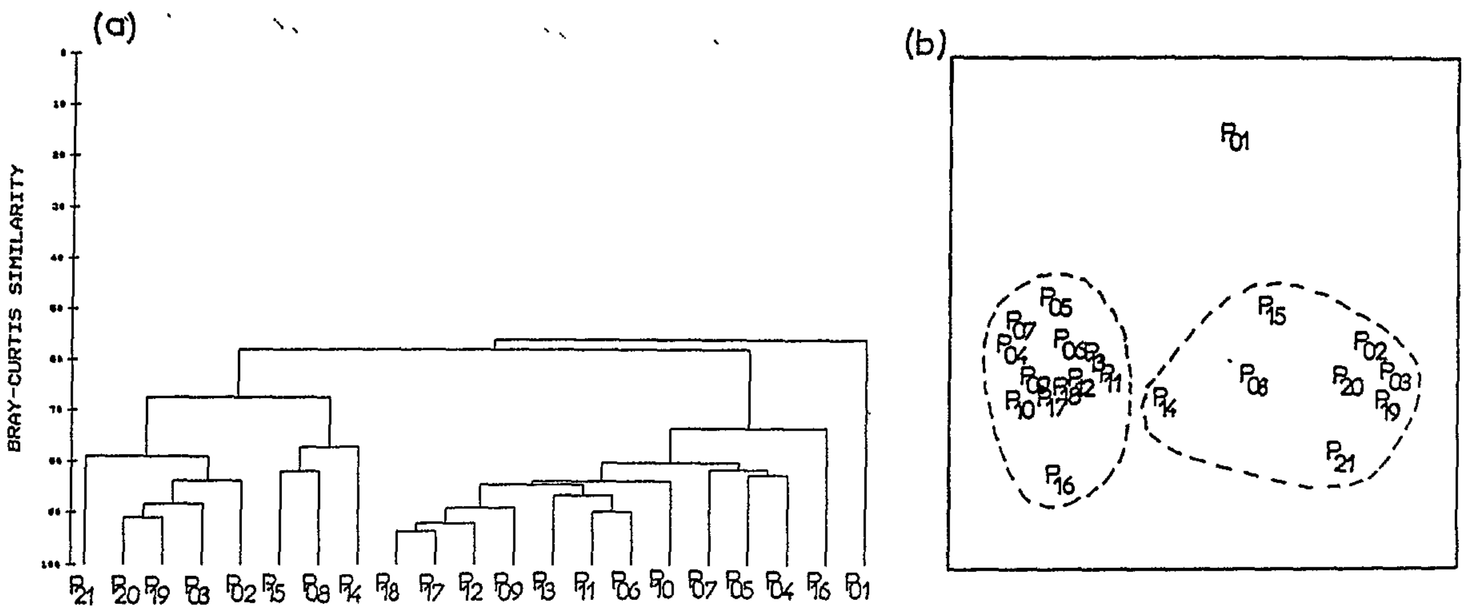


Fig. 50 Dendrogram (a) and MDS plot (b, stress=0.102) showing stations grouping according to phytoplankton species distribution in Saronikos Gulf, during September 1989

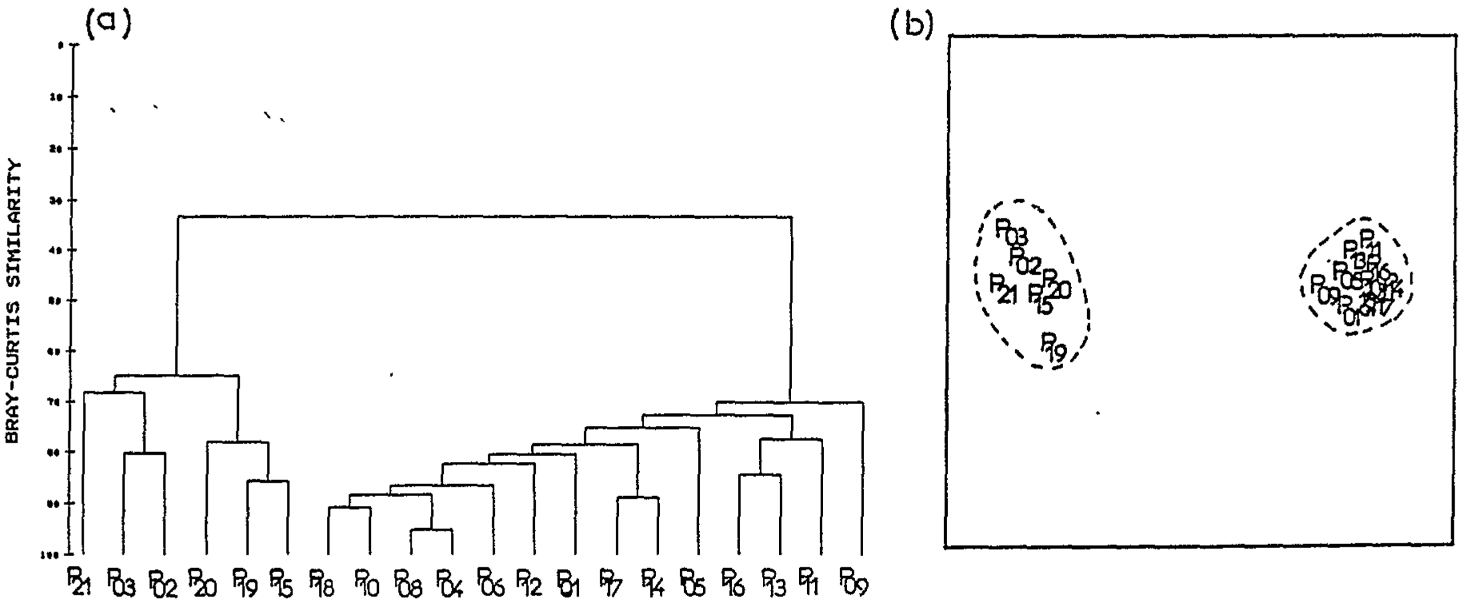


Fig. 51 Dendrogram (a) and MDS plot (b, stress=0.051) showing stations grouping according to phytoplankton species distribution in Saronikos Gulf, during December 1989

consisting from stations P02, P03, P15, P19, P20 and P21. All other stations seemed to be more closely related, though scattered through all areas (P01, P04, P05, P06, P08, P09, P10, P11, P12, P13, P14, P16, P17, P18), consisting the second group, which is a more tight group, as it is obvious from the MDS plot also (stress=0.051).

February 1990: The similarity pattern during this period is quite unclear, since groups as defined by the dendrogram (Fig. 52) are not only loose, but also are consisting from stations scattered among areas. Thus at the similarity level of 64% two groups are distinguished. The first group is constructed from stations P01, P02, P03 from inner Saronikos, P09, P11, P12 from the Channel, P14, P15 from eastern and central Elefsis bay and P21 from the western basin. Stations P06, P07, P08 from inner Saronikos and P18 from central Elefsis bay constituted the second group, whereas station P05 from western inner Saronikos and P20 from western Elefsis formed a small group joining the other two at 60% similarity level. Station P19 from western Elefsis bay joined the above groups at the similarity level of 53% and P13 from eastern Elefsis bay at 47% (Fig. 52). The same scattered distribution of stations was confirmed from the MDS plot (stress=0.173).

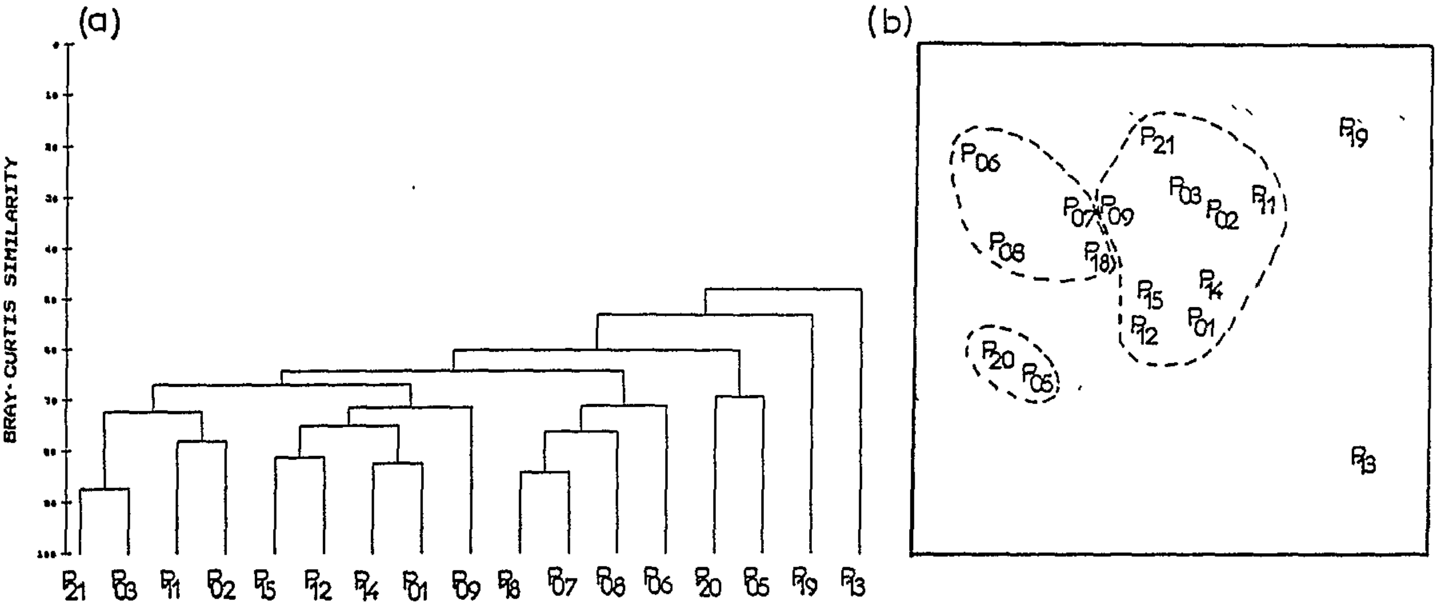


Fig. 52 Dendrogram (a) and MDS plot (b, stress=0.173) showing stations grouping according to phytoplankton species distribution in Saronikos Gulf, during February 1990

June 1990: At the 70% similarity level a major group was distinguished, which was further separated in two subgroups, the first constructed from stations P01, P05, P06 of the western inner Saronikos, P08 near the sewage outfall, P10 from Keratsini, P14 and P15 from Elefsis bay (72% similarity) and the second from stations P09 from Keratsini, P11 from the Channel, P13 and P19 from Elefsis bay (75% similarity). Stations P02 of eastern Saronikos and P20 of Elefsis bay joined the above major group at 60 % similarity level, whereas stations P03 of inner Saronikos and P21

of the western basin formed a last group joining all others at 57% (Fig. 53). The above picture did not became more clear at the MDS plot (stress=0.161), since positioning of stations according to this analysis, was even more scattered.

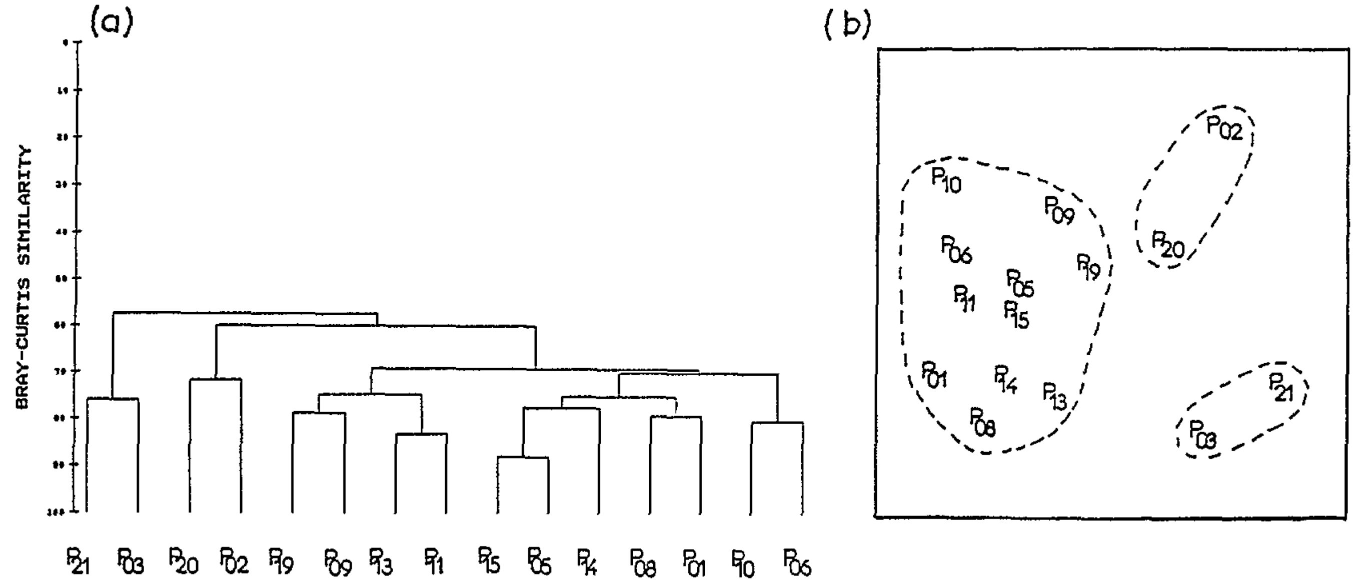


Fig. 53 Dendrogram (a) and MDS plot (b, stress=0.161) showing stations grouping according to phytoplankton species distribution in Saronikos Gulf, during June 1990

May 1991: During this period a more clear picture of the spatial distribution of stations was obtained according to the cluster analysis. From the dendrogram (Fig. 54) it is obvious that two well defined groups were separated at the 60% similarity level. The first group consisted from stations P01, P02, P05 and P06, which are located at inner Saronikos, but are the least influenced by the outfall and station P21 from the western basin. The second group constructed from all other stations, such as P03, P08, southern of the outfall, P09 at Keratsini, P11 in the Channel, P13, P14, P15, P17, P19, P20 at Elefsis bay, which are expected to be more influenced by the pollution. The above described picture was confirmed by the MDS plot (stress=0.104).

6.1.4 Community structure

September 1989: Diversity values ranged from 0.45 bits/ind. (st. P06) to 3.08 bits/ind. (st. P08). As it is obvious from Fig. 55, with the exception of station P08, where the maximum was recorded, diversity was higher at stations of inner Saronikos, least influenced by the sewage outfall (stations P01, P02, P03) at the westernmost part of Elefsis bay (stations P19, P20) and at station P21 of the western basin. In all other stations diversity had very low values usually not exceeding 1 bit/ind. Species number (15 at st. P16 - 49 at st. P19) fluctuated according to the diversity index, but stayed low at station P08, whereas dominance index varied inversely to that of diversity (Fig. 55) ranging from 49.29% (st. P08) to 96.89% (st. P06). Strong

differentiation between stations, according to the k-dominance curves (Fig. 56), was prevailed only for stations P03, P08, P21, which were by far more diversified than all others.

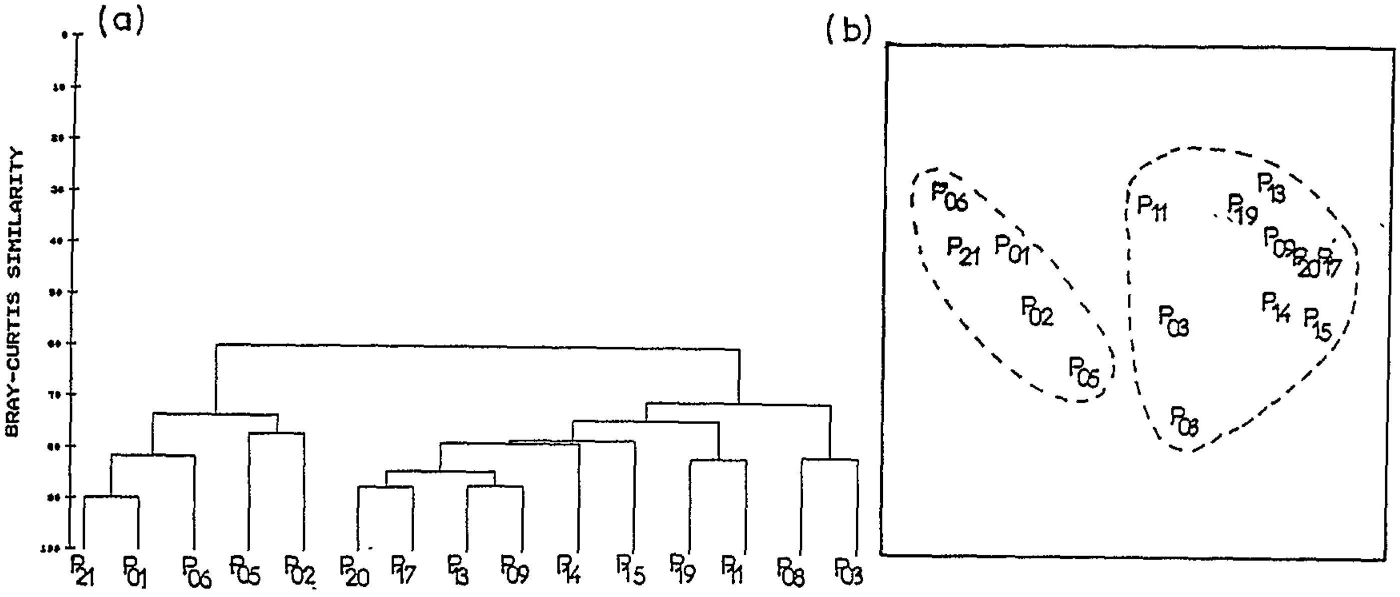


Fig. 54 Dendrogram (a) and MDS plot (b, stress=0.104) showing stations grouping according to phytoplankton species distribution in Saronikos Gulf, during May 1991

December 1989: Diversity values presented a wider range than during September, varying from 0.16 bits/ind. (st. P12) to 3.89 bits/ind. (st. P03) and were higher at stations of inner Saronikos gulf, decreasing near the outfall and reaching their minima in Elefsis bay (Fig. 55). Species number ranged from 9 (st. P04) to 32 (st. P20), whereas dominance index had its maximum at station P12 (98.84%) and its minimum at station P03 (33.41%). The different spatial pattern of diversity between areas was verified by the k-dominance curves, which showed that stations P09 through P20, located at Keratsini and Elefsis bay were less diversified than stations P01, P04, P05, P06, P08 of inner Saronikos and even less than stations P02, P03 and P21 (Fig. 57).

February 1990: All indexes varied in narrow ranges during this period (Fig. 55). Diversity values ranged from 1.51 bits/ind. (st. P19) to 3.07 bits/ind. (st. P09), species number from 8 (st. P01, P13) to 16 (st. P11) and dominance index from 43.68% (st. P09) to 83.87% (st. P13). All areas were quite diversified according to the k-dominance curves (Fig. 58), which demonstrated stations (P03, P05, P06, P07, P08, P09) from inner Saronikos gulf in the vicinity of Psittalia island and the sewage outfall to be even more diversified than the others and stations from Elefsis bay (P13, P14, P15, P18, P19) the less.

June 1990: Diversity fluctuated in higher levels (Fig. 55) during June than all other previous sampling periods, ranging from 2.26 bits/ind. (st. P14) to 3.70 bits/ind. (st. P02), whereas dominance stayed low, from 32.56% (st. P02) to 69.55% (st. P06). Species number fluctuated from 9 (st. P14) to 24 (st. P10). K-dominance curves (Fig. 59) did not revealed strong differentiations between areas and all stations were highly diversified.

May 1991: Again there was not observed a clear spatial pattern for the studied indexes (Fig. 55). However diversity fluctuated on the highest level among all sampling periods and its minimum was computed for station P21 (2.26 bits/ind.), whereas its maximum (3.85 bits/ind.) was computed for station P17. On the other hand dominance index ranged from 32.94% (st. P15) to 63.89% (st. P14), exhibiting the lowest values among seasons. Species number varied between 8 (st. P21) and 26 (st. P17). Finally, strong differentiation between areas was not evident, though differences among stations were revealed according to the k-dominance curves (Fig. 60), indicating that stations P01, P03, P05, P06 of the inner gulf, P09 at Keratsini bay, P19 in Elefsis bay and P21 at the western basin are less diversified than stations P02 and P08 at the inner Saronikos, P11 in the Channel and P13, P14, P15, P17 and P20 in Elefsis bay.

6.2 Zooplankton

6.2.1 Quantitative aspect

Biomass and total abundances' spatial and temporal variations are presented in Table 15 and in Figure 61. Both parameters do not vary in parallel and this disagreement must be related to the following factors: (a) Due to pollution, samples often contained an amount of organic material which could not be eliminated for the biomass estimation and thus increasing the biomass values. Due to this problem, biomass estimation was not performed in samples containing a large amount of organic material. (b) During September 1989 and June 1990 cladocerans dominated zooplankton, but they have low dry-weight values. This difference can be seen when comparing February and June 1990 biomass values.

During most sampling periods, higher values were found near the sewage outfall (stations P05 to P09), in the inner Saronikos gulf (P01, P02) and in the western Saronikos (P21). An exception was recorded during February 1990, when Elefsis bay stations (P13 to P16) revealed higher values. Zooplankton was generally more abundant during September and June at almost all stations, during February, as stated before, in Elefsis bay, whereas biomass and abundance values were lower during May and even more during December 1989. During September maximum values were found at station P08 (48.28 mg/m^3 and 4324 ind/m^3), whereas in December higher values (6.76 mg/m^3 and 887 ind/m$^{3)}$ were recorded at the same area but at station P07. Extremely high values were recorded during February at station P15 (67.28 mg/m^3 and 11219 ind/m^3). During June maximum total abundance was found at stations P01 (7851 ind/m^3) and P08 (7795 ind/m^3) and maximum biomass at station P09 (46.65 mg/m^3). Both parameters revealed maximum values at station P21 during May 1991 (20.5 mg/m^3 and 1975 ind/m^3).

