MEDITERRANEAN ACTION PLAN
MED POL

UNITED NATIONS ENVIRONMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

STUDY OF ECOSYSTEM MODIFICATIONS IN AREAS INFLUENCED BY POLLUTANTS (ACTIVITY I)

ETUDE DES MODIFICATIONS DE L'ECOSYSTEME DANS LES ZONES SOUMISES A L'INFLUENCE DES POLLUANTS (ACTIVITE I)

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This volume is the twenty-second issue of the Mediterranean Action Plan Technical Report 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 Oil Combating Centre.

Ce volume constitue le vingt-deuxième 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 de lutte contre la pollution par les hydrocarbures.

INTRODUCTION

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, 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 for appropriate allocations of resources.

MED POL - Phase I (1976-1980)

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.

MED POL - Phase I initially consisted of seven pilot projects (MED POL I - VII), which were later expanded by additional six pilot projects (MED POL VIII - XIII), some of which remained in a conceptual stage only.

MED POL - Phase I was implemented in the period from 1975 to 1980. The large number of national research centres designated by their Governments to participate in MED POL (83 research centres from 15 Mediterranean States and the EEC), the diversity of the programme and its geographical coverage, the impressive number of Mediterranean scientists and technicians (about 200) and the number of co-operating agencies and supporting organizations involved in it, qualifies MED POL as certainly one of the largest and most complex co-operative scientific programmes with a specific and well-defined aim ever undertaken in the Mediterranean basin.

The overall co-ordination and guidance for MED POL - Phase I was provided by UNEP, acting as the secretariat of the Mediterranean Action Plan (MAP). Co-operating specialized United Nations Agencies (ECE, UNIDO, FAO, UNESCO, WHO, WMO, IAEA, IOC) were responsible for the technical implementation and day-to-day co-ordination of the work of national research centres participating in the pilot projects.

MED POL - Phase II (1981-1990)

The Intergovernmental Review Meeting of Mediterranean Coastal States and First Meeting of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution, and its related protocols (Geneva, 5-10 February 1979), having examined the status of MED POL - Phase I, recommended that during the 1979/80 biennium a Long-term pollution monitoring and research programme should be formulated.

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.

For this purpose, monitoring was organized on several levels:

- monitoring of sources of pollution providing information on the type and amount of pollutants released directly into the environment;

- monitoring of nearshore areas, including estuaries, under the direct influence of pollutants from identifiable primary (outfalls, discharge and coastal dumping points) or secondary (rivers) sources;

- monitoring of offshore areas (reference areas) providing information on the general trends in the level of pollution in the Mediterranean;

- monitoring of the transport of pollutants to the Mediterranean through the atmosphere, providing additional information on the pollution load reaching 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);

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 first eight volumes of the MAP Technical Reports Series present the collection of final reports of the Principal Investigators who participated in the relevant pilot projects (MED POL I - MED POL VIII). The ninth volume of the MAP Technical Reports Series is the final report on the implementation of MED POL - Phase I, prepared, primarily, on the basis of individual final reports of the principal investigators with the co-operation of relevant United Nations Agencies (FAO, UNESCO, WHO, WMO, IAEA, IOC).

The tenth volume of the MAP Technical Reports Series was the first one to include final reports on projects implemented within the framework of the research component of MED POL - Phase II. This twenty-second volume of the Series includes final reports on projects dealing with ecosystem modifications in areas influenced by pollutants.

INTRODUCTION

Le Programme des Nations Unies pour l'environnement (PNUE) a convoqué une réunion intergouvernementale sur la protection de la Méditerranée (Barcelone, 28 janvier - 4 février 1975) à laquelle ont pris part des représentants de 16 Etats riverains de la mer Méditerranée. La réunion a examiné les diverses mesures nécessaires à la prévention et à la lutte antipollution en mer Méditerranée, et elle s'est conclue sur l'adoption d'un Plan d'action comportant trois éléments fondamentaux:

- Planification intégrée du développemet et de la gestion des ressources du bassin méditerranéen (élément "gestion");

- Programme coordonné de surveillance continue, de recherche, d'échange de renseignements et d'évaluation de l'état de la pollution et des mesures de protection (élément "évaluation");

- Convention cadre et protocoles y relatifs avec leurs annexes techniques pour la protection du milieu méditerranéen (élément juridique).