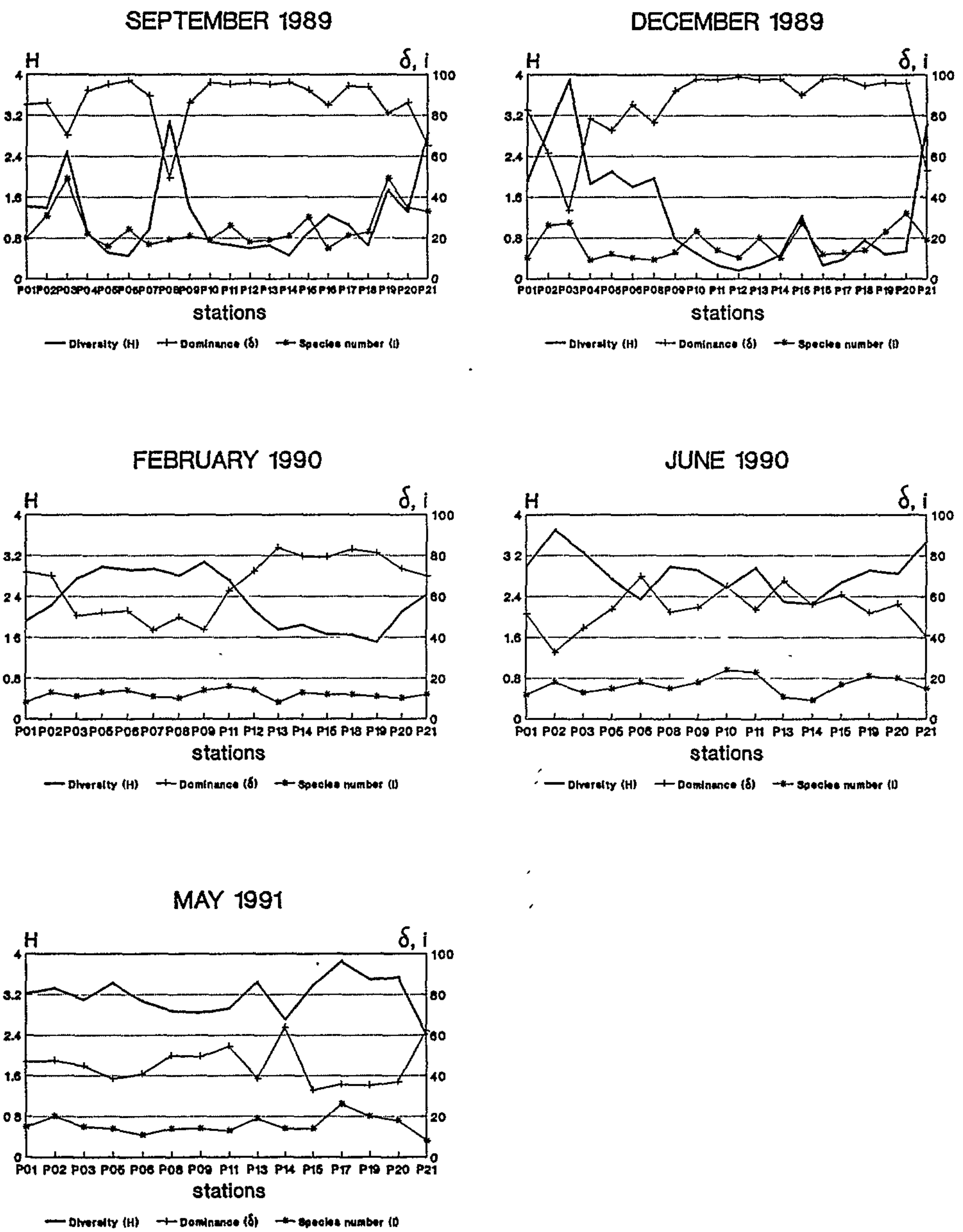


Fig. 55 Spatial distribution of diversity index (H), dominance index (*δ*) and species number during the five sampling periods in Saronikos Gulf

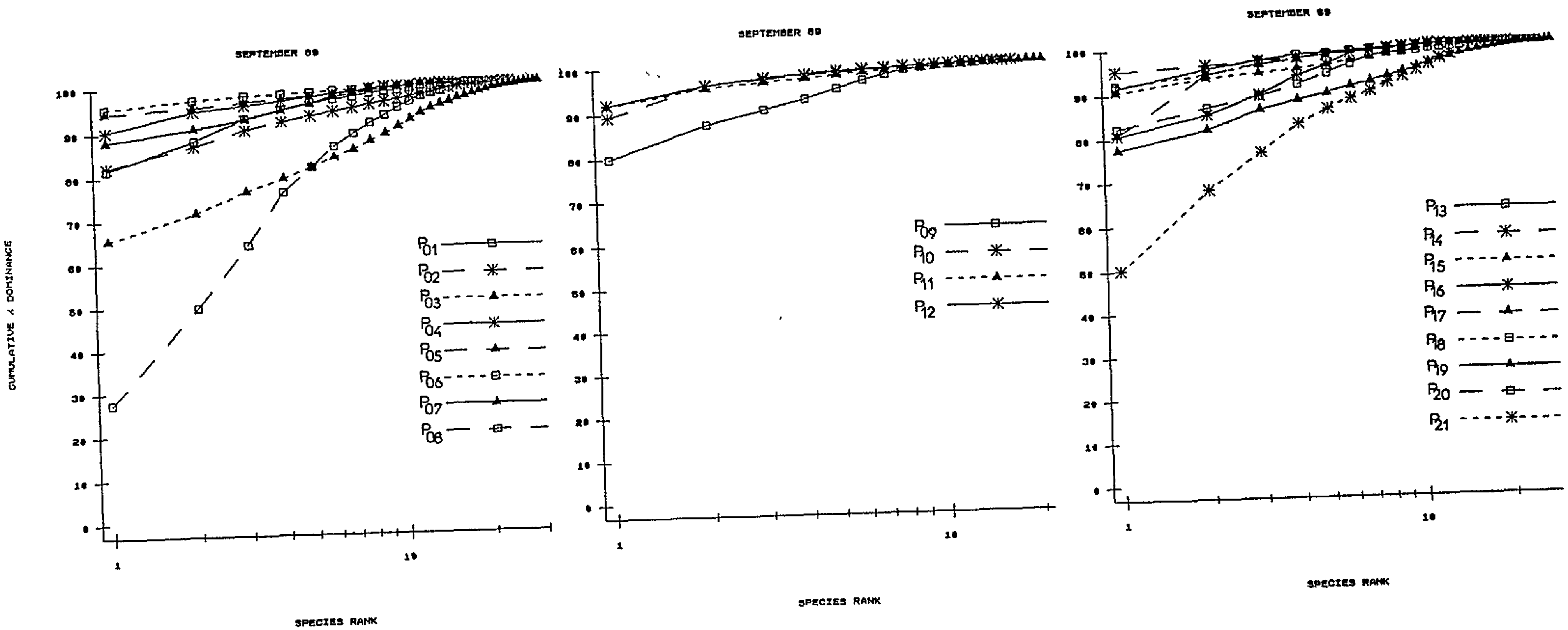


Fig. 56 K-dominance curves of phytoplankton species during September 1989

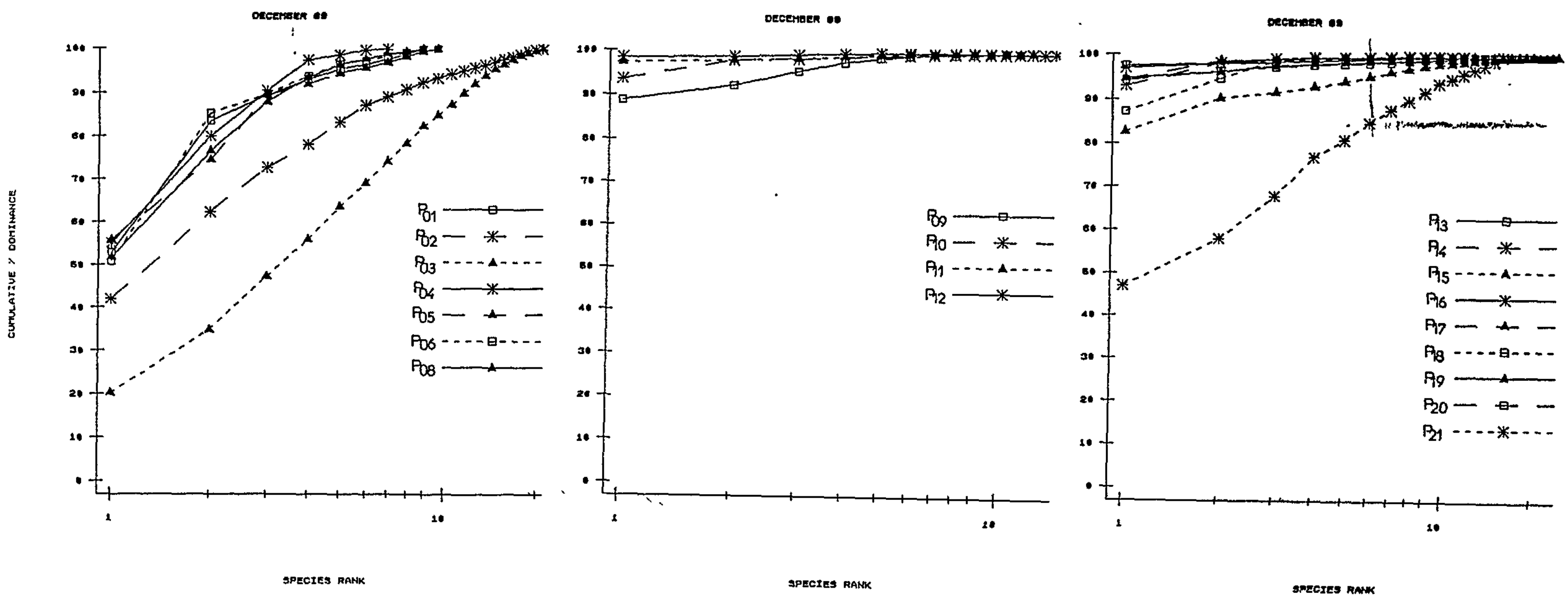


Fig. 57 K-dominance curves of phytoplankton species during December 1989

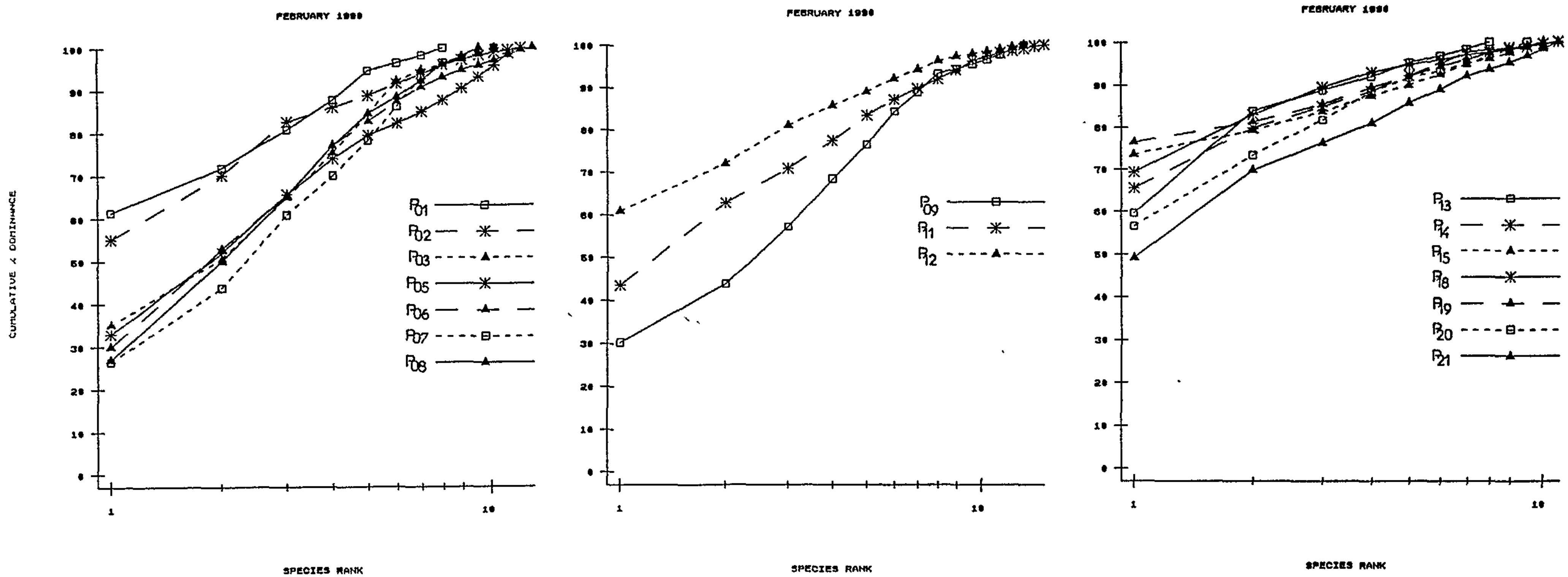


Fig. 58 K-dominance curves of phytoplankton species during February 1990

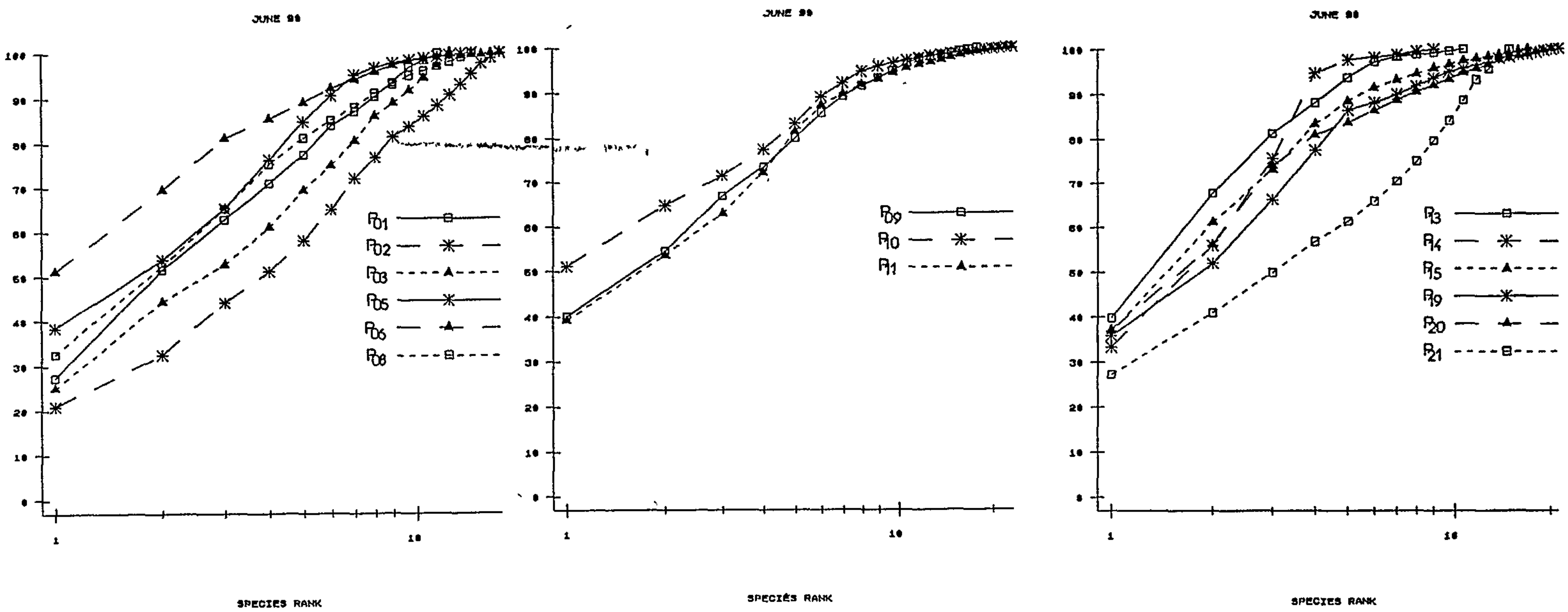


Fig. 59 K-dominance curves of phytoplankton species during June 1990

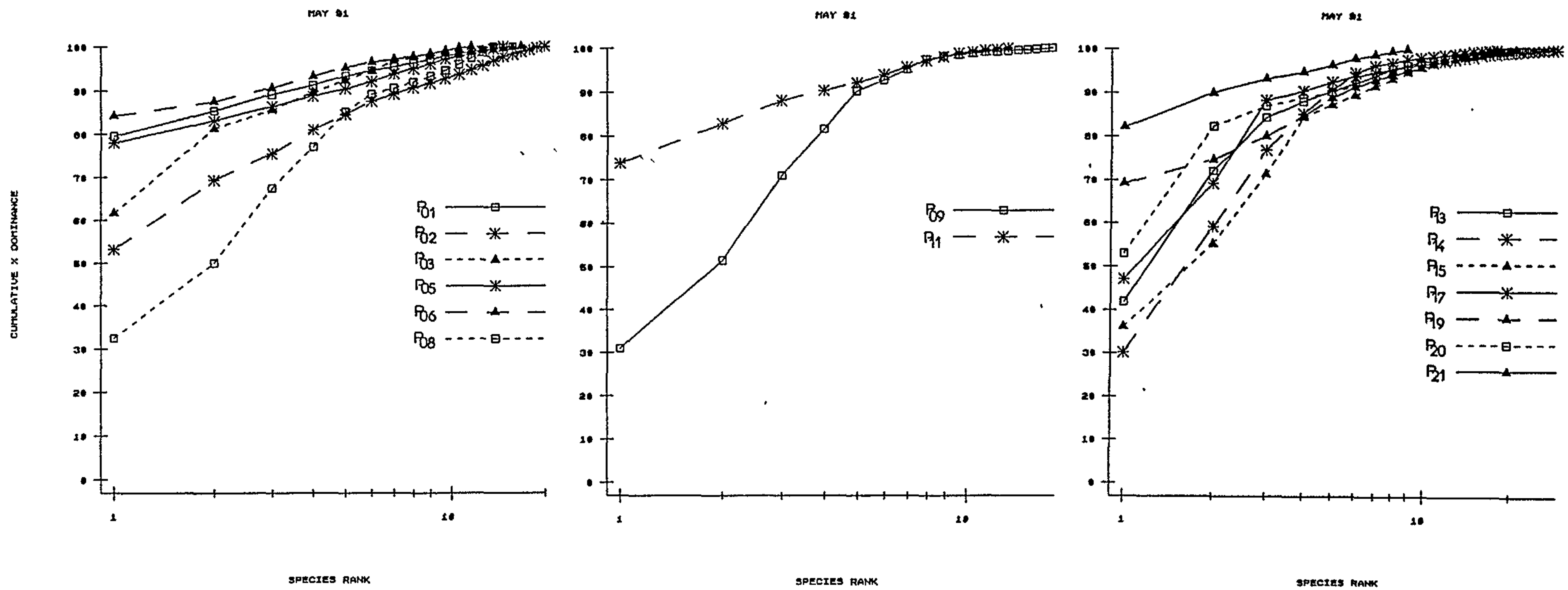


Fig. 60 K-dominance curves of phytoplankton species during May 1991

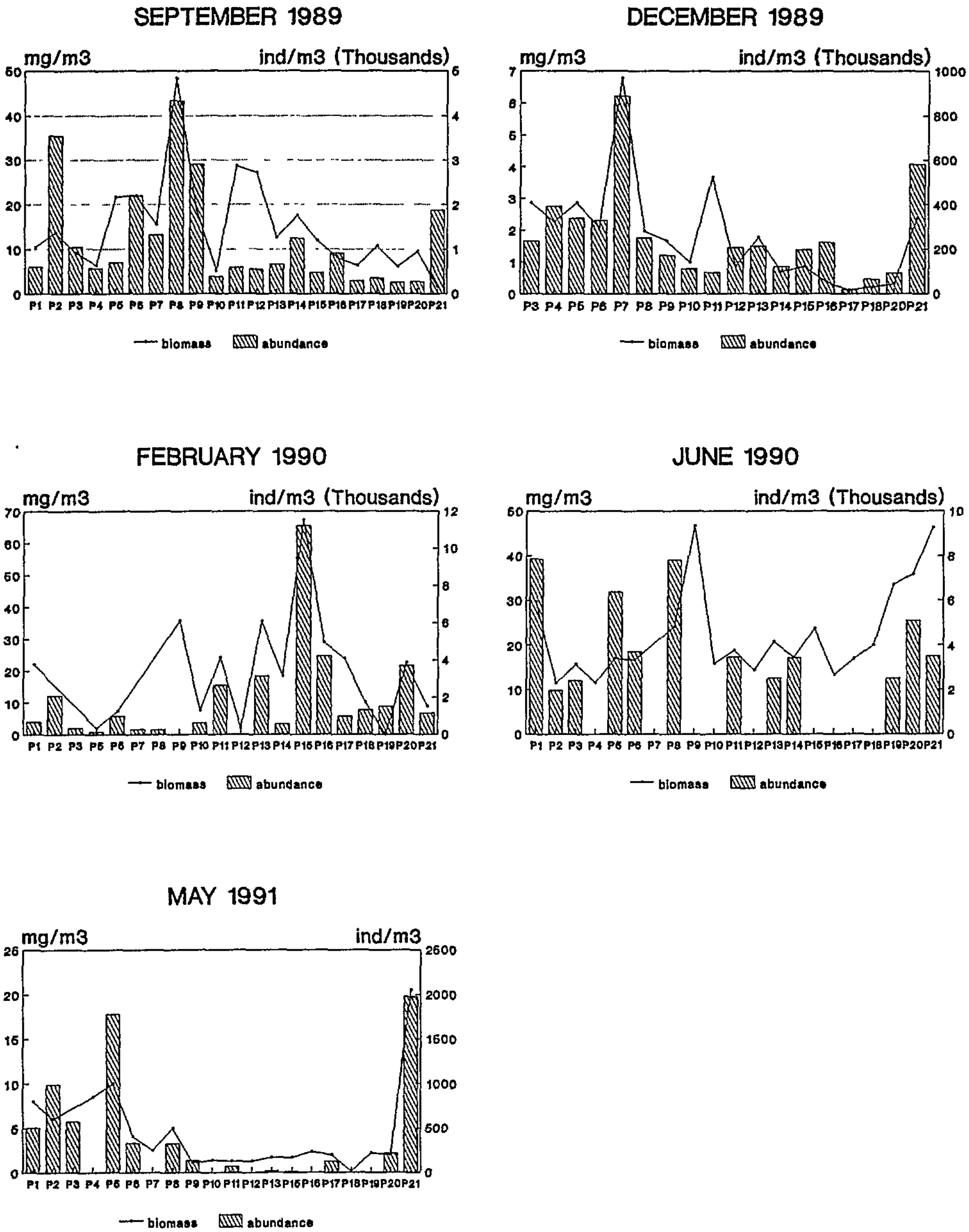


Fig. 61 Biomass (mg/m^3) and total abundances (ind./m^3) of zooplankton spatial and temporal variations, in Saronikos Gulf