Tous les éléments du Plan d'action étaient interdépendants et fournissaient le cadre d'une action d'ensemble en vue de promouvoir, tant la protection que le développement continue de l'écorégion méditerranéenne. Aucun élément ne constituait une fin à lui seul. Le Plan d'action était destiné à aider les gouvernements méditerranéens à formuler leurs politiques nationales en matière de développement continu et de protection de zone de la Méditerranée et à accroître leur faculté d'identifier les diverses options s'offrant pour les schémas de développement, d'arrêter leurs choix et d'y affecter les ressources appropriées.

MED POL - Phase I (1976 - 1980)

Le programme coordonné de surveillance continue et de recherche en matière de pollution de la Méditerranée (MED POL) a été approuvé au titre de l'élément "évaluation" (scientifique/technique) du Plan d'action.

Sa phase pilote (MED POL - Phase I) avait les objectifs généraux ci-dessous, élaborés au cours d'une série de réunions d'experts et de réunions intergouvernementales:

- formuler et exécuter un programme coordonné de surveillance continue et de recherche en matière de pollution en tenant compte des buts du Plan d'action pour la Méditerranée et de l'aptitude des centres de recherche méditerranéens à y participer;

- aider les centres de recherche nationaux à se rendre plus aptes à cette participation;

- étudier les sources, l'étendue, le degré, les parcours, les tendances et les effets des polluants affectant la mer Méditerranée;

- fournir l'information scientifique et technique nécessaire aux gouvernements des pays méditerranéens et à la Communauté économique européenne pour négocier et mettre en oeuvre la Convention pour la protection de la mer Méditerranée contre la pollution et les protocoles y relatifs;

- constituer des séries chronologiques cohérentes de données sur les sources, les cheminements, les degrés et les effets des polluants de la mer Méditerranée et contribuer par là à la connaissance scientifique de cette mer.

La Phase I du MED POL comportait à l'origine sept projets pilotes (MED POL I - VII) auxquels sont venus ultérieurement s'ajouter six autres (MED POL VIII - XIII) dont certains n'en sont restés qu'au stade de la conception.

La Phase I du MED POL a été mise en oeuvre au cours de la période 1975 - 1980. Le grand nombre de centres de recherche nationaux désignés par leurs gouvernements pour participer au MED POL (83 centres de recherche de 15 Etats méditerranéens et de la CEE), la diversité du programme et sa couverture géographique, l'effectif impressionnant de scientifiques et techniciens méditerranéens (environ 200) ainsi que la quantité d'organismes coopérants et d'organisations d'appui qui y étaient engagés permettent sans conteste de caractériser le MED POL comme l'un des programmes de coopération scientifique les plus vastes et les plus complexes, comportant un objectif spécifique et bien défini, qui ai jamais été entrepris dans le bassin méditerranéen.

La coordination et la direction générales de MED POL - Phase I ont été assurées par le PNUE, faisant fonction de secrétariat du Plan d'action pour la Méditerranée (PAM). Les organismes spécialisés coopérants des Nations Unies (CEE - Commission économique pour l'Europe, ONUDI, FAO, UNESCO, OMS, OMM, AIEA, COI) étaient chargés de l'exécution technique et de la coordination quotidienne des travaux des centres de recherche nationaux participant aux projets pilotes.

MED POL - Phase II (1981 - 1990)

La réunion intergouvernementale des Etats riverains de la Méditerranée chargés d'évaluer l'état d'avancement du Plan d'action et première réunion des Parties contractantes à la Convention pour la protection de la mer Méditerranée contre la pollution et aux protocoles y relatifs (Genève, 5-10 février 1979), ayant examiné la situation de la Phase I du MED POL, a recommandé que, durant la période biennale 1979 - 80, soit formulé un programme à long terme de surveillance continue et de recherche en matière de pollution.

Sur la base des recommandations énoncées lors des diverses réunions d'experts et réunions intergouvernementales, un projet de programme à long terme (1981 - 1990) de surveillance continue et de recherche en matière de pollution (MED POL - Phase II) a été formulé par le secrétariat de la Convention de Barcelone (PNUE), en coopération avec les organismes des Nations Unies chargés de l'exécution technique de MED POL - Phase I, et il a été officiellement approuvé lors de la deuxième réunion des Parties contractantes à la Convention pour la protection de la mer Méditerranée contre la pollution et aux Protocoles y relatifs et réunion intergouvernementale des Etats riverains de la mer Méditerranée chargée d'évaluer l'état d'avancement du Plan d'action, qui s'est tenue à Cannes du 2 au 7 mars 1981.

L'objectif général à long terme de la Phase II du MED POL était de concourir à la réalisation des objectifs de la Convention de Barcelone en aidant les Parties contractantes à prévenir, réduire et combattre la pollution dans la zone de la mer Méditerranée ainsi qu'à protéger et améliorer le milieu marin dans cette zone. Les objectifs particuliers étaient de fournir constamment aux Parties contractantes à la Convention de Barcelone et aux Protocoles y relatifs:

- les renseignements dont elles avaient besoin pour appliquer la Convention et les protocoles;

- des indications et une évaluation de l'efficacité des mesures prises pour prévenir la pollution en application de la Convention et des protocoles;

- des renseignements scientifiques qui pourraient servir à réviser et modifier les dispositions pertinentes de la Convention et des protocoles et à rédiger des protocoles additionnels;

- des informations qui pourraient servir à formuler sur les plans national, bilatéral et multilatéral, les décisions de gestion, respectueuses de l'evnironnement, qui seraient indispensables à la poursuite du développement socio-économique de la région méditerranéenne;

- une évaluation périodique de l'état de pollution de la mer Méditerranée.

La surveillance continue des polluants affectant le milieu marin de la Méditerranée ainsi que la recherche menée à leur sujet répondent en premier lieu aux prescriptions immédiates et à long terme de la Convention de Barcelona et des protocoles y relatifs, mais elles tiennent également compte des facteurs requis pour la compréhension des relations existant entre le développement socio-économique de la région et la pollution de la mer Méditerranée.

A cette fin, la surveillance continue était organisée à plusieurs niveaux:

- surveillance continue des sources de pollution fournissant des renseignements sur la nature et la quantité des polluants directement libérés dans l'environnement;

- surveillance continue des zones situées à proximite du littoral, y compris les estuaires, et qui sont sous l'influence directe de polluants émis par des sources identifiables primaires (émissaires, rejets et sites côtiers d'immersion) ou secondaires (cours d'eau);

- surveillance continue des zones du large (zones de référence) fournissant des renseignements sur les tendances générales du niveau de pollution en Méditerranée;

- surveillance continue du transfert des polluants à la Méditerranée par voie atmosphérique, fournissant des renseignements supplémentaires sur la charge polluante qui atteint la Méditerranée.

Les sujets de recherche et d'étude inclus initialement dans MED POL - Phase II étaient les suivants:

- mise au point de techniques d'échantillonnage et d'analyse pour la surveillance des sources et des niveaux de pollution. Essai et harmonisation de ces méthodes à l'échelle méditerranéenne, et formulation de méthodes de référence. Substances figurant sur les listes de priorité des protocoles sur les opérations d'immersion et sur la pollution d'origine tellurique (activité A);

- mise au point de la présentation type des rapports à soumettre en application des protocoles relatifs à l'immersion, à la pollution résultant de situations critiques et à la pollution d'origine tellurique, (activité B);

- élaboration des fondements scientifiques des critères de qualité de l'environnement qui serviront à définir des normes d'émission, des normes d'usage ou des directives concernant les substances énumérées dans les annexes I et II du protocole relatif à la pollution d'origine tellurique, conformément aux articles 5, 6 et 7 de ce protocole (activité C);

- études épidémiologiques relatives à la confirmation (ou révision éventuelle) des critères de la qualité de l'environnement (normes d'usage) proposés pour les eaux servant à la baignade, à la culture de coquillages et à l'élevage d'autres organismes marins comestibles (activité D);