Table 15

Biomass (mg/m^3) and total abundances (ind./m^3) of zooplankton spatial and temporal variations, in Saronikos Gulf

Months Stations	SEPTEMBER 1989		DECEMBER 1989		FEBRUARY 1990		JUNE 1990		MAY 1991	
	mg/m^3	ind/m^3	mg/m^3	ind/m^3	mg/m^3	ind/m^3	mg/m^3	ind/m^3	mg/m^3	ind/m^3
P01	10.44	607.42			22.05	660.67	29.60	7851.71	8.00	504.48
P02	13.73	3546.91				2095.86	11.47	1969.32	6.00	993.26
P03	9.12	1045.75	2.85	235.66		336.84	15.69	2413.23		571.39
P04	6.44	565.37	2.27	395.07			11.61		8.50	
P05	21.61	692.47	2.85	337.55	1.99	149.78	17.06	6371.71	10.00	1779.65
P06	21.99	2206.38	2.07	329.74	7.34	989.21	16.72	3702.28	4.04	331.58
P07	15.52	1323.49	6.76	887.86		284.81			2.50	
P08	48.28	4324.98	1.97	251.41		255.43	24.15	7795.28	5.00	326.43
P09	18.77	2911.28	1.65	171.40	35.66		46.65		1.10	136.71
P10	5.15	381.66	0.99	112.05	7.56	616.72	15.83		1.40	
P11	28.72	592.94	3.67	95.57	24.23	2649.32	18.76	3456.96	1.30	72.62
P12	27.13	550.43	0.87	206.26	2.04		14.41		1.30	
P13	12.62	656.94	1.77	213.93	35.44	3132.66	20.75	2515.74	1.70	16.92
P14	17.48	1240.11	0.69	121.15	18.31	571.01	17.23	3435.54		
P15	11.98	481.96	0.86	196.26	67.28	11219.81	23.67		1.70	14.53
P16	8.16	903.77	0.36	230.14	29.01	4229.26	13.31		2.30	
P17	6.41	294.73	0.11	18.39	23.77	982.51	16.93		2.00	129.79
P18	10.70	346.94	0.21	64.53	10.03	1305.05	20.01		0.15	
P19	6.11	259.38			0.05	1507.05	33.46	2494.80	2.20	2.55
P20	9.37	267.96	0.31	93.01	22.51	3711.00	35.94	5097.02	2.00	217.60
P21	1.67	1881.54	2.39	582.00	8.82	1146.19	46.32	3497.55	20.50	1975.06

6.2.2 Groups and species composition

September 1989: The dominant zooplankton species and groups composition during September 1989 are presented in Tables 16, 17 and Figure 62. At stations P01, P02 and P21 the copepods *Clausocalanus furcatus, Paracalanus parvus, Temora stylifera* and the cladocerans *Penilia avirostris* and *Evadne tergestina* were abundant. The presence of both cladocerans species was quite important at stations P03 to P09, whereas that of the above mentioned copepods decreased. The maximum relative abundance of *P. avirostris* (42.19%) was recorded at station P08 and at the nearby station P09 *E. tergestina* represented 58.65% of zooplankton abundance. Stations P10 and P11 were characterized by the dominance of the copepod *Centropages ponticus* (67.72% at station P11), accompanied by *T. stylifera* and *E. tergestina*. In Elefsis bay (stations P12 to P20) the copepod *Acartia grani* was dominant, with abundances fluctuating between 23.96% (P17) and 65.51% (P12) of total zooplankton abundance, followed by *C. ponticus*, *Acartia margalefi* and decapods larvae. Among the other groups and species, the presence of doliolids was important at station P01, also of the copepods *Corycaeus spp.* at P02 and of the copepod *Acartia clausi* at P18.

December 1989: During this sampling period stations P03 to P05 were characterized by the abundance of the copepods *Oithona plumifera, T. stylifera, P. parvus* and of the appendicularians (Tables 18, 19, Fig. 63). At station P05 apart from the above species, the presence of *A. clausi* was important, increasing at stations P06 to P08, up to 534 ind/m^3 and 60.13% of the total abundance. At these stations *A. clausi* was accompanied by *Podon polyphemoides* and *Oncaea spp.* Cirripeds larvae were abundant at stations P09 to P11 (maximum relative abundance 48.27% at st. P10), whereas the presence of *A. clausi* decreased at stations P09 and P10 and increased that of *P.polyphemoides.* However, *A. clausi* highly dominated in Elefsis bay (stations P11 to P18), representing 76.18% of zooplankton abundance at station P16 and it was accompanied by *P. polyphemoides*. An exception was recorded at station P17, where *A. clausi* decreased to 4.35% and *P. polyphemoides* was dominant (58.15%), accompanied by cirripeds larvae (14.67%). The presence of appendicularians was quite important in Elefsis bay, representing 32.45% of zooplankton abundance at station P20. In the latter station *P. polyphemoides, A. clausi, C. ponticus* and *C. furcatus* were abundant. At station P21 of the western Saronikos gulf *A. clausi* was dominant (236 ind/m^3 and 40.56%) accompanied by *Clausocalanus pergens, Clausocalanus jobei, Calocalanus pavoninus* and appendicularians.

February 1990: During late winter *A.clausi* was very abundant at almost all stations with densities ranging between 114 ind/m^3 (st. P05) and 10435 ind/m^3 (st. P15). This copepod dominated highly the zooplankton community: 44.74 % at station P06 to 97.91% at station P16 (Table 21, Fig. 63). Its presence was less important at stations P02 and P03 (29.35% and 25.80% respectively). The presence of *C. pergens, Ctenocalanus vanus, P. parvus, P. polyphemoides* was important at stations P01 to P07, whereas the latter two species accompanied in dominance *A. clausi* at stations P08 to P21. Apart from copepods and cladocerans, lamellibranchs larvae were present at stations P19 and P20 (Table 20).

Table 16

Zooplankton groups abundances (ind./m^3) and relative abundances (%) during September 1989

STATION GROUP		P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Appendicularia	ind/m^3	17.39	152.33	25.85	25.21	12.89	3.96	11.34	13.85	7.09	5.68	0.52	0.59	0.84	5.16	0.00	0.00	0.00	0.00	0.00	3.42	10.19
	(%)	2.86	4.29	2.47	4.46	1.86	0.18	0.86	0.32	0.24	1.49	0.09	0.11	0.13	0.42	0.00	0.00	0.00	0.00	0.00	1.28	0.54
Chaetognatha	ind/m^3	1.80	10.29	4.88	0.72	0.00	0.00	0.00	10.39	3.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	3.06
	(%)	0.30	0.29	0.47	0.13	0.00	0.00	0.00	0.24	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.16
Cirripeda larvae	ind/m^3	0.00	0.00	0.00	0.00	1.21	257.48	19.84	848.37	86.13	90.50	14.64	1.76	0.00	2.58	3.79	2.50	5.55	3.69	0.00	5.38	30.58
	(%)	0.00	0.00	0.00	0.00	0.17	11.67	1.50	19.62	2.96	23.71	2.47	0.32	0.00	0.21	0.79	0.28	1.88	1.06	0.00	2.01	1.63
Cladocera	ind/m^3	140.31	1064.28	664.81	218.23	330.32	538.72	879.96	2486.26	2147.24	44.59	50.72	9.97	9.61	6.88	7.96	3.13	22.81	8.61	6.52	18.09	396.49
	(%)	23.10	30.01	63.57	38.60	47.70	24.42	66.49	57.49	73.76	11.68	8.55	1.81	1.46	0.55	1.65	0.35	7.74	2.48	2.51	6.75	21.07
Copepoda	ind/m^3	374.17	2190.31	315.58	301.05	329.92	1311.15	395.35	837.99	571.52	202.42	489.41	509.98	609.33	1185.93	424.36	870.00	245.41	313.11	252.17	213.68	1336.24
	(%)	61.60	61.75	30.18	53.25	47.64	59.43	29.87	19.38	19.63	53.04	82.54	92.65	92.75	95.63	88.05	96.26	83.26	90.25	97.22	79.74	71.02
Decapoda larvae	ind/m^3	2.40	8.23	0.98	1.44	4.43	75.26	5.67	45.02	66.88	36.29	36.08	25.79	32.99	36.12	44.33	26.27	19.73	17.22	0.00	22.98	6.12
	(%)	0.39	0.23	0.09	0.25	0.64	3.41	0.43	1.04	2.30	9.51	6.08	4.69	5.02	2.91	9.20	2.91	6.69	4.96	0.00	8.58	0.33
Doliolidae	ind/m^3	65.96	74.11	29.27	16.56	11.28	3.96	9.92	65.79	27.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.71
	(%)	10.86	2.09	2.80	2.93	1.63	0.18	0.75	1.52	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.82
Euphausiacea larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Fish eggs	ind/m^3	0.60	39.11	1.46	0.72	1.21	7.92	1.42	3.46	1.01	1.75	0.00	0.00	0.84	0.00	0.00	0.63	0.00	0.00	0.00	0.00	4.08
	(%)	0.10	1.10	0.14	0.13	0.17	0.36	0.11	0.08	0.03	0.46	0.00	0.00	0.13	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.22
Fish larvae	ind/m^3	0.00	4.12	0.49	0.00	0.40	3.96	0.00	3.46	0.00	0.44	0.52	0.00	1.25	0.00	0.76	0.00	0.00	0.00	0.69	0.98	1.02
	(%)	0.00	0.12	0.05	0.00	0.06	0.18	0.00	0.08	0.00	0.11	0.09	0.00	0.19	0.00	0.16	0.00	0.00	0.00	0.26	0.36	0.05
Gastropoda larvae	ind/m^3	4.80	2.06	0.98	0.00	0.81	0.00	0.00	10.39	0.00	0.00	0.00	0.00	0.00	0.00	0.38	1.25	0.00	0.00	0.00	0.00	1.02
	(%)	0.79	0.06	0.09	0.00	0.12	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.14	0.00	0.00	0.00	0.00	0.05
Lamellibranchia larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medusae	ind/m^3	0.00	2.06	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.06	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaeta larvae	ind/m^3	0.00	0.00	0.00	0.72	0.00	3.96	0.00	0.00	1.01	0.00	1.05	2.34	2.09	3.44	0.38	0.00	1.23	4.31	0.00	2.93	0.00
	(%)	0.00	0.00	0.00	0.13	0.00	0.18	0.00	0.00	0.03	0.00	0.18	0.43	0.32	0.28	0.08	0.00	0.42	1.24	0.00	1.09	0.00
Pteropoda	ind/m^3	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siphonophora	ind/m^3	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02
	(%)	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Table 17

Distribution of zooplankton dominant species abundances (ind./m^3) and relative abundances (%) during September 1989

STATION SPECIES		P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Acartia clausi	ind/m^3	0.00	31.25	1.36	0.00	0.00	0.00	2.16	0.00	0.00	0.00	29.28	0.00	0.00	0.00	0.00	0.00	0.00	79.67	0.42	0.00	0.00
	%	0.00	0.88	0.13	0.00	0.00	0.00	0.16	0.00	0.00	0.00	4.94	0.00	0.00	0.00	0.00	0.00	0.00	22.96	0.16	0.00	0.00
Acartia margalefi	ind/m^3	4.64	1.25	0.17	0.00	2.22	8.39	0.00	0.00	41.37	2.08	5.23	36.84	25.25	169.11	59.69	122.91	24.33	5.90	19.98	2.93	0.00
	%	0.76	0.04	0.002	0.00	0.32	0.38	0.00	0.00	1.42	0.54	0.88	6.69	3.84	13.64	12.39	13.60	8.25	1.70	7.70	1.09	0.00
Acartia grani	ind/m^3	43.33	0.00	10.18	7.92	15.51	62.91	150.88	0.00	32.60	6.23	29.28	360.59	411.60	699.49	217.66	561.96	70.63	98.36	161.10	109.04	0.00
	%	7.13	0.00	0.97	1.40	2.24	2.85	11.40	0.00	1.12	1.63	4.94	65.51	62.65	56.41	45.16	62.18	23.96	28.35	62.11	40.69	0.00
Centropages ponticus	ind/m^3	10.79	80.28	3.41	31.69	31.42	411.96	46.76	6.93	112.48	136.84	401.57	102.00	172.06	293.26	133.37	175.13	135.04	118.72	68.79	85.08	0.00
	%	1.78	2.26	0.33	5.61	4.54	18.67	3.53	0.16	3.86	35.85	67.72	18.53	26.19	23.65	27.67	19.38	45.82	34.22	26.52	31.75	0.00
Clausocalanus furcatus	ind/m^3	56.96	1017.28	129.26	38.17	41.09	245.59	5.67	93.49	32.43	1.75	0.00	0.59	0.00	2.58	0.00	0.00	0.00	0.00	0.00	8.80	842.38
	%	9.38	28.68	12.36	6.75	5.93	11.13	0.43	2.16	1.11	0.46	0.00	0.11	0.00	0.21	0.00	0.00	0.00	0.00	0.00	3.28	44.77
Corycaeus spp.	ind/m^3	7.20	502.29	3.41	5.04	11.68	0.00	14.17	10.39	5.07	1.31	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.49	23.44
	%	1.18	14.16	0.33	0.89	1.69	0.00	1.07	0.24	0.17	0.34	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.18	1.25
Oithona plumifera	ind/m^3	27.58	57.64	42.39	30.25	33.84	34.66	32.47	72.72	8.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	69.31
	%	4.54	1.63	4.05	5.35	4.89	1.57	2.45	1.68	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68
Paracalanus parvus	ind/m^3	86.95	230.56	20.49	33.13	28.60	114.87	53.85	602.52	125.65	4.37	1.05	1.17	0.42	1.72	0.76	0.00	0.62	2.46	0.00	2.44	270.10
	%	14.31	6.50	1.96	5.86	4.13	5.21	4.07	13.93	4.32	1.15	0.18	0.21	0.06	0.14	0.16	0.00	0.21	0.71	0.00	0.91	14.36
Temora stylifera	ind/m^3	136.12	222.33	97.55	152.69	163.55	423.85	83.60	13.85	203.68	48.53	22.48	8.79	0.00	19.78	12.88	10.01	14.80	6.77	0.00	4.40	114.16
	%	22.41	6.27	9.33	27.01	23.62	19.21	6.32	0.32	7.00	12.71	3.79	1.60	0.00	1.60	2.67	1.11	5.02	1.95	0.00	1.64	6.07
Evadne spinifera	ind/m^3	88.74	90.58	15.12	1.44	4.43	7.92	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.50
	%	14.61	2.55	1.45	0.25	0.64	0.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41
Evadne tergestina	ind/m^3	44.37	547.58	222.42	92.91	151.06	376.31	595.14	661.39	1707.45	23.01	23.01	3.52	6.26	5.16	6.06	1.88	9.87	6.77	5.66	3.91	53.00
	%	7.31	15.44	21.27	16.43	21.82	17.06	44.97	15.29	58.65	3.88	3.88	0.64	0.95	0.42	1.26	0.21	3.35	1.95	2.18	1.46	2.82
Penilia avirostris	ind/m^3	7.20	426.12	427.28	123.88	174.83	122.80	283.40	1824.87	408.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	281.31
	%	1.18	40.86	40.86	21.91	25.25	5.57	21.41	42.19	14.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.95
Podon polyphemoides	ind/m^3	0.00	0.00	0.00	0.00	0.00	31.69	0.00	0.00	31.41	3.93	27.71	6.45	3.34	1.72	1.89	1.25	12.95	1.85	0.86	14.18	35.67
	%	0.00	0.00	0.00	0.00	0.00	1.44	0.00	0.00	1.08	1.03	4.67	1.17	0.51	0.14	0.39	0.14	4.39	0.53	0.33	5.29	1.90

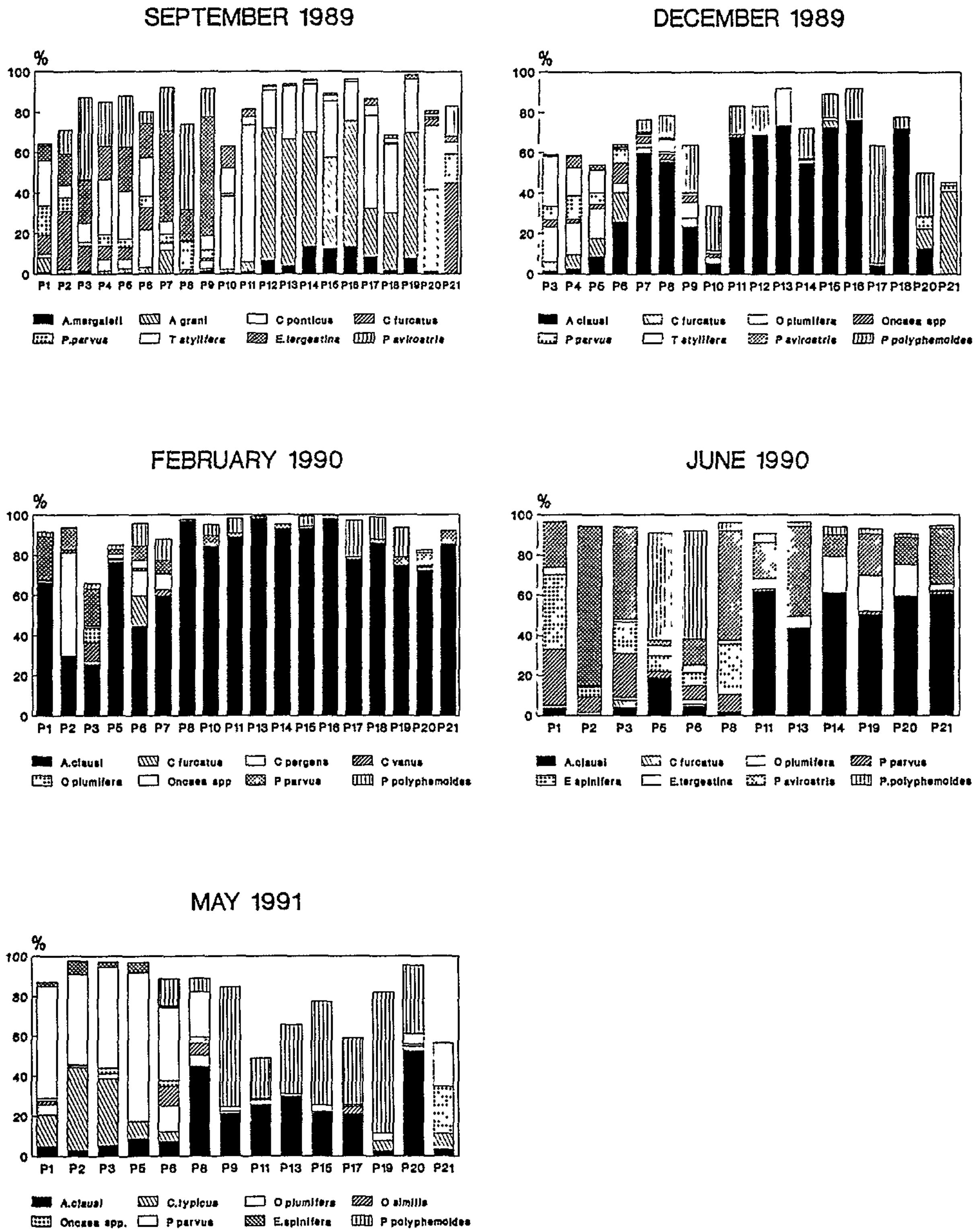


Fig. 62 Distribution of dominant zooplankton species percentages (%), during the five sampling periods in Saronikos Gulf

Table 18

Zooplankton groups abundances (ind./m^3) and relative abundances (%) during December 1989

STATION GROUP		P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P20	P21
Appendicularia	ind/m^3	11.20	54.03	44.68	3.08	11.02	3.51	0.26	0.90	2.77	21.70	6.06	28.83	7.37	8.76	0.50	9.64	30.19	44.01
	%)	4.75	13.68	13.24	0.93	1.24	1.39	0.15	0.80	2.90	10.52	2.83	23.80	3.76	3.81	2.72	14.93	32.45	7.56
Chaetognatha	ind/m^3	13.28	14.24	10.34	4.62	22.77	6.01	1.31	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63
	%)	5.64	3.60	3.06	1.40	2.56	2.39	0.77	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45
Cirripeda larvae	ind/m^3	0.26	0.00	0.00	2.57	19.83	4.51	29.66	54.08	5.86	3.62	2.02	1.68	3.69	2.76	2.70	2.28	8.60	0.66
	%)	0.11	0.00	0.00	0.78	2.23	1.79	17.31	48.26	6.13	1.75	0.94	1.39	1.88	1.20	14.67	3.54	9.24	0.11
Cladocera	ind/m^3	2.86	25.24	10.34	5.64	59.48	30.05	42.26	25.55	13.26	29.33	39.75	17.97	22.69	36.17	10.69	3.68	20.67	7.88
	%)	1.22	6.39	3.06	1.71	6.70	11.95	24.66	22.80	13.87	14.22	18.58	14.83	11.56	15.72	58.15	5.70	22.22	1.35
Copepoda	ind/m^3	196.86	279.56	244.48	276.37	691.79	198.32	83.73	25.85	70.29	145.18	162.39	71.25	158.82	177.26	2.40	46.91	29.98	497.26
	%)	83.54	70.76	72.43	83.82	77.92	78.88	48.85	23.07	73.55	70.39	75.91	58.81	80.92	77.03	13.05	72.69	32.23	85.44
Decapoda larvae	ind/m^3	1.04	1.29	0.00	0.77	1.47	0.00	1.57	1.05	1.85	3.48	2.36	0.26	0.00	2.27	1.10	0.00	0.41	0.66
	%)	0.44	0.33	0.00	0.23	0.17	0.00	0.92	0.93	1.94	1.69	1.10	0.21	0.00	0.99	5.98	0.00	0.44	0.11
Doliolidae	ind/m^3	2.08	14.24	20.68	2.57	13.95	1.50	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.88	3.60	6.13	0.78	1.57	0.60	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiacea larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.71
	%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.39
Fish eggs	ind/m^3	1.30	0.97	1.65	0.51	0.73	0.50	0.52	0.15	0.00	0.00	0.34	0.26	0.00	0.16	0.00	0.13	0.20	0.00
	%)	0.55	0.25	0.49	0.16	0.08	0.20	0.31	0.13	0.00	0.00	0.16	0.21	0.00	0.07	0.00	0.20	0.22	0.00
Fish larvae	ind/m^3	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda larvae	ind/m^3	6.51	2.59	2.48	32.07	62.42	6.51	9.97	1.49	1.23	2.14	1.01	0.13	0.00	2.43	0.60	0.51	2.46	5.91
	%)	2.76	0.66	0.74	9.73	7.03	2.59	5.82	1.33	1.29	1.04	0.47	0.11	0.00	1.06	3.26	0.79	2.64	1.02
Lamellibranchia larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medusae	ind/m^3	0.00	0.00	0.41	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.10	0.13	0.00	1.31
	(%)	0.00	0.00	0.12	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.54	0.20	0.00	0.23
Polychaeta larvae	ind/m^3	0.26	1.29	1.65	1.54	4.41	0.00	1.05	2.84	0.31	0.67	0.00	0.78	2.55	0.32	0.30	1.27	0.51	1.31
	%)	0.11	0.33	0.49	0.47	0.50	0.00	0.61	2.53	0.32	0.32	0.00	0.64	1.30	0.14	1.63	1.96	0.55	0.23
Pteropoda	ind/m^3	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siphonophora	ind/m^3	0.00	0.65	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.16	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 19