- mise au point de projets de directives et de critères régissant l'application du protocole relatif à la pollution d'origine tellurique, conformément à l'article 7 de ce protocole (activité E);

- recherches sur les processus océaniques, et particulièrement sur la circulation en surface et les déplacements verticaux. Cette information est nécessaire à la connaissance de la répartition des polluants en Méditerranée et à la mise au point de plans pour parer aux situations critiques (activité F);

- recherches sur la toxicité, la persistance, la bioaccumulation et le caractère cancérigène et mutagène de certaines substances énumérées dans les annexes du protocole relatif à la pollution d'origine tellurique et du protocole relatif aux opérations d'immersion (activité G);

- recherches sur l'eutrophisation et les floraisons de plancton qui l'accompagnent. Cette information est nécessaire pour évaluer la possibilité de prévenir les effets et les dégâts causés par ces floraisons périodiques (activité H);

- étude des modifications de l'écosystème dans les zones soumises à l'influence des polluants et dans celles où ces modifications sont dues à d'importantes activités industrielles sur la côte ou à l'intérieur des terres (activité I);

- effets des pollutions thermiques sur les écosystèmes marins et côtiers, y compris l'étude des effets connexes (activité J);

- cycle biogéochimique de certains polluants intéressant particulièrement la santé (mercure, plomb, survie des organismes pathogènes dans la mer Méditerranée, etc.) (activité K);

- étude des processus de transfert des polluants (i) aux points de contact entre les cours d'eau et la mer et entre l'air et la mer, (ii) par sédimentation et (iii) à travers les détroits qui relient la Méditerranée aux mers voisines (activité L).

Comme lors de la Phase I du MED POL, la coordination et la direction générales de la Phase II étaient assurées par le PNUE, par l'intermédiaire du secrétariat du Plan d'action pour la Méditerranée (PAM). Les organismes spécialisés coopérants des Nations Unies (FAO, UNESCO, OMS, OMM, AIEA, COI) étaient chargés de l'exécution technique et de la coordination quotidienne des travaux des centres de recherche nationaux participant au programme de surveillance continue et de recherche.

Les huit premiers volumes de la Série des rapports techniques du PAM rassemblent les rapports finaux de chercheurs responsables qui ont participé aux projets pilotes correspondants (MED POL I - MED POL VIII). Le neuvième volume de cette même Série se compose du rapport final sur la mise en oeuvre de la Phase I du programme MED POL, établi essentiellement sur la base des rapports finaux individuels des chercheurs responsables avec la coopération des organismes compétents des Nations Unies (FAO, UNESCO, OMS, OMM, AIEA, COI).

Le dixième volume de la Série des rapports techniques du PAM, etait le premier à comprendre les rapports finaux sur les projets mises en oeuvre dans le cadre de la composante "recherche" du MED POL - Phase II. Ce vingt-deuxième volume de la Série comprend les rapports finaux sur les projets traitant des modifications de l'écosystème dans les zones soumises à l'influence des polluants.

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MONITORING OF ECOSYSTEMS' MODIFICATIONS IN THE NORTHERN ADRIATIC SEA INDUCED BY EUTROPHICATION AND ANTHROPOGENIC ACTIVITIES

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A B S T R A C T

Previous baseline studies of pelagic and benthic ecosystems in coastal and offshore waters of the northern Adriatic Sea revealed a probability of large-scale modifications of communities as a consequence of continuous inputs of the Po River, mariculture and touristic activities. The scope of the present research was to identify possible community variations and to estimate the rate of alterations caused by inputs, especially of pollutants.

The study of selected physical, chemical and biological parameters was carried out by standard oceanographic working methods and techniques. Water and sea bed characteristics, as well as phytoplankton and benthic communities, were surveyed in the Limski canal and along the transect Rovinj - Po River mouth.

During the research period several phytoplankton blooms were identified and evaluated with special regard to their dependence on interactions with basic hydrographic and nutrient remineralisation processes. In general, phytoplankton blooms were most intensive in the western part of the surveyed area and they occurred mostly in the surface and middle layers. In the bottom layer, heavy deficiencies of oxygen saturation occurred several times and these were especially related to the richness of the nutrients. The dominance of the nanoplankton fraction in the biomass and the productivity of the phytoplankton community are particularly pointed out.