Distribution of zooplankton dominant species abundances (ind./m^3) and relative abundances (%) during December 1989

STATION SPECIES		P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P20	P21
Acartia clausi	ind/m^3	3.12	10.03	29.37	84.92	533.89	139.73	40.16	5.53	64.43	142.37	155.65	66.46	142.86	175.32	0.80	46.40	11.77	0.66
	%	1.32	2.54	8.70	25.75	60.13	55.58	23.43	4.94	67.42	69.03	72.76	54.86	72.79	76.18	4.35	71.90	12.65	0.11
Calocalanus spp.	ind/m^3	15.62	28.47	30.61	15.91	27.91	5.51	3.41	0.45	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	44.01
	%	6.63	7.21	9.07	4.82	3.14	2.19	1.99	0.40	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	7.56
Centropages ponticus	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.00	0.65	0.28	0.49	0.90	0.00	0.20	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.53	0.14	0.21	4.89	0.00	0.22	0.00
C. furcatus	ind/m^3	11.20	27.61	30.61	47.04	23.50	2.17	7.61	0.45	0.00	0.00	1.01	2.20	6.57	0.16	0.20	0.13	8.90	236.07
	%	4.75	6.99	9.07	14.27	2.65	0.86	4.44	0.40	0.00	0.00	0.47	1.82	3.35	0.07	1.09	0.20	9.57	40.56
Corycaeus sp.	ind/m^3	16.14	11.32	9.51	8.72	22.77	7.51	9.97	4.18	2.77	1.47	1.01	0.52	1.42	0.65	0.30	0.38	2.15	5.91
	%	6.85	2.87	2.82	2.65	2.56	2.99	5.82	3.73	2.90	0.71	0.47	0.43	0.72	0.28	1.63	0.59	2.31	1.02
Oithona plumifera	ind/m^3	40.88	61.77	49.32	15.60	19.83	1.00	13.12	3.29	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	17.35	15.64	14.61	4.73	2.23	0.40	7.65	2.94	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oncaea spp.	ind/m^3	8.07	6.79	7.45	33.10	29.38	7.01	5.51	2.09	1.23	0.13	0.34	0.26	0.00	0.00	0.00	0.00	0.31	1.31
	%	3.43	1.72	2.21	10.04	3.31	2.79	3.22	1.87	1.29	0.06	0.16	0.21	0.00	0.00	0.00	0.00	0.33	0.23
Paracalanus parvus	ind/m^3	15.62	46.27	19.03	22.83	8.81	2.00	0.26	0.15	0.00	0.00	0.00	0.26	2.84	0.00	0.00	0.00	5.63	14.45
	%	6.63	11.71	5.64	6.92	0.99	0.80	0.15	0.13	0.00	0.00	0.00	0.21	1.45	0.00	0.00	0.00	6.05	2.48
Temora stylifera	ind/m^3	58.59	54.68	37.64	3.34	3.67	16.03	1.57	1.64	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.10	2.63
	%	24.86	13.84	11.15	1.01	0.41	6.37	0.92	1.47	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.11	0.45
Penilia avirostris	ind/m^3	1.30	22.97	9.10	1.54	7.34	2.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.55	5.81	2.70	0.47	0.83	0.80	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Podon polyphemoides	ind/m^3	0.78	1.94	0.41	2.82	52.14	27.55	40.16	24.65	13.26	29.33	39.75	17.97	22.69	36.17	10.69	3.68	19.95	7.88
	%	0.33	0.49	0.12	0.86	5.87	10.96	23.43	22.00	13.87	14.22	18.58	14.83	11.56	15.72	58.15	5.70	21.45	1.35

Table 20

Zooplankton groups abundances (ind./m^3) and relative abundances (%) during February 1990

Station Group		P01	P02	P03	P05	P06	P07	P08	P10	P11	P13	P14	P15	P16	P17	P18	P19	P20	P21
Appendicularia	ind/m^3	2.00	8.18	39.13	3.47	1.65	12.20	0.00	1.28	1.82	0.87	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.30	0.39	11.62	2.32	0.17	4.28	0.00	0.21	0.07	0.03	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaetognatha	ind/m^3	0.00	0.00	0.24	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.07	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cirripeda larvae	ind/m^3	2.67	27.81	0.00	0.00	1.65	0.00	0.00	4.49	3.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95
	%)	0.40	1.33	0.00	0.00	0.17	0.00	0.00	0.73	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Cladocera	ind/m^3	18.00	11.45	8.64	3.65	112.29	32.96	0.00	33.34	194.30	3.49	0.59	572.85	63.01	177.72	140.54	217.36	80.79	10.75
	%)	2.72	0.55	2.57	2.44	11.35	11.57	0.00	5.41	7.33	0.11	0.10	5.11	1.49	18.09	10.76	14.42	2.18	0.94
Copepoda	ind/m^3	626.00	2046.78	286.66	137.54	861.29	231.08	255.43	570.56	2427.78	3123.07	559.84	10610.47	4151.13	793.74	1162.26	1214.98	3109.01	1128.61
	%)	94.75	97.66	85.10	91.83	87.07	81.13	100.00	92.52	91.64	99.69	98.04	94.57	98.15	80.79	89.02	80.62	83.78	98.47
Decapoda larvae	ind/m^3	0.00	1.64	0.96	0.00	9.46	0.33	0.00	0.64	0.00	0.00	0.59	0.00	0.00	0.92	0.00	1.70	5.21	0.00
	%)	0.00	0.08	0.29	0.00	0.96	0.12	0.00	0.10	0.00	0.00	0.10	0.00	0.00	0.09	0.00	0.11	0.14	0.00
Doliolidae	ind/m^3	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiacea larvae	ind/m^3	0.00	0.00	0.24	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.07	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish eggs	ind/m^3	7.33	0.00	0.00	4.38	0.41	2.31	0.00	0.00	7.26	3.49	1.76	0.00	0.00	0.92	0.70	0.00	2.61	1.95
	%)	1.11	0.00	0.00	2.93	0.04	0.81	0.00	0.00	0.27	0.11	0.31	0.00	0.00	0.09	0.05	0.00	0.07	0.17
Fish larvae	ind/m^3	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda larvae	ind/m^3	0.67	0.00	0.24	0.37	0.41	0.99	0.00	0.64	3.63	1.74	1.18	3.65	0.00	0.92	0.00	0.00	54.73	0.00
	%)	0.10	0.00	0.07	0.24	0.04	0.35	0.00	0.10	0.14	0.06	0.21	0.03	0.00	0.09	0.00	0.00	1.47	0.00
Lamellibranchia larvae	ind/m^3	3.33	0.00	0.00	0.00	0.00	4.62	0.00	1.28	1.82	0.00	6.47	32.84	15.12	8.29	2.11	73.02	458.66	1.95
	%)	0.50	0.00	0.00	0.00	0.00	1.62	0.00	0.21	0.07	0.00	1.13	0.29	0.36	0.84	0.16	4.85	12.36	0.17
Medusae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaeta larvae	ind/m^3	0.67	0.00	0.48	0.37	0.41	0.00	0.00	4.49	7.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.10	0.00	0.14	0.24	0.04	0.00	0.00	0.73	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteropoda	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siphonophora	ind/m^3	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%)	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

<u>Table 21</u>

Distribution of zooplankton dominant species abundances (ind./m^3) and relative abundances (%) during February 1990

STATION SPECIES		P01	P02	P03	P05	P06	P07	P08	P10	P11	P13	P14	P15	P16	P17	P18	P19	P20	P21
Acartia clausi	ind/m^3	438.67	615.18	86.91	114.71	442.57	170.10	246.65	516.07	2349.70	3075.11	531.02	10435.33	4141.05	763.36	1120.10	1119.04	2686.83	978.13
	%	66.40	29.35	25.80	76.59	44.74	59.72	96.56	83.68	88.69	98.16	93.00	93.01	97.91	77.69	85.79	74.25	72.40	85.34
Acartia grani	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.28	7.69	5.45	5.23	5.29	25.54	7.56	13.81	9.84	2.55	2.61	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.25	0.21	0.17	0.93	0.23	0.18	1.41	0.75	0.17	0.07	0.00
Calocalanus spp.	ind/m^3	0.00	0.00	7.68	2.19	4.52	0.00	0.00	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	2.28	1.46	0.46	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centropages typicus	ind/m^3	22.00	21.27	25.93	1.46	2.88	0.00	4.54	0.64	0.00	0.00	2.35	3.65	0.00	0.00	1.41	5.09	39.09	13.68
	%	3.33	1.01	7.70	0.98	0.29	0.00	1.78	0.10	0.00	0.00	0.41	0.03	0.00	0.00	0.11	0.34	1.05	1.19
Clausocalanus furcatus	ind/m^3	0.00	10.63	5.97	0.00	147.73	0.00	1.13	0.00	0.00	0.00	0.00	7.30	0.00	0.00	0.00	2.72	45.38	0.00
	%	0.00	0.51	1.77	0.00	14.93	0.00	0.44	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.18	1.22	0.00
Clausocalanus pergens	ind/m^3	6.00	1077.39	0.00	1.46	126.62	0.00	1.98	1.92	0.00	0.00	0.00	7.30	0.00	0.00	0.70	1.36	22.69	0.00
	%	0.91	51.41	0.00	0.98	12.80	0.00	0.78	0.31	0.00	0.00	0.00	0.07	0.00	0.00	0.05	0.09	0.61	0.00
Corycaeus spp.	ind/m^3	10.67	6.54	6.48	6.58	6.58	7.58	0.00	1.28	3.63	5.23	2.94	0.00	2.52	1.84	2.81	10.19	13.03	48.86
	%	1.61	0.31	1.92	4.39	0.67	2.66	0.00	0.21	0.14	0.17	0.51	0.00	0.06	0.19	0.22	0.68	0.35	4.26
Ctenocalanus vanus	ind/m^3	2.67	26.18	29.77	0.00	11.11	8.24	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.92	0.70	5.09	10.42	0.00
	%	0.40	1.25	8.84	0.00	1.12	2.89	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.09	0.05	0.34	0.28	0.00
Oithona plumifera	ind/m^3	0.00	0.00	25.70	1.37	0.00	0.99	0.00	0.00	7.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	7.63	0.91	0.00	0.35	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oncaea spp.	ind/m^3	2.67	4.91	3.36	3.11	39.49	21.43	0.00	1.28	0.00	1.74	0.00	3.65	0.00	0.00	0.70	0.00	7.82	0.00
	%	0.40	0.23	1.00	2.07	3.99	7.52	0.00	0.21	0.00	0.06	0.00	0.03	0.00	0.00	0.05	0.00	0.21	0.00
Paracalanus parvus	ind/m^3	140.00	225.78	62.18	3.29	69.51	19.78	0.00	34.62	56.29	34.88	12.94	120.41	0.00	13.81	26.00	64.53	237.15	76.22
	%	21.19	10.77	18.46	2.20	7.03	6.94	0.00	5.61	2.12	1.11	2.27	1.07	0.00	1.41	1.99	4.28	6.39	6.65
Podon polyphemoides	ind/m^3	14.00	4.91	8.64	3.29	111.05	30.00	0.00	33.34	188.85	0.00	0.00	558.25	63.01	177.72	140.54	216.51	52.12	0.00
	%	2.12	0.23	2.57	2.20	11.23	10.53	0.00	5.41	7.13	0.00	0.00	4.98	1.49	18.09	10.76	14.37	1.40	0.00

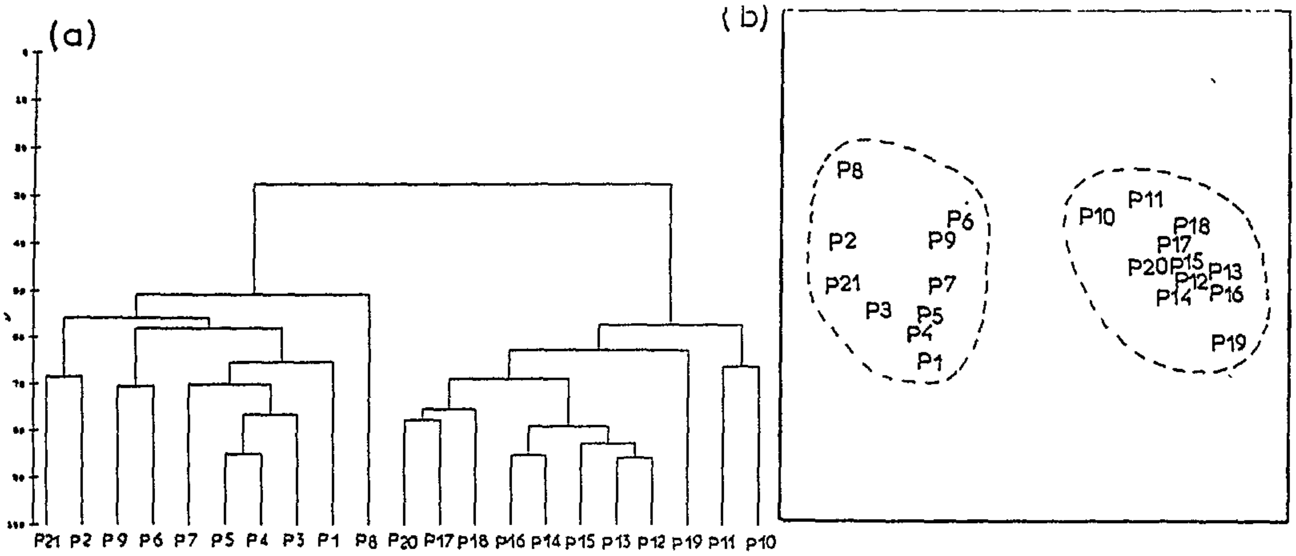


Fig. 63 Dendrogram (a) and MDS plot (b, stress=0.06) showing stations grouping according to zooplankton species distribution in Saronikos Gulf, during September 1989

June 1990: *A. clausi* was the dominant species at the samples from the stations P05 and P11 to P21 (maximum abundance 3005 ind/m^3 at P20 and relative abundance 70% at P11) during this period (Tables 22, 23). Stations P01, P02, P03 and P08 were characterized by the dominance of *P. avirostris, Evadne spinifera, P. parvus* (Fig. 63). All the above species were quite important at stations P05 and P06 whereas *P. polyphemoides* was dominant at station P05 (3400 ind/m^3-53.3%) and at station P06 (2000 ind/m^3-54%). The latter species together with *A. clausi* were dominant at P11 to P21 and were accompanied by *E. tergestina*.

May 1991: During May 1991, *P. parvus* was dominant at stations P01 to P06, where it was accompanied by *Centropages typicus, A. clausi, E. spinifera* (Table 25, Fig. 63). The presence of *Oithona similis* and *Oithona plumifera* was important at stations P05 and P06. *A. clausi* abundances increased at stations P08 to P17 and P20 (up to 52.55% at P20). At these stations *P. polyphemoides* was also abundant (up to 59.87% at P09). The latter species was relatively more abundant at P19 (70.51%) but only 1.8 ind/m^3 were found. The presence of cirripeds larvae was significant at stations P09 to P17 (16.21 ind/m^3 at P11 and 10.48% at P17, Table 24).

6.2.3 Similarities among stations

September 1989: Hierarchical clustering based on species and groups composition in September (Fig. 63), distinguished two groups of stations at the 28% similarity level. The first group concerned stations P01 to P09 and station P21, that is the inner Saronikos, the western Saronikos and the Psittalia area. Stations P10 to P20 positioned in the Keratsini and Elefsis bay formed a second group. The ordination technique (MDS) revealed a similar picture where the two groups are well separated (stress=0.06).

<u>Table 22</u>

Zooplankton groups abundances (ind./m^3) and relative abundances (%) during June 1990

STATIONS GROUPS		P01	P02	P03	P05	P06	P08	P11	P13	P14	P19	P20	P21
Appendicularia	ind/m^3	80.39	91.15	32.74	65.14	71.20	133.84	86.05	24.91	31.25	28.99	176.44	13.47
	(%)	1.02	4.63	1.36	1.02	1.92	1.72	2.49	0.99	0.91	1.16	3.46	0.38
Chaetognatha	ind/m^3	0.00	1.20	0.00	3.10	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.06	0.00	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cirripeda larvae	ind/m^3	49.13	2.40	0.00	127.17	111.44	5.95	39.72	0.00	9.62	13.53	19.60	0.00
	i(%)	0.63	0.12	0.00	2.00	3.01	0.08	1.15	0.00	0.28	0.54	0.38	0.00
Cladocera	ind/m^3	4979.90	1673.09	1525.36	4457.17	2888.15	6700.71	954.84	1329.48	1127.55	1024.20	1607.52	1158.00
	(%)	63.42	84.96	63.21	69.95	78.01	85.96	27.62	52.85	32.82	41.05	31.54	33.11
Copepoda	ind/m^3	2679.77	195.49	814.68	1619.87	591.25	924.95	2303.53	1120.88	2170.95	1366.25	3162.77	2235.20
	(%)	34.13	9.93	33.76	25.42	15.97	11.87	66.63	44.55	63.19	54.76	62.05	63.91
Decapoda larvae	ind/m^3	0.00	0.00	0.00	27.92	0.00	2.97	72.81	37.36	93.76	61.84	84.95	74.06
	(%)	0.00	0.00	0.00	0.44	0.00	0.04	2.11	1.49	2.73	2.48	1.67	2.12
Doliolidae	ind/m^3	13.40	6.00	17.33	0.00	0.00	14.87	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.17	0.30	0.72	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiacea larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish eggs	ind/m^3	0.00	0.00	0.00	9.31	6.19	2.97	0.00	3.11	0.00	0.00	0.00	3.37
	(%)	0.00	0.00	0.00	0.15	0.17	0.04	0.00	0.12	0.00	0.00	0.00	0.10
Fish larvae	ind/m^3	0.00	0.00	0.00	9.31	0.00	0.00	0.00	0.00	2.40	0.00	26.14	6.73
	(%)	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.07	0.00	0.51	0.19
Gastropoda larvae	ind/m^3	22.33	0.00	11.56	12.41	3.10	2.97	0.00	0.00	0.00	0.00	13.07	3.37
	(%)	0.28	0.00	0.48	0.19	0.08	0.04	0.00	0.00	0.00	0.00	0.26	0.10
Lamellibranchia larvae	ind/m^3	17.87	0.00	1.93	0.00	18.57	0.00	0.00	0.00	0.00	0.00	6.53	0.00
	(%)	0.23	0.00	0.08	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.13	0.00
Medusae	ind/m3	0.00	0.00	0.00	3.10	0.00	2.97	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Polychaeta larvae	ind/m3	0.00	0.00	0.00	34.12	6.19	2.97	0.00	0.00	0.00	0.00	0.00	3.37
	(%)	0.00	0.00	0.00	0.54	0.17	0.04	0.00	0.00	0.00	0.00	0.00	0.10
Pteropoda	ind/m3	8.93	0.00	9.63	3.10	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.11	0.00	0.40	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siphonophora	ind/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 23

Distribution of zooplankton dominant species abundances (ind./m^3) and relative abundances (%) during June 1990

STATIONS SPECIES		P01	P02	P03	P05	P06	P08	P11	P13	P14	P19	P20	P21
Acartia clausi	ind/m^3	294.77	2.40	98.22	1172.45	167.16	62.46	2143.02	1092.85	2089.21	1258.03	3005.93	2114.02
	%	3.75	0.12	4.07	18.40	4.52	0.80	61.99	43.44	60.81	50.43	58.97	60.44
Acartia grani	ind/m^3	0.00	0.00	0.00	12.41	6.19	0.00	57.92	6.23	28.85	13.53	104.55	0.00
	%	0.00	0.00	0.00	0.19	0.17	0.00	1.68	0.25	0.84	0.54	2.05	0.00
Clausocalanus typicus	ind/m^3	17.87	3.60	44.30	80.64	0.00	56.51	11.03	6.23	7.21	0.00	6.53	25.30
	%	0.23	0.18	1.84	1.27	0.00	0.72	0.32	0.25	0.21	0.00	0.13	0.72
Clausocalanus arcuicornis	ind/m^3	6.83	0.00	0.00	28.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.09	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clausocalanus furcatus	ind/m^3	109.29	4.80	88.59	5.76	37.15	41.64	1.65	0.00	2.40	0.00	0.00	0.00
	%	1.39	0.24	3.67	0.09	1.00	0.53	0.05	0.00	0.07	0.00	0.00	0.00
Oithona nana	ind/m^3	0.00	0.00	0.00	52.73	0.00	0.00	36.41	6.23	9.62	38.65	6.53	30.30
	%	0.00	0.00	0.00	0.83	0.00	0.00	1.05	0.25	0.28	1.55	0.13	0.87
Oithona plumifera	ind/m^3	4.47	27.58	32.74	28.69	89.77	35.69	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.06	1.40	1.36	0.45	2.42	0.46	0.00	0.00	0.00	0.00	0.00	0.00
Oncaea spp.	ind/m^3	4.47	0.00	5.78	12.41	18.57	17.84	1.65	0.00	0.00	0.00	0.00	0.00
	%	0.06	0.00	0.24	0.19	0.50	0.23	0.05	0.00	0.00	0.00	0.00	0.00
Paracalanus parvus	ind/m^3	2206.34	148.72	529.64	198.51	253.84	684.05	38.06	3.11	16.83	38.65	0.00	40.40
	%	28.10	7.55	21.95	3.12	6.86	8.78	1.10	0.12	0.49	1.55	0.00	1.15
Temora stylifera	ind/m^3	17.87	4.80	15.41	3.10	0.00	14.87	4.96	0.00	0.00	0.00	13.07	13.47
	%	0.23	0.24	0.64	0.05	0.00	0.19	0.14	0.00	0.00	0.00	0.26	0.38
Evadne spinifera	ind/m^3	2916.48	98.35	379.41	496.28	244.55	1954.00	0.00	3.11	0.00	0.00	26.14	26.93
	%	37.14	4.99	15.72	7.79	6.61	25.07	0.00	0.12	0.00	0.00	0.51	0.77
Evadne tergestina	ind/m^3	272.44	17.99	34.67	322.58	136.20	151.68	175.41	149.45	622.68	446.40	803.76	111.09
	%	3.47	0.91	1.44	5.06	3.68	1.95	5.07	5.94	18.12	17.89	15.77	3.18
Penilia avirostris	ind/m^3	1764.18	1556.75	1099.72	173.70	476.71	4247.06	630.49	1127.10	370.24	515.97	679.60	966.12
	%	22.47	79.05	45.57	2.73	12.88	54.48	18.24	44.80	10.78	20.68	13.33	27.62
Podon polyphemoides	ind/m^3	26.80	0.00	5.78	3396.39	1999.73	309.31	148.94	49.82	134.63	59.91	98.02	53.86
	%	0.34	0.00	0.24	53.30	54.01	3.97	4.31	1.98	3.92	2.40	1.92	1.54

Table 24

Zooplankton groups abundances (ind./m^3) and relative abundances (%) during May 1991

STATIONS GROUPS		P01	P02	P03	P05	P06	P08	P09	P11	P13	P15	P17	P19	P20	P21
Appendicularia	ind/m^3	10.17	4.12	0.00	0.00	0.00	0.00	0.23	0.00	0.09	0.00	0.00	0.00	0.00	6.59
	(%)	2.02	0.41	0.00	0.00	0.00	0.00	0.17	0.00	0.53	0.00	0.00	0.00	0.00	0.33
Chaetognatha	ind/m^3	13.07	0.00	1.08	5.60	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	4.39
	(%)	2.59	0.00	0.19	0.31	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.22
Cirripeda larvae	ind/m^3	0.48	0.00	0.00	0.00	11.16	3.65	12.68	16.21	0.36	0.28	13.60	0.03	0.26	0.00
	(%)	0.10	0.00	0.00	0.00	3.37	1.12	9.27	22.33	2.14	1.95	10.48	1.28	0.12	0.00
Cladocera	ind/m^3	12.59	66.90	15.09	93.37	48.62	23.37	81.84	14.52	5.88	7.64	44.50	1.80	74.47	6.59
	(%)	2.50	6.74	2.64	5.25	14.66	7.16	59.87	20.00	34.76	52.60	34.29	70.51	34.22	0.33
Copepoda	ind/m^3	453.64	917.09	543.36	1648.93	253.47	277.50	35.97	21.28	5.79	4.15	39.56	0.39	135.74	1911.35
	(%)	89.92	92.33	95.09	92.65	76.44	85.01	26.31	29.30	34.22	28.57	30.48	15.38	62.38	96.77
Decapoda larvae	ind/m^3	0.48	1.03	3.23	0.00	7.17	2.19	3.69	14.19	2.08	1.60	14.83	0.23	3.43	30.76
	(%)	0.10	0.10	0.57	0.00	2.16	0.67	2.70	19.53	12.30	11.04	11.43	8.97	1.58	1.56
Doliolidae	ind/m^3	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiacea larvae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
Fish eggs	ind/m^3	9.20	1.03	5.39	28.01	7.97	17.53	1.61	1.01	1.18	0.09	6.18	0.10	0.53	8.79
	(%)	1.82	0.10	0.94	1.57	2.40	5.37	1.18	1.40	6.95	0.65	4.76	3.85	0.24	0.44
Fish larvae	ind/m^3	0.00	0.00	1.08	0.00	0.00	0.73	0.23	2.36	1.36	0.76	3.71	0.00	1.58	4.39
	(%)	0.00	0.00	0.19	0.00	0.00	0.22	0.17	3.26	8.02	5.19	2.86	0.00	0.73	0.22
Gastropoda larvae	ind/m^3	1.94	1.03	1.08	1.87	1.59	1.46	0.46	0.68	0.09	0.00	0.00	0.00	1.06	0.00
	(%)	0.38	0.10	0.19	0.10	0.48	0.45	0.34	0.93	0.53	0.00	0.00	0.00	0.49	0.00
Lamellibranchia larvae	ind/m^3	0.48	1.03	0.00	0.00	0.00	0.00	0.00	0.34	0.09	0.00	6.18	0.00	0.00	0.00
	(%)	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.47	0.53	0.00	4.76	0.00	0.00	0.00
Medusae	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaeta larvae	ind/m^3	0.00	0.00	0.00	1.87	0.00	0.00	0.00	2.03	0.00	0.00	1.24	0.00	0.26	0.00
	(%)	0.00	0.00	0.00	0.10	0.00	0.00	0.00	2.79	0.00	0.00	0.95	0.00	0.12	0.00
Pteropoda	ind/m^3	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siphonophora	ind/m^3	1.94	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.38	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

<u>Table 25</u>

Distribution of zooplankton dominant species abundances (ind./m^3) and relative abundances (%) during May 1991

STATIONS SPECIES		P01	P02	P03	P05	P06	P08	P09	P11	P13	P15	P17	P19	P20	P21
Acartia clausi	ind/m^3	25.66	29.85	30.19	153.13	24.71	146.05	28.82	18.58	4.88	3.02	27.19	0.07	114.35	61.51
	%	5.09	3.01	5.28	8.60	7.45	44.74	21.08	25.58	28.88	20.78	20.95	2.56	52.55	3.11
Acartia grani	ind/m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00
Centropages typicus	ind/m^3	79.40	409.65	189.74	153.13	15.94	0.00	0.23	0.00	0.00	0.09	0.00	0.13	4.75	162.57
	%	15.74	41.24	33.21	8.60	4.81	0.00	0.17	0.00	0.00	0.65	0.00	5.13	2.18	8.23
Clausocalanus arcuicornis	ind/m^3	2.90	0.00	0.00	4.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.58	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clausocalanus furcatus	ind/m^3	14.52	4.12	1.08	0.93	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	30.27
	%	2.88	0.41	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	1.53
CLausocalanus jobei	ind/m^3	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	645.74
	%	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.69
Ctenocalanus vanus	ind/m^3	0.48	0.00	0.00	0.00	0.00	2.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85.68
	%	0.10	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.34
Oithona nana	ind/m^3	0.00	2.06	0.00	0.00	0.80	0.00	0.00	0.00	0.54	0.38	3.71	0.03	0.26	0.00
	%	0.00	0.21	0.00	0.00	0.24	0.00	0.00	0.00	3.21	2.60	2.86	1.28	0.12	0.00
Oithona plumifera	ind/m^3	25.35	10.29	15.09	3.73	42.81	18.99	1.38	1.69	0.09	0.09	0.00	0.00	1.06	0.00
	%	5.03	1.04	2.64	0.21	12.91	5.82	1.01	2.33	0.53	0.65	0.00	0.00	0.49	0.00
Oithona similis	ind/m^3	9.51	0.00	0.00	0.00	32.11	18.99	0.00	0.00	0.00	0.00	4.94	0.00	0.00	0.00
	%	1.88	0.00	0.00	0.00	9.68	5.82	0.00	0.00	0.00	0.00	3.81	0.00	0.00	0.00
Oncaea spp.	ind/m^3	6.78	6.18	16.17	0.00	9.56	10.22	0.23	0.34	0.09	0.00	1.24	0.00	1.85	463.56
	%	1.34	0.62	2.83	0.00	2.88	3.13	0.17	0.47	0.53	0.00	0.95	0.00	0.85	23.47
Paracalanus parvus	ind/m^3	281.77	448.77	288.93	1324.00	121.15	73.76	3.00	0.34	0.18	0.47	0.00	0.10	11.09	424.01
	%	55.85	45.18	50.57	74.40	36.54	22.60	2.19	0.47	1.07	3.25	0.00	3.85	5.10	21.47
Evadne spinifera	ind/m^3	11.14	63.82	15.09	91.50	3.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	4.39
	%	2.21	6.42	2.64	5.14	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.22
Podon polyphemoides	ind/m^3	0.00	1.03	0.00	0.00	44.64	22.64	81.84	14.52	5.88	7.55	43.26	1.80	74.21	2.20
	%	0.00	0.10	0.00	0.00	13.46	6.94	59.87	20.00	34.76	51.95	33.33	70.51	34.10	0.11

December 1989: In December (Fig. 64) also two groups were distinguished, at a 33% similarity level. Moreover station P09 was grouped together with the Elefsis bay stations. At a 50% similarity level station P21 (western Saronikos) was discriminated from the Psittalia group, and station P17 from the Elefsis bay group. These similarities were also obvious in the MDS plot (stress 0.073) and furthermore the positioning of station P09 between the two groups is in accordance with its geographical location.

February 1990: The pattern is different during February (Fig. 65) since Elefsis bay stations constitute a group together with station P01 (inner Saronikos) and station P21 (western Saronikos) at a 50% similarity level. Two small groups are also distinguished: a group of stations P02 and P06 and a group of stations P03, P05, P07, whereas P08 is joining this group at a lower level (38%). The positioning of stations in the MDS plot (stress=0.1) does not coincide absolutely with the clustering and the similarity pattern between areas is quite unclear since stations are scattered. However most of Elefsis bay stations (P11, P13, P16, P17, P18, P19) are close positioned.

June 1990: Differences between stations located in Elefsis bay and the other areas reappeared during the cluster analysis of the June 1990 samples, as it can be seen from the dendrogram as well as the MDS plot (stress=0.06, Fig. 66).

May 1991: A different picture revealed when studying May 1991 samples (Fig. 67). Elefsis bay stations were divided in two groups: at the 45% similarity level, stations P06, P08, P09, P11, P17, P20 constitute one group and stations P13, P15, P19 another smaller one. Stations P01, P02, P03, P05 and P21 were clustered in a third group. A similar pattern is obvious from the MDS plot (stress=0.044).

6.2.4 Community structure

September 1989: During this sampling period, diversity index values varied between 1.02 bits/ind (P11) and 2.48 bits/ind (P09, Fig. 68). Generally, diversity values were higher in the inner Saronikos gulf and at stations near the Psittalia island (stations P03 to P09), when compared to those recorded at stations in Elefsis bay and the western Saronikos. Fluctuations of dominance index values varied inversely to those of diversity. The maximum value was found at station P10 (91.58%) and the minimum at P09 (57.62%). Differentiation between stations was also evident by the graphical descriptors (k-dominance curves, Fig. 69). Stations P09, P11, P12, P13, P14, P16, P19 were less diversified than stations P03, P07, P08, P10, P15, P17, P18, P20, P21 and even less than stations P01, P02, P04, P05, P06.

December 1989: A similar spatial pattern for both indices was observed during December (Fig. 68), with the exception of stations P20 and P21, where values were at the same level to those calculated for stations in the Psittalia area. Diversity values presented a wider range than during September: diversity index varied between 0.46 bits/ind (st. P18) and 3.64 bits/ind (st. P05), whereas dominance index was maximum at station P16 (99.09%) and minimum at station P05 (34.13%). From the k-dominance curves (Fig. 70), is obvious that stations in Elefsis bay were less diversified than those from the other areas.

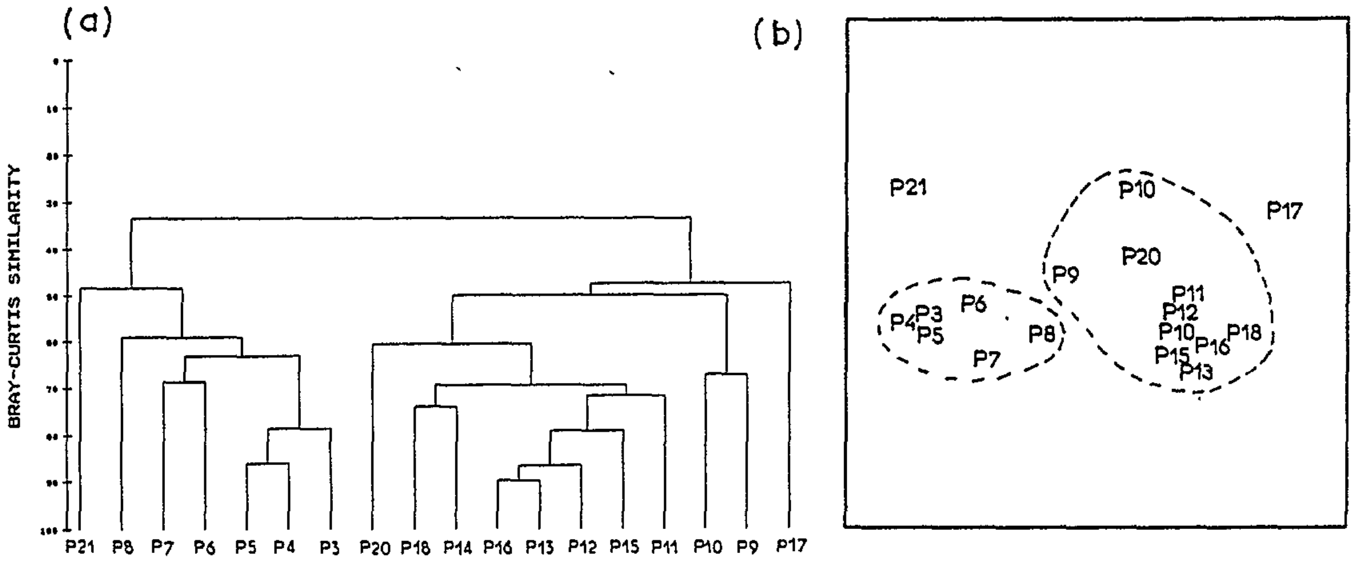


Fig. 64 Dendrogram (a) and MDS plot (b, stress=0.073) showing stations grouping according to zooplankton species distribution in Saronikos Gulf, during December 1989

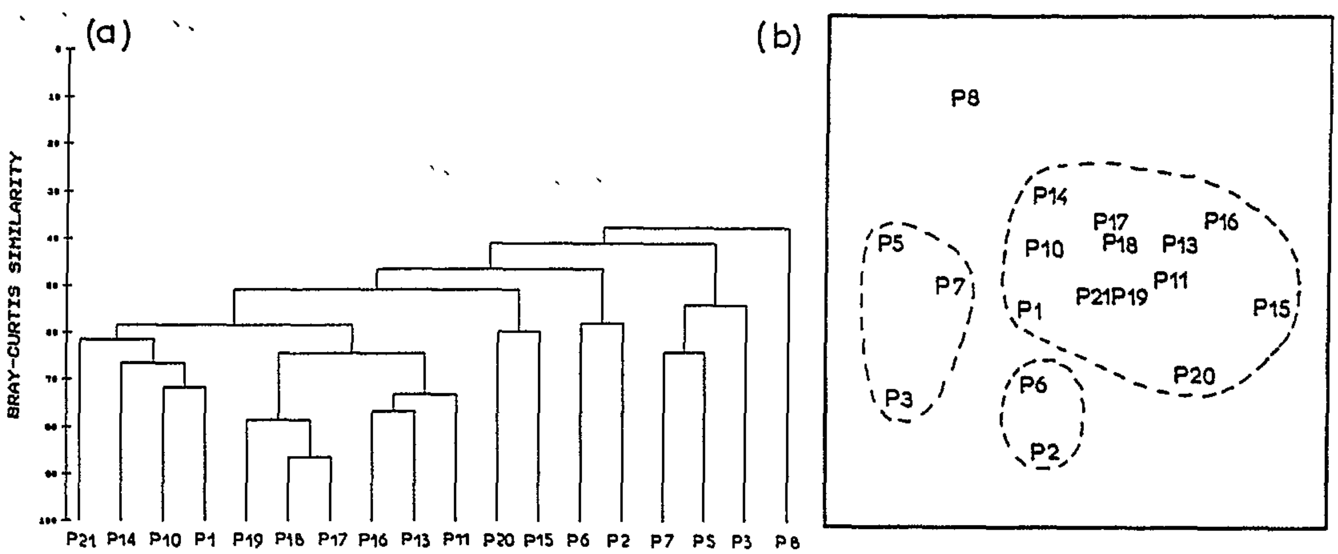


Fig. 65 Dendrogram (a) and MDS plot (b, stress=0.1) showing stations grouping according to zooplankton species distribution in Saronikos Gulf, during February 1990

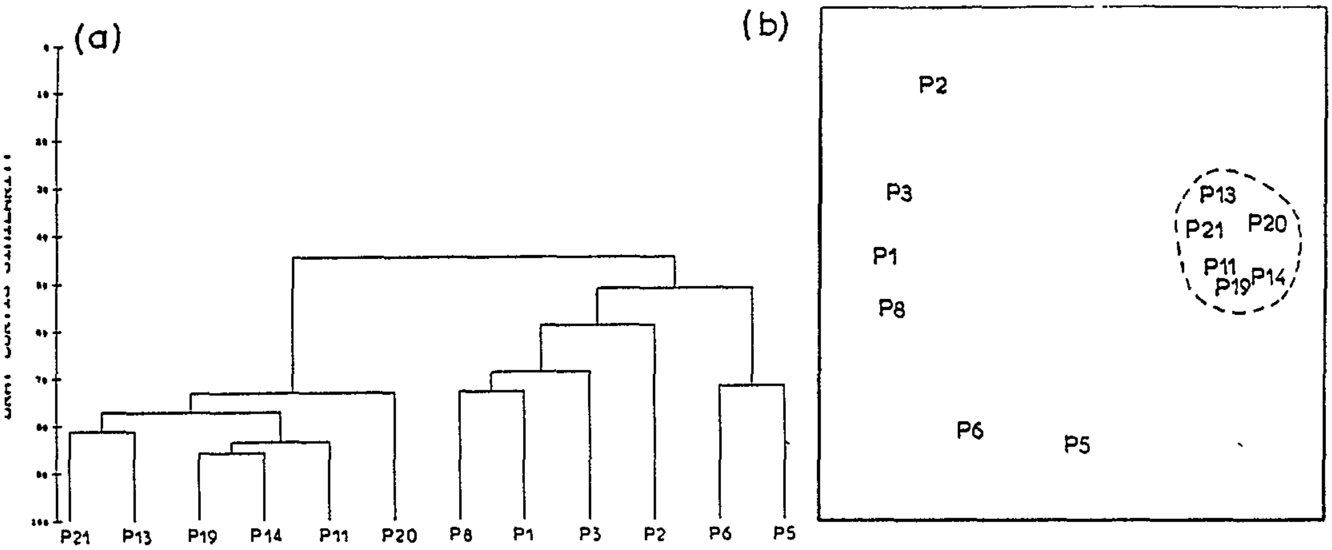


Fig. 66 Dendrogram (a) and MDS plot (b, stress=0.06) showing stations grouping according to zooplankton species distribution in Saronikos Gulf, during June 1990

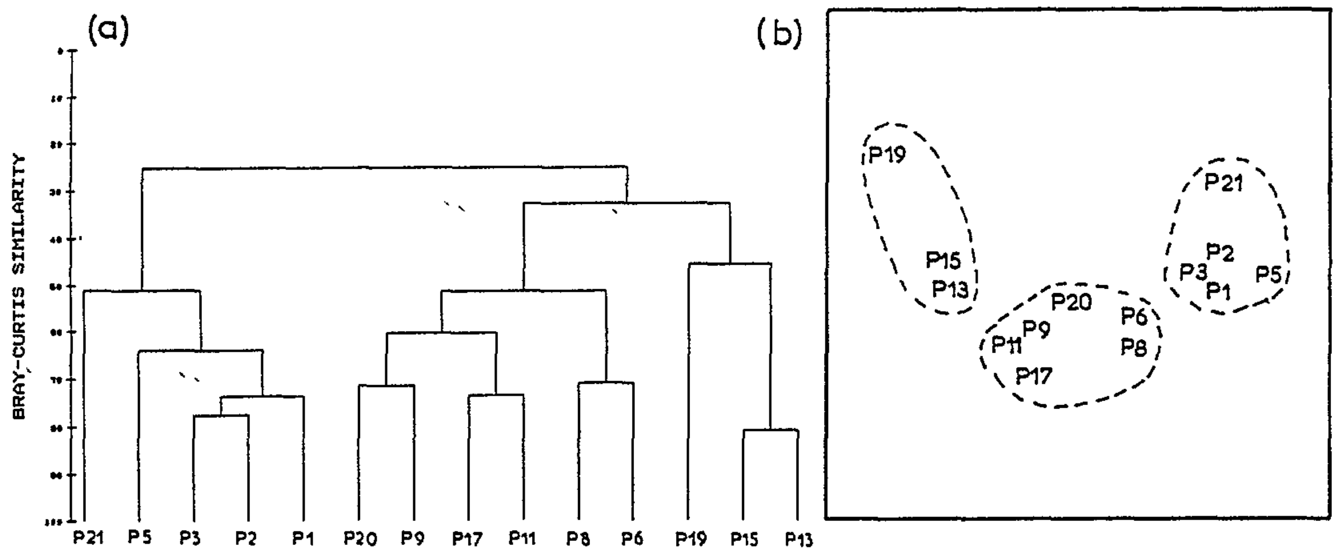


Fig. 67 Dendrogram (a) and MDS plot (b, stress=0.044) showing stations grouping according to zooplankton species distribution in Saronikos Gulf, during May 1991