In macrofaunal assemblages temporal variations were noted at each station, but these could only be interpreted with some difficulty, even for the most abundant species; this was probably due to the unexpected patchiness of their local distribution.

A marked dominance of the polychaete Notomastus latericeus and the brittle star Amphiura filiformis was observed at all stations facing the Po River mouth. In the meiofauna fraction, nematodes largely prevailed and among them the most abundant were detritus film feeders. At coastal stations in the Limski canal, the dominance of sediment-living macrofaunal and meiofaunal species was not so prevalent as at offshore stations. The decrease in the numbers of benthic species and in the densities of sediment meiofauna at stations located in the vicinity of detritus sources was most indicative. Both the diversity of the species, and the dynamics of the benthic communities indicated that the stability of the ecosystems was disturbed; nevertheless for the time being the areas studied could not be considered as polluted areas.

1. INTRODUCTION

Previous studies on the general oceanographic conditions and dynamics of the pelagic ecosystem (Stirn, 1969; Revelante and Gilmartin, 1976; Degobbis et al., 1979; Smodlaka and Revelante, 1984) revealed the large scale influence of the Po River discharge in the whole shallow northern Adriatic. It was supposed that the continuous input of organic and inorganic materials also had an impact on benthos, at least in the area facing the actual mouth of the river.

On the other hand, a relatively enclosed coastal marine ecosystem in the Lìmski canal, an 11 km long fjord-like bay, could be subject to changes due to the input of nutrients and organic materials from freshwater springs, restaurants and intensive shellfish and fish farming, similar to those described by Mattson and Linden (1983). In this area intensive research on hydrography and benthos had previously been conducted (Vatova, 1931, 1935, 1943; Vatova and di Villagrazia, 1950; Bozic et al., 1964; Zavodnik, 1971).

To establish possible alterations and seasonal dynamics in pelagic and benthic ecosystems in both areas, with regard to previous data, and to check the assumptions concerning input effects on pelagic and benthic populations, a repeat survey was undertaken as part of the MED POL - Phase II project.

2. DESCRIPTION OF RESEARCH

2.1 Area investigated

Samplings and measurements were carried out offshore in the northern Adriatic at five stations (ciphered SJ) located along the transect Rovinj - Punta della Maestra (mouth of the Po River), and at three coastal stations (ciphered LK) situated in the Limski canal, i.e. in an inland fjord-like bay (Fig. 1, Table I).

2.2 Time of research

Field sampling began in October 1982, and continued at offshore stations until October 1983, and at coastal stations until October 1984. Surveys were carried out at one or two month intervals.

2.3 Working techniques

All parameters were studied by using standard sampling and preparation methods adopted for the coordinated Yugoslav-Italian monitoring of the northern Adriatic Sea (Zavodnik, 1982).

Sea water samples for chemical analysis were taken with Niskin and Van Dorn bottles; the latter were also used for phytoplankton sampling. For quantitative sampling of the sediment-inhabiting fauna an 0.1 m^2 Van Veen grab was used. Subsamples for sediment meiofauna and heterotrophic bacteria were taken from undisturbed grab samples with 5-3 cm hand corers. At shallow depths (down to 30 metres) core samples were taken by Scuba divers (Vidakovic, 1984).

Temperature was measured by Richter and Wiese reversing thermometers mounted on Niskin water bottles.