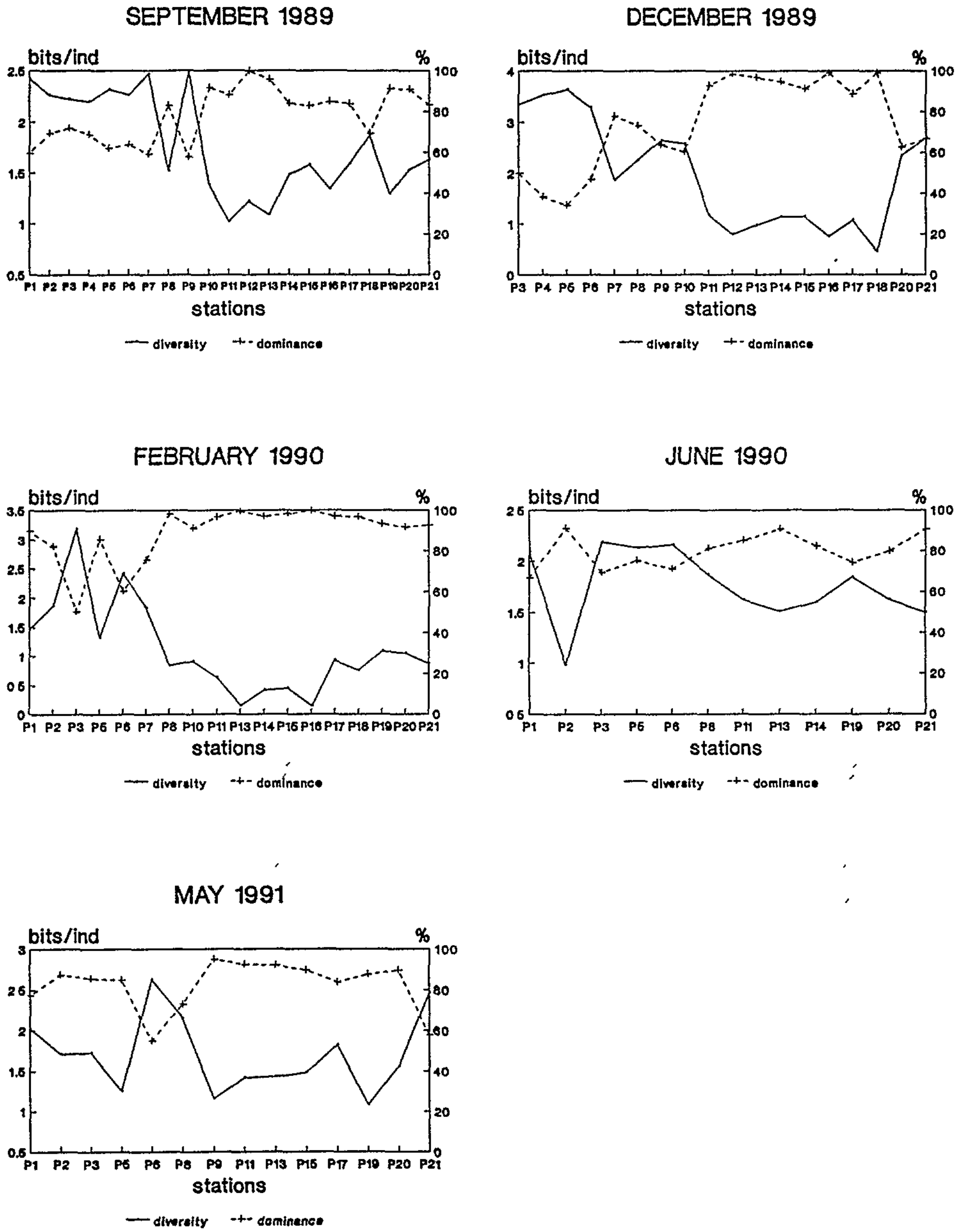


Fig. 68 Spatial distribution of diversity (H') and dominance index (δ) during the five sampling periods in Saronikos Gulf

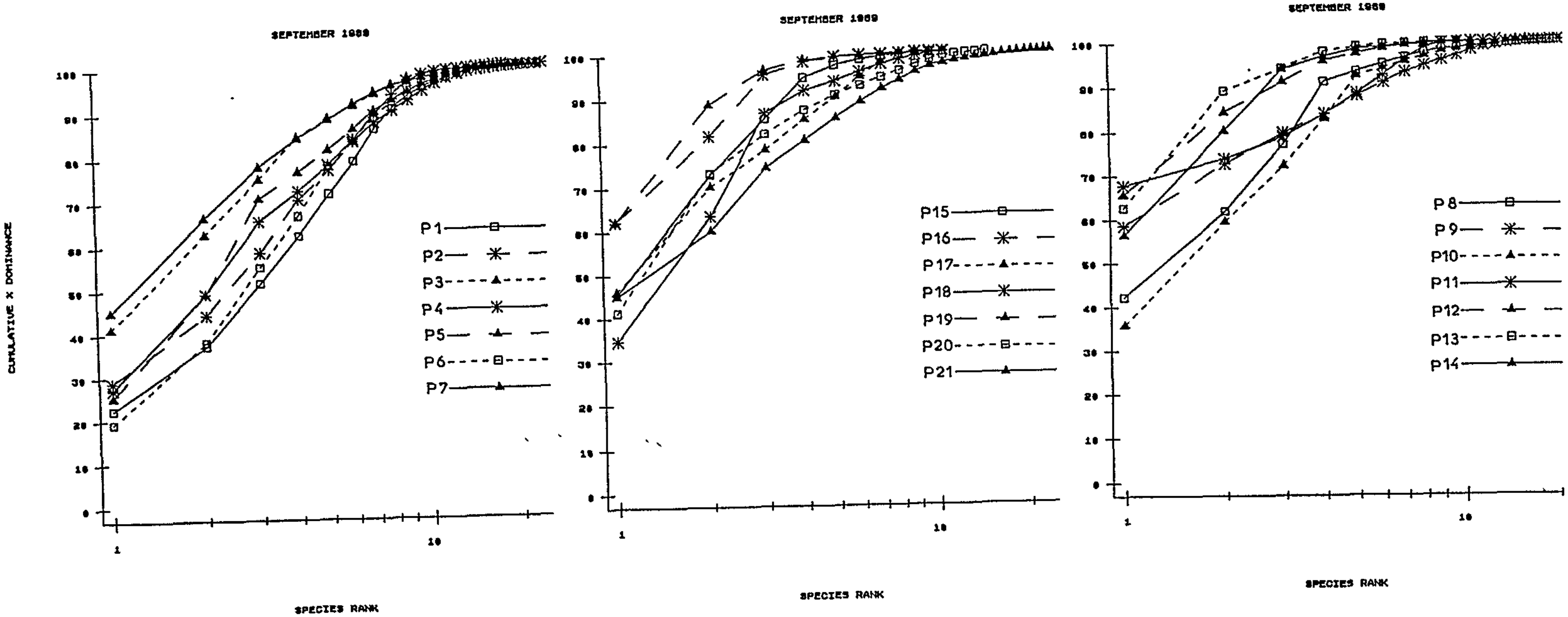


Fig. 69 K-dominance curves of zooplankton species during September 1989

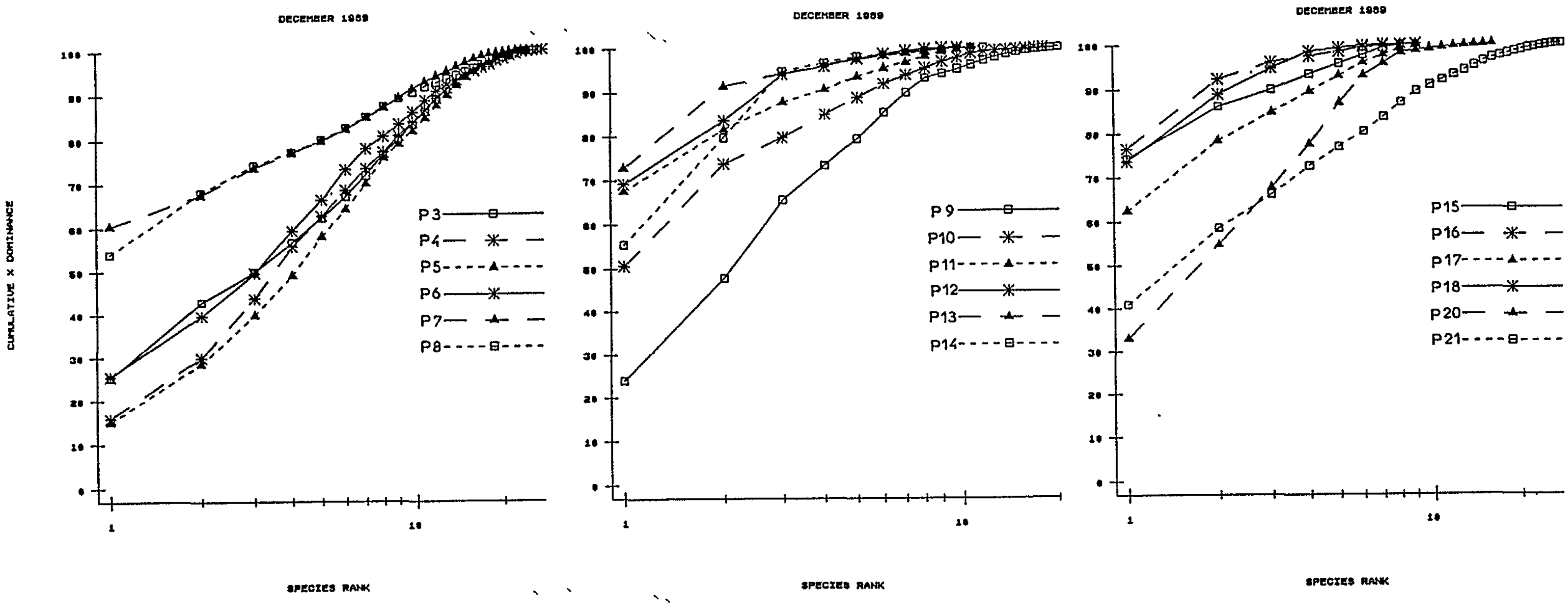


Fig. 70 K-dominance curves of zooplankton species during December 1989

February 1990: Differences among areas were more important during February (Fig. 68). In the inner gulf and the western part of Psittalia island, diversity values fluctuated between 1.32 bits/ind (st. P05) and 3.18 bits/ind (st. P03). At station P08 (Keratsini bay), in Elefsis bay stations and the western Saronikos, values varied between 0.14 bits/ind (st. P16) and 1.08 bits/ind (st. P19). At all these stations dominance index values were very high (91.19% to 99.76%). K-dominance curves (Fig. 71) reinforces this differentiation of Elefsis bay from the other areas.

June 1990: Diversity values were generally higher during this month, than the previous sampling periods and fluctuations among stations were not so important (Fig. 68): 1.5 bits/ind at station P21 to 2.16 bits/ind at station P06, with the exception of a low value (0.98 bits/ind) at station P02. On the other hand, dominance values varied between 66.88% (station P01) and 91.27% (station P02). No clear differentiation among stations was revealed by k-dominance curves (Fig. 72).

May 1991: Not a clear spatial pattern was observed for diversity and dominance index values (Fig. 68). The maximum diversity was found at station P06 (2.63 bits/ind) and the minimum at station P19 (1.08 bits/ind). Dominance index varied between 54.88% (st. P06) and 95.05% (st. P09). K-dominance curves (Fig. 73) were not similar among stations but strong differentiation was not evident between areas.

6.3 Principal Components Analysis of both environmental and biological data

September 1989: The first two components extract 56% of the total information of the September data set analysis. On the first two axes plan (Fig. 74) a clear discrimination of the areas can be seen with the relevant species and environmental parameters: Elefsis bay is distinguished from the Psittalia area and the Keratsini bay and the latter from the inner and the western Saronikos. Stations P04 to P09, positioned near the sewage outfall, were projected close to nitrates, phosphates and ammonium. Along the first axis the zooplanktonic species *Acartia grani, Acartia margalefi, Centropages ponticus*, chlorophyll a and silicates are opposed to *Penilia avirostris, Clausocalanus furcatus, Paracalanus parvus*. This axis should be related to high chlorophyll a and silicates values which were found in Elefsis bay and therefore it expresses the opposition between the Elefsis bay environment and the other areas. Along the second axis cirripeds larvae and station P09 are opposed to the phytoplanktonic species *Nitzschia closterium, Thalassionema nitzschioides*, the temperature and station P19. This axis could be related to temperature which presented high values at P19 and P20 stations.

December 1989: The first two components extract 52% of the total information of the December data set analysis. There is again a clear discrimination of areas on the first two axes plan (Fig. 75). The Elefsis bay stations (except P15 and P20) and the species *Gyrodinium aureolum, Coccolithus pelagicus* (phytoplankton), *A. clausi, P. polyphemoides* (zooplankton) are opposed along the first axis to the stations P03 (outer Psittalia), P21 (western Saronikos) and the species *Thalassionema nitzschioides, Chilomonas marina* (phytoplankton), *C. furcatus, C. pergens, C. jobei* (zooplankton). Chlorophyll a and silicates, projected close to the Elefsis bay stations, are also related to this axis. Along the second axis stations P15

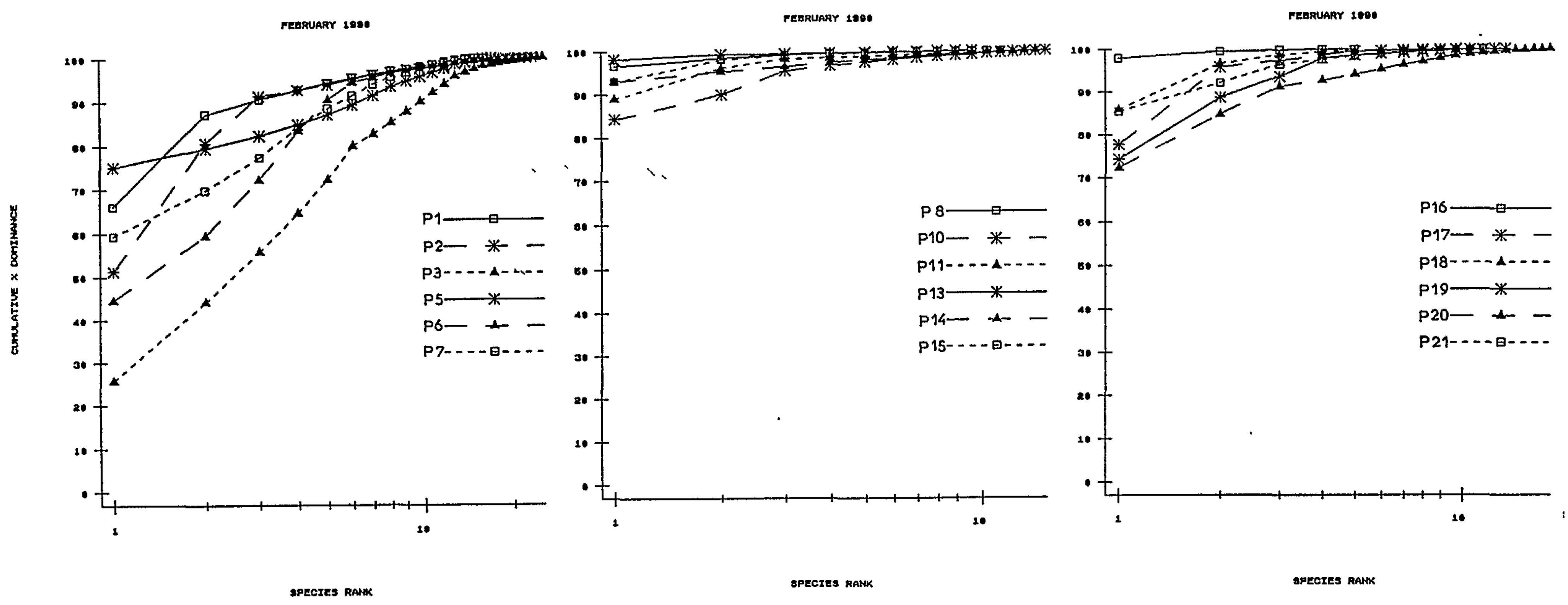


Fig. 71 K-dominance curves of zooplankton species during February 1990

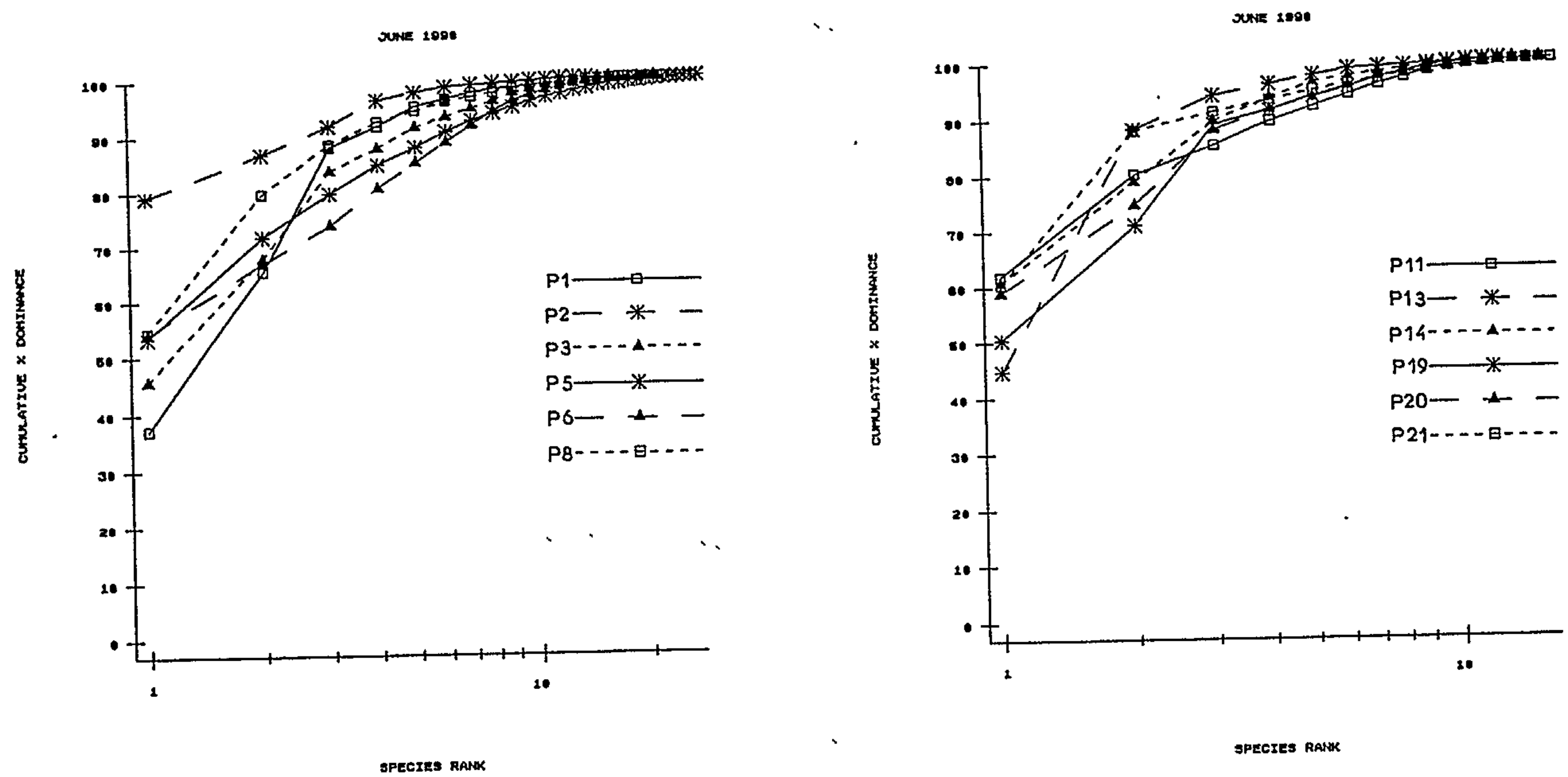


Fig. 72 K-dominance curves of zooplankton species during June 1990

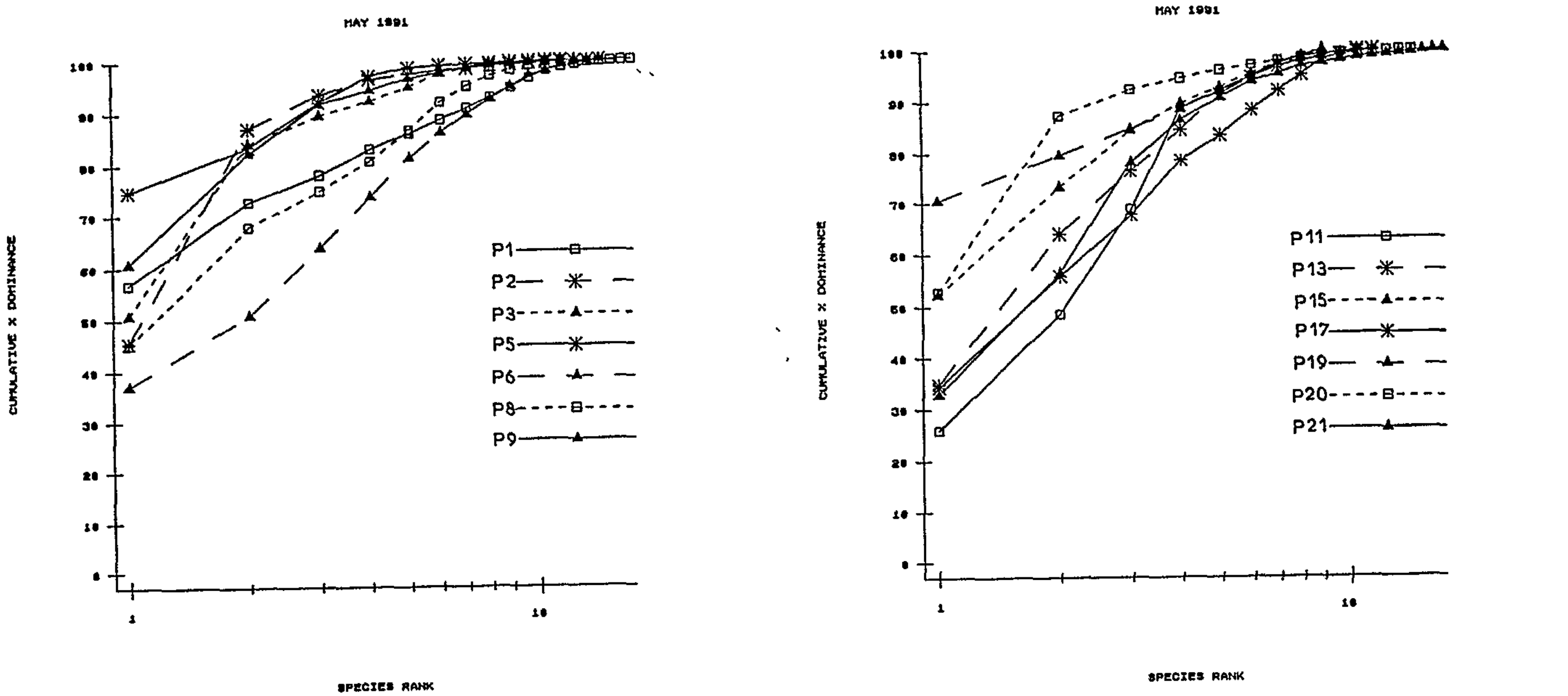


Fig. 73 K-dominance curves of zooplankton species during May 1991

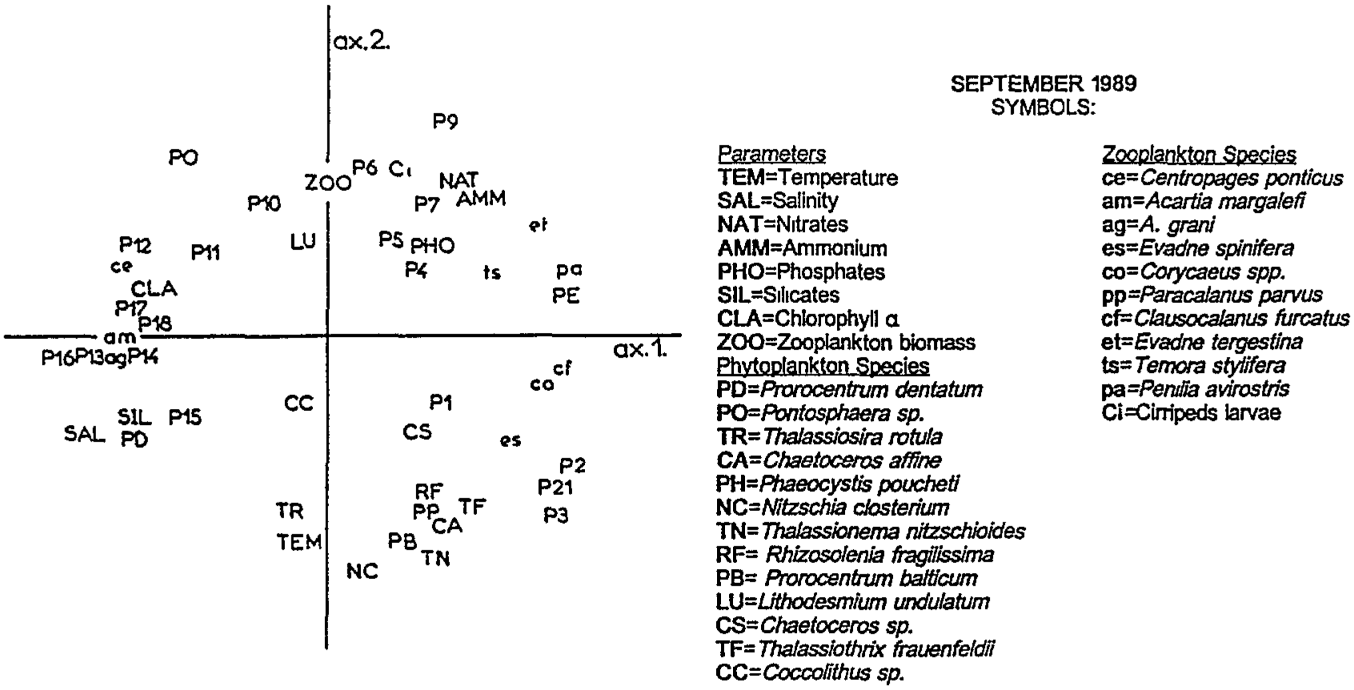


Fig. 74 Principal component analysis of environmental and biological data for September 1989

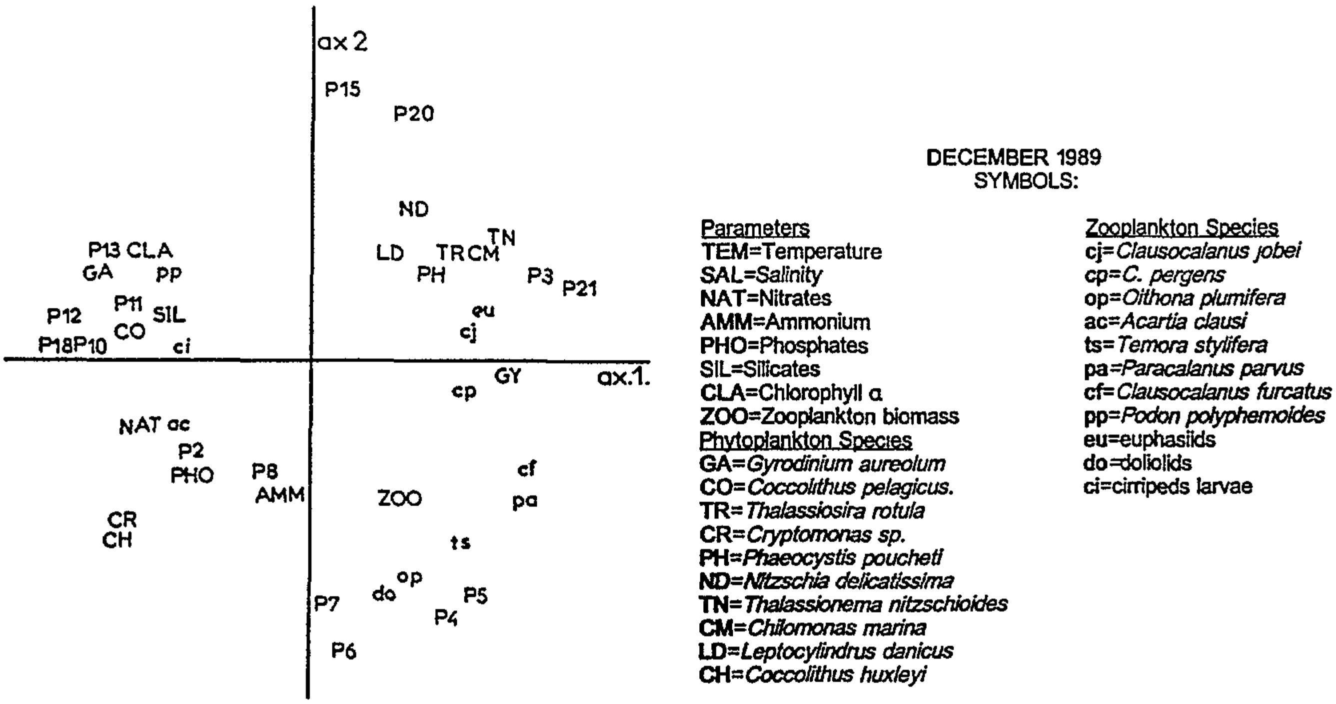


Fig. 75 Principal component analysis of environmental and biological data for December 1989

and P20 are opposed to the Psittalia stations (P04 to P07) with *O. plumifera* and doliolids (zooplankton). Stations near the sewage outfall (P08, P09) and nitrates, phosphates, ammonium, are projected between Elefsis bay and Psittalia area, in accordance to their geographical position.

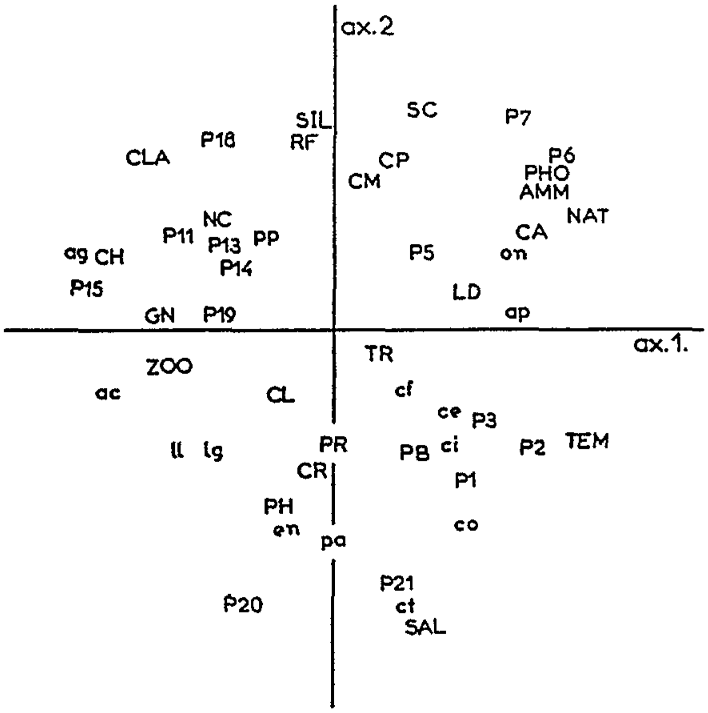
February 1990: The positioning of species, parameters and stations on the first two axes plan (43% of total information, Fig. 76) of the February data set is slightly different than in December. Elefsis bay stations, chlorophyll a, zooplankton biomass and the species *Coccolithus huxleyi, Gonyaulax sp.,* (phytoplankton), *A. clausi, P. polyphemoides, A. grani* (zooplankton) are opposed along the first axis to the inner Saronikos stations and temperature as well as to the Psittalia area and nutrients (phosphates, nitrates, ammonium). The first axis should related to temperature as well as to the above nutrients. The inner Saronikos is characterized by the presence of *Prorocentrum balticum* (phytoplankton) *C. pergens, Corycaeus spp.,* Cirripeds larvae (zooplankton) and the Psittalia area by *Chaetoceros sp., Leptocylindrus danicus* (phytoplankton) and *Oncaea spp.*, and appendicularians (zooplankton). These two areas are distinguished along the second axis. Along this axis are also discriminated station P21 (characterized by *C. typicus*) and P20. This axis should be related to salinity.

June 1990: The first two components extract 54% of the total information (Fig. 77). The studied areas (Elefsis bay, Psittalia and Keratsini channel, inner Saronikos, western Saronikos) are differentiated on the plan of the first two axes. Temperature, salinity and station P21 are opposed along the first axis to nutrients (phosphates, nitrates, ammonium) and station P10. This axis could be related to the above environmental parameters. Along the second axis Elefsis bay stations (mainly P11) with the species *Thalassiosira rotula, Prorocentrum micans* (phytoplankton), *E. tergestina* (zooplankton) are opposed to the inner Saronikos.

May 1991: The first two components of the May 1991 data set analysis extract 55% of the total information (Fig. 78). On the plan of the first two axes, Elefsis bay is discriminated from the other areas. Station P09 is projected near Elefsis bay stations indicating similarities among them. All these stations characterized by phytoplankton species *Polykrikos sp*., *Prorocentrum dentatum*, *Peridinium pyriforme*, silicates, chlorophyll a, are opposed along the first axis to the inner and western Saronikos and Psittalia area characterized by the zooplankton species *C. typicus, C. furcatus, E. spinifera, P. parvus* and zooplankton biomass. Station P08, nitrates, ammonium and phosphates are projected apart from the other stations at the edge of the second axis, indicating its differentiation.

7. DISCUSSION

Many areas of the Mediterranean Sea have been affected by urban and industrial waste disposal during the recent years. The northern part of Saronikos Gulf represents a typical example of such a marine polluted environment mainly from the sewage outfall of Athens located at Keratsini bay and several industrial and naval activities.



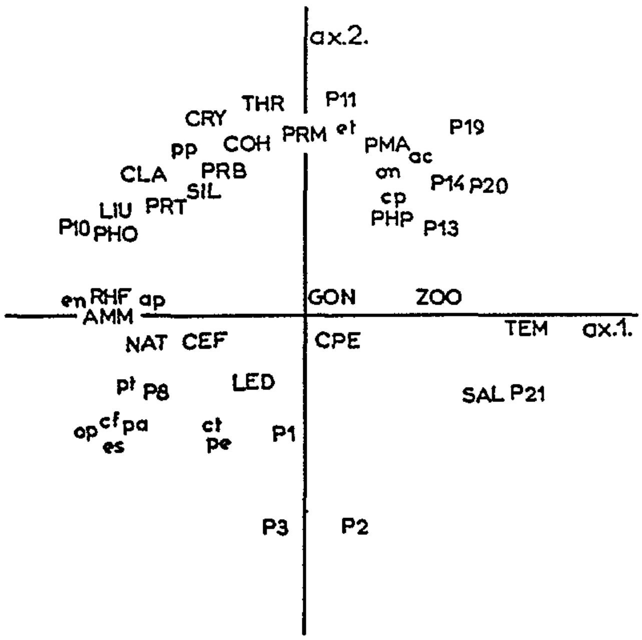
FEBRUARY 1990
SYMBOLS:

Parameters
TEM=Temperature
SAL=Salinity
NAT=Nitrates
AMM=Ammonium
PHO=Phosphates
SIL=Silicates
CLA=Chlorophyll α
ZOO=Zooplankton biomass

Phytoplankton Species
GN=*Gonyaulax sp.*
CP=*Coccolithus pelagicus.*
TR=*Thalassiosira rotula*
CR=*Cryptomonas sp.*
PH=*Phaeocystis poucheti*
NC=*Nitzschia closterium*
RF=*Rhizosolenia fragilissima*
CM=*Coccolithus multiporus*
LD=*Leptocylindrus danicus*
CH=*Coccolithus huxleyi*
SC=*Sceletonema costatum*
PB=*Prorocentrum balticum*
PR=*Prorocentrum micans*
CA=*Chaetoceros sp.*
CL=*Calyptrosphaera sp.*

Zooplankton Species
cf=*Clausocalanus furcatus*
cp=*C. pergens*
on=*Oithona nana*
ac=*Acartia clausi*
co=*Corycaeus spp.*
en=*Evadne nordmanii*
ct=*Centropages typicus*
pp=*Podon polyphemoides*
ag=*Acartia granii*
ap=appendicularians
ci=cirripeds larvae
ll=lamelibranchs larvae
lg= gastropods larvae

Fig. 76 Principal component analysis of environmental and biological data for February 1990



JUNE 1990
SYMBOLS:

Parameters
TEM=Temperature
SAL=Salinity
NAT=Nitrates
AMM=Ammonium
PHO=Phosphates
SIL=Silicates
CLA=Chlorophyll α
ZOO=Zooplankton biomass

Phytoplankton Species
GON=*Gonyaulax sp.*
CPE=*Coccolithus pelagicus.*
THR=*Thalassiosira rotula*
CRY=*Cryptomonas sp.*
PHP=*Phaeocystis poucheti*
LIU=*Lithodesmium undulatum*
RHF=*Rhizosolenia fragilissima*
PRT=*Prorocentrum triestinum*
LED=*Leptocylindrus danicus*
COH=*Coccolithus huxleyi*
RHD=*Rhizosolenia delicatula*
PRB=*Prorocentrum balticum*
PRM=*Prorocentrum micans*
PMA=*Prorocentrum maximum*
CEF=*Ceratium furca*

Zooplankton Species
cf=*Clausocalanus furcatus*
et=*Evadne tergestina*
op=*Oithona plumifera*
ac=*Acartia clausi*
cp=*Centropages ponticus*
en=*Evadne nordmanii*
ct=*Centropages typicus*
pp=*Podon polyphemoides*
es=*Evadne spinifera*
pe=*Penilia avirostris*
pa=*Paracalanus parvus*
ap=appendicularians

Fig. 77 Principal component analysis of environmental and biological data for June 1990

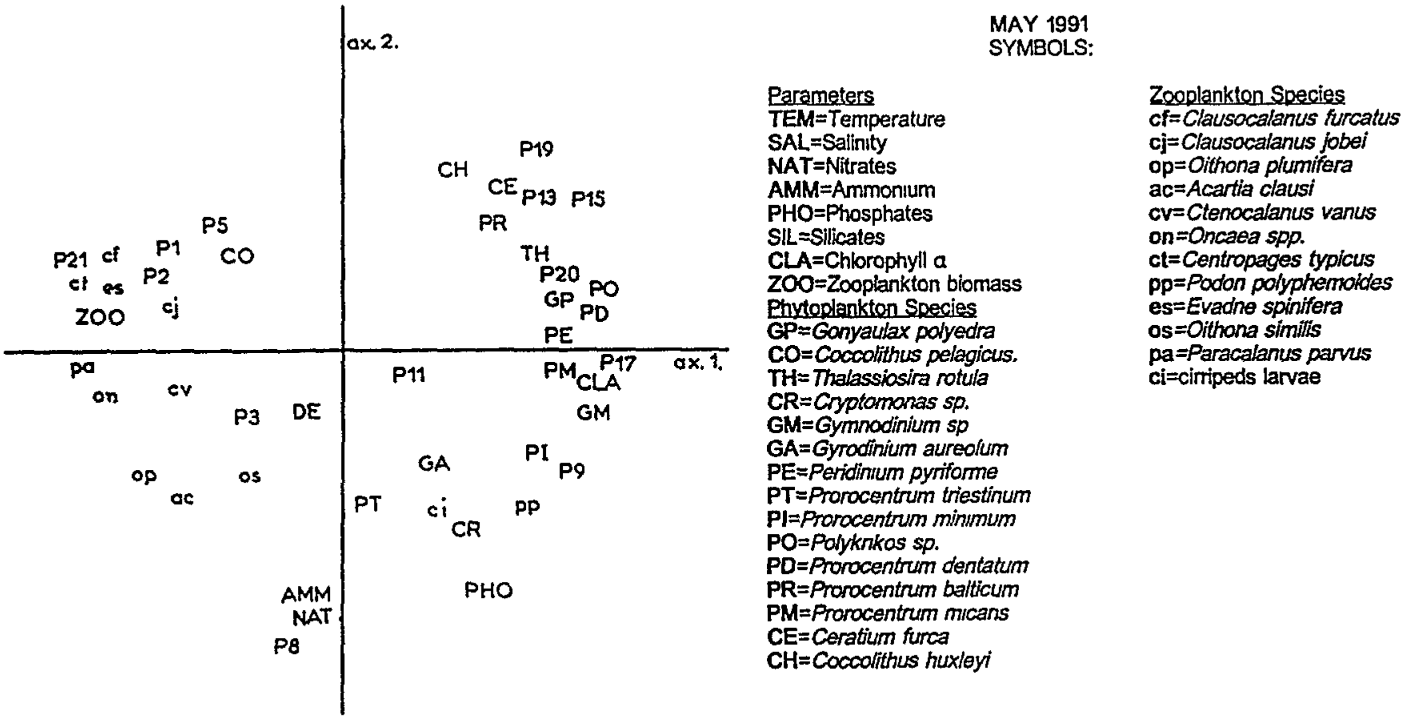


Fig. 78 Principal component analysis of environmental and biological data for May 1991

Water mass circulation

Circulation of the water masses near the sewage outfall is limited. The dispersion and dilution of the sewage is more effective when north winds are blowing, the sewage being dispersed to the south, where it gets exposed to deeper mixing due to the waves and a large scale circulation. Winds blowing from other directions aggregate sewage along the coastline (Hopkins and Coachman, 1975; Friligos, 1981b, 1982a, 1988). It must be noted that in the Greek Seas the tidal effects (apart from a few exceptions) are of minor influence to the circulation pattern of both mesoscale and large scale motions. The same is true in Saronikos Gulf so that the water mass circulation is mainly influenced by the wind field and by hydrodynamics of the fluid. The circulation pattern in the Saronikos Gulf can be both clockwise and anticlockwise depending on the wind field direction (Coachman and Hopkins, 1975; Coachman et al., 1976; Laskaratos and Kaltsounidis, 1989).

According to the hydrographic measurements of the present study it seems that the water masses of Saronikos Gulf are strongly influenced by the intrusion of water masses from the Aegean Sea, so that the physical characteristics are more or less similar to the ones of the Aegean Sea.

On the other hand Elefsis Bay has somehow different values of the basic physical parameters (temperature and salinity) as a result of its geomorphology. The limited communication of the bay with Saronikos Gulf and the restricted water mass

of the bay react differently evolving higher temperature values during early summer but also lower temperatures than Saronikos Gulf during winter. These cold water masses with high density seem to remain stagnant in the bottom of the bay provoking anoxic conditions during summer, when stratification develops (Friligos and Nacopoulou, 1991). During winter, the total homogenization of the water column renews the water masses.

At certain periods, with the right weather conditions, there is a rather intense exchange of water masses between Elefsis Bay and Saronikos Gulf. It seems that inflow and outflow from Elefsis bay happens mainly from Keratsini Strait, whereas through the western strait occurs mainly inflow from Saronikos Gulf towards Elefsis Bay.

Nutrients

Friligos and Nacopoulou (1991) have stated that the discharge of sewage and industrial effluents into the Saronikos Gulf has changed the character of the water body from the oligotrophy of the Aegean Sea into a weak eutrophy.

Environmental studies focusing, in detail, on Keratsini and Elefsis Bay are extremely scarce (Pagou, 1985, 1994; Pagou and Ignatiades, 1988). However the results concerning the chemical and biological parameters studied during this project verify the eutrophic character of these areas, where nutrients reached high values in comparison with those from the oligotrophic outer Saronikos Gulf (Ignatiades and Becacos-Kontos, 1969; Friligos, 1982a,b, 1984; Friligos and Nacopoulou, 1991) and of course those from the Aegean Sea (Ignatiades, 1973; Souvermezoglou, 1989), namely 2.13 µg-at/l for nitrites (st. P16, June 1990), 2.73 µg-at/l for nitrates (st. P18, December 1989), 6.73 µg-at/l for ammonium (st. P06, December 1989) and 3.23 µg-at/l for phosphates (st. P09, June 1990). However, these values are in agreement with those of Pagou and Ignatiades (1988) and Pagou (1994) for the area mostly influenced by the sewage.

Though nitrates is the dominant nitrogen compound in sea water, nitrites and ammonium are also quite important especially in areas of intense biological activities (Raymont, 1980). Phytoplankton uptakes the demanded nitrogen, in order of preference from ammonium, nitrates and finally nitrites. However, McIsaac and Dugdale (1972), Yentch et al. (1977), Wafar et al. (1983) and others proved that in eutrophic environments phytoplankton growth is depended mainly on nitrates uptake.

The results of the present study, for all three measured forms of nitrogen (nitrites, nitrates and ammonium) showed that the highest concentrations were recorded around the sewage outlet usually at 2m depth, during all sampling periods, with the exception of December 1989, when high concentrations for all forms were recorded also in Elefsis bay at 10m. This fact could suggest that another source of nitrogen (external or recycling-upwelling) was enriching seawater during this period. These results disagree with those of Friligos and Nacopoulou (1991) or Psyllidou- Giouranovits et al. (1990), reporting higher concentrations of these nutrients in Elefsis bay than at the sewage area. However, it must be noted here that, apart from the present study, where sampling was performed at several stations of Keratsini bay, ie

exactly at the seawater body receiving the sewage, in the two previously mentioned studies the nearest station to the sewage outfall was identical to station P03 of this study, where a dilution of nutrients concentrations, due to the distance from the outfall already took place.

Although seasonality patterns for nitrogen concentrations, is rather difficult to be defined from the data presented here, which are obtained only from five sampling periods between September 1989 and May 1991, it must be noted that maxima were observed during winter (December 1989) and this is in agreement with previous studies in Saronikos gulf and Elefsis bay (Psyllidou-Giouranovits et al., 1990; Friligos and Nacopoulou, 1991; Pagou, 1994).

Ryther and Dunstan (1971) have reported phosphate concentrations between 0.2-6.7 µg-at/l in eutrophic areas. Northern Saronikos gulf and especially Keratsini bay is polluted by the sewage of Athens and therefore enriched in phosphates. However the effects of this pollution are minimized at a distance of 15 km from the sewage (Karydis et al., 1983). It has been proved that in Saronikos gulf, phosphates influence phytoplankton densities (Ignatiades et al., 1983), growth (Ignatiades, 1969) and primary production (Becacos-Kontos, 1967, 1973) thus giving an important role for the localized phytoplankton blooms. During the five sampling periods studied for this project phosphates presented low to moderate values in most areas, whereas the highest concentrations were always recorded at Keratsini bay or near Psittalia island at the surface layer (2m), not exceeding 1.21 µg-at/l (st. P06-2m, February 1990). However during June 1991, the highest concentrations among all studied seasons were recorded, especially at the sewage area reaching 3.23 µg-at/l (st. P09-2m). It must be noted that the above reported values are within the ranges of phosphates concentrations already recorded from previous studies for Saronikos gulf and Elefsis bay (Ignatiades, 1977, 1984, 1985, 1990; Moraitou-Apostolopoulou and Ignatiades, 1980; Pagou and Ignatiades, 1990; Psyllidou-Giouranovits et al., 1990; Friligos and Nacopoulou, 1991), or the eutrophic Thermaikos gulf (Gotsis-Skretas and Friligos, 1990; Psyllidou-Giouranovits, 1994). Again seasonal trends from the present data is difficult to be detected, but the highest values recorded during June are in agreement with other summer maxima reported by Pagou and Ignatiades (1988), Psyllidou-Giouranovits et al. (1990) and Pagou (1994). However these summer maxima for phosphates did not coincide with the occurrence of maxima for the other nutrients studied for this project, which were recorded during winter, as mentioned for nitrogen.

Pratt (1965) after investigations concluded that silicate is as much important as nitrogen not only for the timing but also for the amount of diatoms bloom. During this project silicates concentrations in Saronikos gulf ranged in quite high values, not permitting this nutrient to be a limiting one. Thus silicates ranged from 0.36 µg-at/l (May 1991, st. P02-10m) to 11.98 µg-at/l (December 1989, st. P07-2m), values that are usually recorded in inner Saronikos gulf or Elefsis bay (Ignatiades, 1977; Moraitou-Apostolopoulou and Ignatiades, 1980; Friligos, 1981a,b; Pagou and Ignatiades, 1988; Ignatiades, 1990) or the oligotrophic outer Saronikos gulf (Ignatiades and Becacos-Kontos, 1969; Moraitou-Apostolopoulou and Ignatiades, 1980). However, not only in Elefsis bay, but also in the oligotrophic south Aegean Sea, even higher concentrations have been recorded exceeding the 20 µg-at/l (Ignatiades, 1984;

Psyllidou-Giouranovits and Hadjigeorgiou, 1988; Friligos et al., 1991; Vounatsou and Karydis, 1991). Silicates have a different spatial pattern from all other studied nutrients with higher concentrations characterizing Elefsis bay and not the sewage area, especially at the 10m depth. Friligos and Nacopoulou (1991) stated that the highest values of silicates observed in Elefsis bay during their study, can be attributed to industrial effluents and this may explain the different spatial pattern from nitrogen and phosphorus, since for these latter nutrients the main source for enrichment of the marine environment is the sewage. The seasonal cycle of silicates in eutrophic areas like Elefsis bay (Ignatiades, 1977), inner Saronikos and Keratsini bay (Pagou and Ignatiades, 1988; Psyllidou-Giouranovits et al., 1990; Pagou, 1994) or oligotrophic areas such as outer Saronikos (Ignatiades and Becacos-Kontos, 1969) and South Aegean (Ignatiades, 1973) is well established and known, with maxima during winter and early spring. This type of seasonal variation of silicates is characterizing temperate or subtropical seas (Wafar et al., 1983) and data from this study are in agreement with it.

Phytoplankton

Phytoplankton biomass was estimated by the concentration of chlorophyll ß in sea water. Chlorophyll ß data can be interpreted in two ways, as an index of productivity and as an index of the plant population. Also these data can give an accurate and synoptic picture of the behaviour of phytoplankton populations in time and in space. Chlorophyll ß concentrations ranged from 0.07 µg/l at st. P21-2m during June 1991 to 29.86 µg/l at st. P17-2m during December 1989. However, extremely low values characterized always stations P01, P02 of inner Saronikos and P21 from the western basin and during December 1989, June 1990 and May 1991 stations P03 and P04 at the South of Psittalia island. On the other hand stations P05 through P20 presented high chlorophyll content during all sampling periods (> 1 µg/l) exceeding several times even the 10 µg/l (Table 4). It must be noted that chlorophyll ß concentrations ranging between 10-40 µg/l are typical of phytoplankton blooms in eutrophic coastal waters (Riley and Chester, 1971), whereas values of the order of 0.05 µg/l are oftenly found in the extremely oligotrophic tropical seas (Bienfang and Gundersen, 1977). Such high chlorophyll ß concentrations, as those recorded during this project, or even higher (132.7 µg/l, Pagou, 1988; 201.46 µg/l, Pagou, 1994) have been reported during previous studies also, for the eutrophic waters of Saronikos receiving effluents from the sewage (Scoullos et al., 1983; Pagou, 1988, 1990, 1991; Pagou and Ignatiades, 1988; Psyllidou-Giouranovits et al., 1990). These high chlorophyll concentrations had a different spatial distribution among studied seasons and sometimes among depths. So the highest concentrations aggregated around the sewage outfall during September 1989 (2m and 10m), June 1990 (2m and 10m) and May 1991 (2m), whereas Elefsis bay was characterized by high chlorophyll content during September 1989 also (2m), December 1989 (2m and 10m) and May 1991 (10m). During February 1990 chlorophyll ß distribution was quite uniform among all areas, with somewhat higher concentrations at eastern Elefsis bay, at 10m. Pagou (1994) studying the spatial distribution of chlorophyll ß in Keratsini and Elefsis bay during September and November 1984, also found that during the first period the higher concentrations were characterizing the outfall area, whereas during the second period, Elefsis bay. She suggested that such distributions could be attributed to intense water mass exchange between Elefsis bay and Saronikos gulf occurring

during these seasons. Since, according to the nutrients data from the present study nitrites, nitrates and ammonium concentrations are higher in Elefsis bay only during December, phosphates are always higher at Keratsini and silicates in Elefsis bay, is obvious that nutrients distributions alone cannot explain the chlorophyll distribution, for which water movements must also been taken into account.

Although chlorophyll ß concentrations and total phytoplankton cells concentrations are both biomass estimators, their fluctuations do not coincide always, as it is obvious from the present data. Phytoplankton densities (not including µ-flagellates) ranged from 3200 c/l at st. P21 during June 1990 to 2968100 c/l at st. P19 during September 1989, whereas the lowest value of chlorophyll was recorded at station P21 during June 1990, but the highest at station P17 during December 1989. However as with chlorophyll the lowest concentrations for all areas were recorded during February 1990 and though the lack of coincidence exist between maxima of these two parameters, very high cell densities (of the same order, as during September 1989) were recorded during December 1989, when chlorophyll maxima were reported. This lack of coincidence can be attributed to cell damage, to failure during cell identification (Johnson and Sieburth, 1979), larger cells and/or more chlorophyll content per cell volume and finally presence of chlorophyll containing detritus (Estrada, 1982). Also chlorophyll ß can vary independently of cell number, dependent upon environmental variables, cell age and species composition (Hallegraeff, 1977).

Furthermore the spatial distribution of phytoplankton abundances and populations did not always coincide with that of chlorophyll ß. During almost all periods, higher phytoplankton abundances were recorded both in Keratsini and Elefsis bay stations, in comparison to those of inner Saronikos and the western basin, pointing out the different trophic status of these areas. The arisen question of the existence of species and/or groups aggregations among areas was not answered by a clear-cut spatial differentiation, since results from cluster analysis grouped together stations from both eutrophic and mesotrophic or oligotrophic areas, during September 1989, December 1989, February 1990 and June 1990, whereas only during May 1991 stations grouping was in accordance with the trophic status of the examined areas. The physical environment during this study was characterised by a well mixed surface water during September, December 1989 and February 1990, similar water masses between Elefsis bay and Saronikos gulf were recorded during June 1990, whereas distinct water masses between these areas were recorded only during May 1991. The above results showed that along the physically well-mixed horizontal network of stations the phytoplankton species distribution was mostly heterogeneous interrupted by homogeneous species associations, as it is very well reflected on the dendrograms and MDS plots of all sampling periods except May 1991. However the homogeneous distinct species aggregations that were recorded gave no indication of spatial scales at which some underlying consistency of the horizontal species organization to a certain pattern existed and in general, neighbouring sites were similar in species composition only occasionally. It could be suggested that this lack of persistent spatial pattern might be related to short-term wind-driven surface water movements. These results are in agreement with previous observations (Vassiliou et al., 1989) at the same area and confirm both the random and deterministic character in phytoplankton distributions (Platt et al., 1970; Williams et al., 1981).

The dominant phytoplankton species and their seasonal succession pattern in Elefsis and Keratsini bay, recorded during this study are in agreement with those reported by Pagou (1994) for eutrophic areas of Saronikos Gulf. Again small diatoms (such as: *Leptocylindrus danicus, Skeletonema costatum, Thalassiosira rotula,* etc.) and dinoflagellates (*Prorocentrum dentatum, Gyrodinium aureolum, Prorocentrum triestinum, Gymnodinium sp.*, etc.) and several times small flagellates (*Phaeocystis poucheti*, small coccolithophores, etc.) were dominating attaining high values and suggesting a highly productive ecosystem, where species succession remains to the first stages occurring in nutrient rich waters (Margalef, 1967) and characterized by small opportunistic organisms (r-selected), not proceeding in more advanced stages. This phenomenon has been accepted as a response of the ecosystem to environmental stress (Parsons et al., 1976; Gray, 1989), as it is eutrophication, and affects not only phytoplankton but also zooplankton by replacement of the usually dominant large copepods by smaller species (Gamble et al., 1977) and has been already reported for polluted areas of Saronikos, during previous studies (Moraitou-Apostolopoulou and Ignatiades, 1980; Siokou-Frangou, 1993).

At this point it must be noted that among flagellates, μ-flagellates had an important role, since they fluctuated in an extremely wide range and exhibited usually high concentrations, ranging from 131000 c/l (December 1989, st. P05) to 9081600 c/l (September 1989, st. P19). However their distribution did not present a spatial pattern, except during May 1991, when higher concentrations were recorded mostly in Keratsini and Elefsis bay. During previous studies in Saronikos Gulf their dominant role among phytoplankton groups had already noticed, especially in eutrophic areas and high concentrations have been reported from Ignatiades and Mimicos (1977) in Elefsis bay, from Ignatiades (1981) and Tett and Ignatiades (1976) in inner and western Saronikos Gulf and from Pagou (1994) in Keratsini Bay. Besides the fact that this group exhibits high concentrations in Saronikos Gulf, it must be taken in account that scientific interest for these organisms is growing during the recent years. μ-flagellates during this study have been described small flagellates, whose identification at the species level was not possible and had cell diameter less than 5μm. Since their taxonomy and role in primary production and marine ecosystem has not been fully understood yet (Smayda, 1980), their concentrations were not included in the total phytoplankton densities. However, during recent years scientists have been aware of the fact that nanoplankton (2 - 20 μm) and picoplankton (0.2 - < 2μm), either autotrophic or eterotrophic, dominates in numbers of the euphotic zone plankton (Li et al., 1983; Davis et al., 1985).

It must be noted that although species composition did not exhibit a distinct spatial differentiation, as has been discussed above, population diversity, according to diversity index values and k-dominance curves was differentiated spatially, mostly during September, December 1989 and February 1990. Stations located at inner Saronikos and the western basin were more diversified than those of Elefsis bay always, whereas stations neighbouring the sewage outfall presented intermediate values during December and the highest diversities between all areas during February. During June 1990 and May 1991 the highest diversities among all periods were recorded for all areas, but a clear spatial differentiation was not evident for these months.

Zooplankton

Generally zooplankton was differentiated spatially. From the quantitative point this differentiation was not similar among the sampling periods. Some stations in Elefsis bay revealed higher biomass and abundance values than in the Psittalia area and the inner Saronikos, only during February 1990. On the contrary during the other sampling months, zooplankton biomass and abundance values were lower in Elefsis bay than in the Psittalia area and Saronikos gulf. This is in accordance with the annual cycle of zooplankton observed in Elefsis bay by Yannopoulos (1976) and Siokou-Frangou (1991a, 1993). The maximum values observed in the period January-March are due to the extreme dominance of *Acartia clausi* and in some years were related to the high chlorophyll ß values recorded in the December-March period. According to Panayotidis et al. (1988) lower zooplankton values during the summer period are due to its predation by the big population of the medusae *Aurelia aurita*. In the Gulf of Fos (France), a semi-enclosed basin receiving a large amount of pollutants, zooplankton did not reveal higher values during January-February in the surface layer but at a lower depth (Patriti, 1984). Nevertheless it is worth mentioning that a great heterogeneity in zooplankton abundance distribution was detected in Elefsis bay. This could be related to a possible heterogeneity of the environment and/or to the patchy distribution of zooplankton.

As mentioned above, high values during September, December 1989, June 1990 and May 1991 were found at stations in the Psittalia area (P03 to P08) and only once near the sewage outfall (P09). This should be related to the high trophic status of the area (high nutrient values). This relation was also obvious in the Principal Components Analysis performed on the September and December data. But it seems that the trophic status is not the only favourable factor for the zooplankton abundance, since high nutrient values were recorded at stations P09 to P11 but zooplankton was not abundant. In this narrow and closed area water transparency is lower than south of the Psittalia island and it is highly influenced by human activities (sewage, naval activities, etc.). These factors modify deeply the water characteristics (although oxygen concentration didn't vary significantly between areas) and therefore affect the zooplankton abundance. Furthermore zooplankton presented high values in the inner and western Saronikos since these areas are less influenced by anthropogenic factors. A similar situation was also observed near the sewage outfall off Marseille (Arfi et al., 1981, EPOPEM, 1979).

A clear spatial differentiation based on species and groups composition was also obvious in most sampling months. Elefsis bay revealed a distinct zooplankton composition from that of the Psittalia area and the inner Saronikos except in February 1990. According to the sampling period among copepods and cladocerans *A. clausi, Acartia grani, Centropages ponticus, Podon polyphemoides, Penilia avirostris* were dominant in Elefsis bay (stations P12 to P20) and in the Keratsini channel (P10, P11). These species were found dominating in this area in previous years (Moraitou-Apostolopoulou, 1974, 1981; Moraitou-Apostolopoulou and Ignatiades, 1980; Siokou-Frangou, 1991a,b; Siokou-Frangou et al., in press). They generally dominate in semi-enclosed and polluted areas such as the gulf of Fos (Benon et al., 1977; Patriti, 1984), the port of Malaga (Rodriguez and Vives, 1984a, b), the port of Mahon (Jansa, 1986), Thessaloniki bay (Siokou-Frangou and Papathanassiou, 1991). According to

Siokou-Frangou (1993) there is a distinct zooplankton community in Elefsis bay, differentiated from that of the Saronikos gulf. This community is impoverished in species, especially during winter-spring, dominated by few opportunistic or r-selected species which can attain extremely high values in some cases (e.g. *A. clausi* in February). The results of this study (species composition, dendrograms, diversity index, k-dominance curves) confirm the above character of this community and define its expansion in the whole Elefsis bay and the Keratsini channel. The single differentiation of stations P13, P15 and P19 in May 1991 by the classification and ordination methods, is due to the extremely low abundances of all species at these stations, a fact probably related to the clogging of sampling nets by the medusae.

On the other hand stations in the Psittalia area (P03 to P08), the inner Saronikos (P01, P02) and the western Saronikos (P21) are characterised by the dominance of the copepods *Clausocalanus furcatus, Centropages typicus, Oithona plumifera, Oithona similis, Paracalanus parvus, Temora stylifera* and the cladocerans *Penilia avirostris, Evadne spinifera*. The above species are abundant in coastal areas of the Mediterranean sea e.g. the coastal area of Spain (Estrada et al., 1984), the bay of Malaga (Rodriguez, 1983), the gulf of Naples (Scotto di Carlo et al., 1985), the coastal area of Adriatic Sea (Hure et al., 1980), Thermaikos gulf (Siokou-Frangou and Papathanassiou, 1991). Previous studies in Saronikos gulf have pointed out the dominance of these species (Moraitou-Apostolopoulou, 1974; Moraitou-Apostolopoulou and Ignatiades, 1980; Siokou-Frangou, 1993). The discrimination of these stations from those of Elefsis bay, was quite clear by the classification and ordination methods. Furthermore, the community structure was differentiated between these areas during some months (September, December, February) by its species richness (diversity index and k-dominance curves). Nevertheless the Psittalia area and the inner Saronikos were not clearly distinguished in the MDS plot from the Elefsis bay during February 1990 and this was due to the dominance of *A. clausi* in the whole study area. This species has a broad coastal distribution during winter-spring period (Specchi et al., 1981; Scotto di Carlo et al., 1985; Christou, 1991; Siokou-Frangou, 1991b) and especially in the surface layer (Siokou-Frangou, 1993).

As for station P09, its composition was similar either to the Elefsis bay stations (February, June 1990, May 1991) or to the Psittalia stations (September, December 1989). This fact could be due to the geographical position of the station (between the two areas) and the dominating water circulation in the channel (westwards or eastwards movement). Furthermore during May 1991 stations P06, P08 (southwards of Psittalia) presented similar species composition with the Keratsini and Elefsis bay stations. This similarity could be related to the water movement. On the other hand station P21 was clustered together with the Elefsis bay stations in February and June 1990, indicating a similar composition probably due to water circulation.

General

The results already discussed did not give a clearcut differentiation of the studied areas according to the pollution impact on the studied parameters, since different patterns were revealed between them not suggesting any interrelationships. At this point, statistical analysis (Principal Component Analysis) upon matrices

constructed from all the collected data (physical, chemical and biological) for each sampling period was considered necessary and this analysis revealed a clear differentiation among three areas: (a) Elefsis bay, (b) the area mostly influenced by the sewage outfall that is Keratsini Bay and the Psittalia area and (c) the area of inner Saronikos and the western basin, which seemed to be the least influenced by pollution. This differentiation was quite persistent during all sampling periods and related to environmental factors such as temperature, salinity, nutrients, zooplankton species distribution and phytoplankton biomass.

Differentiation of areas according to temperature and salinity was expected, due to the hydrology of the studied areas. Furthermore nutrients' spatial distribution depended mainly on the position of the Athens sewage outfall at Keratsini Bay and the dominating circulation. Consequently phytoplankton biomass followed the same pattern as nutrients, whereas zooplankton abundances did not exhibit their highest values in the most eutrophic stations, due to its sensitivity to pollutant factors. Similarly pollution influenced the pattern of the spatial distribution of zooplankton species but not that of phytoplankton species. It seems therefore that planktonic algae and animals have a different response to pollution.

Gotsis-Skretas and Friligos (1990) have not found a clear spatial differentiation of phytoplankton species in Thermaikos gulf between polluted and not polluted areas, although spatial differentiation existed not only in phytoplankton biomass and abundance, but also in zooplankton species distribution which was quite clear and distinct (Siokou-Frangou and Papathanassiou, 1991).

From these results we can conclude that among the parameters describing the plankton populations of Saronikos Gulf, phytoplankton biomass and zooplankton species distribution can be used as a tool for the investigation of pollution impact on plankton communities.

On the other hand, our studies revealed that zooplankton distribution is influenced by water movements and this was obvious from the fact that stations of the Psittalia area, although positioned close to the sewage outfall and as a result having higher nutrient concentrations, presented a species composition similar to that of the inner Saronikos Gulf. The Psittalia area is influenced by the dominating cyclonic flow in the inner Saronikos, which carries and diffuses a part of the sewage discharges in the inner gulf. On the contrary, some of the sewage discharges are "trapped" in the narrow Keratsini Channel and the semi-enclosed Elefsis bay, areas submitted moreover to naval and industrial pollution.

It seems therefore that pollution in Saronikos gulf influences the zooplankton abundance, composition and structure but the intensity of this impact depends on the water circulation and topography of each area. Fortunately this dependence confines the impact to a small area as compared to the amount of the pollutants received by Saronikos gulf. Nevertheless the neighbouring of Elefsis bay with inhabited areas prescribes the necessity of eliminating the pollutant factors.

Furthermore the results of our project confirmed the opinions of Ignatiades et al. (1992), that: (a) comparisons of phytoplanktonic samples should not be limited

to taxonomic relationships but they should be extended to biomass and/or diversity related parameters which might provide additional information for a clearer and more powerful defining of associations. (b) conclusions should be drawn after data analysis with the application of several multivariate approaches (Gauch, 1989), since each approach has its distinctive strengths and might provide complementary information for evaluating the stability of the results found.

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