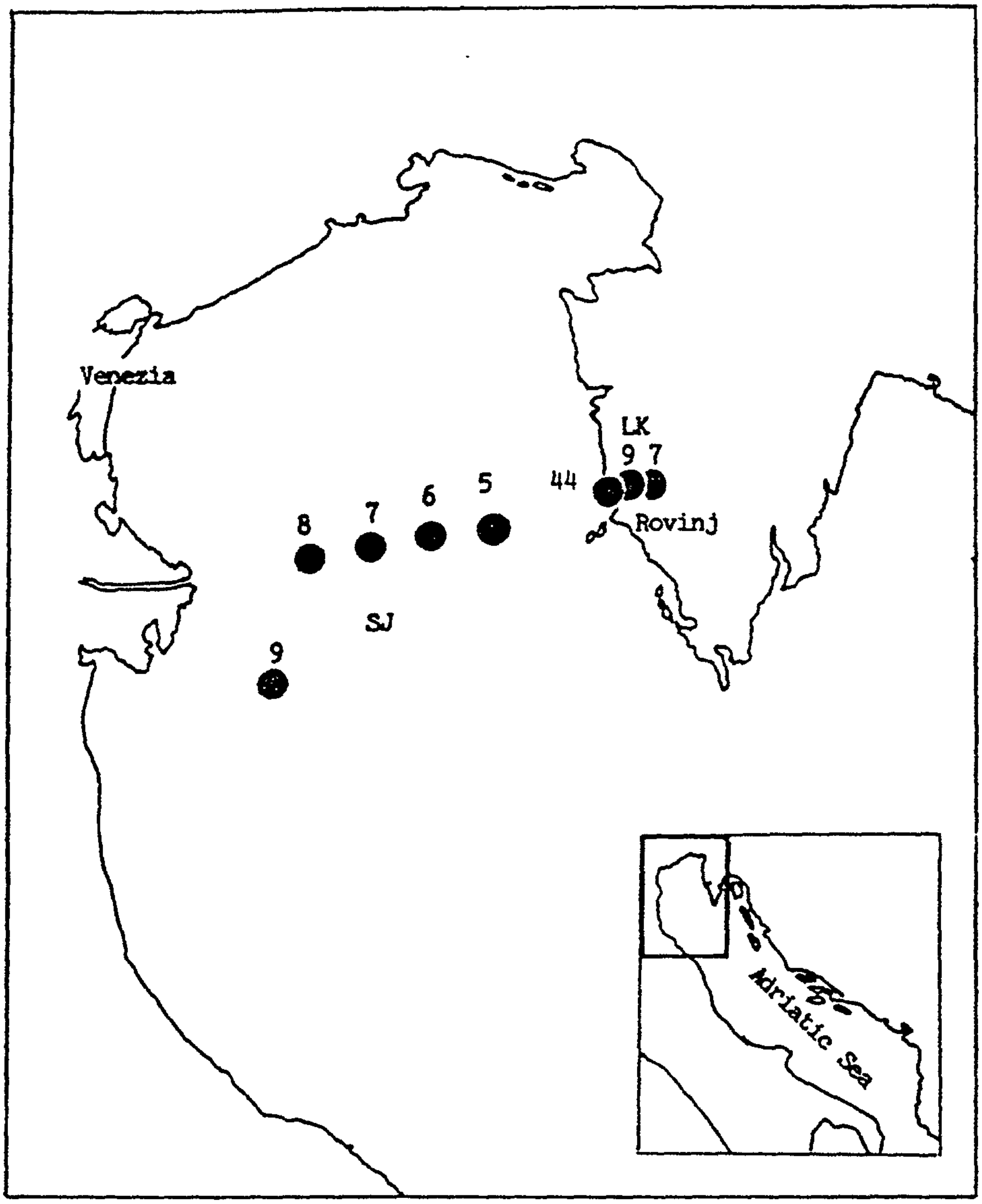

Fig. 1 Research areas (SJ, LK) and stations

Salinity was determined with a high precision Kahlsico laboratory salinometer.

Dissolved oxygen values were obtained using the modified Winkler's titration method.

pH was measured with a Radiometer pH-meter.

Total alkalinity was determined as described in Strickland and Parsons (1972).

Nutrients (reactive phosphate, nitrates, nitrites, ammonia and silicates) were analyzed by spectrophotometric methods described in Strickland and Parsons (1972).

Heterotrophic bacteria were determined according to the method of Oppenheimer and ZoBell (1952).

Chlorophyll a was measured fluorimetrically after sample treatment, and extraction with 90% acetone, according to Strickland and Parsons (1972).

Phytoplankton cell counting was done using Utermöhl's method. Samples were fixed with Lugol solution and sedimented in Opton's chambers.

Macrofauna counting was done after sieving through 2 mm sieves and preservation in neutralized 4% formalin or 60% alcohol.

Table I

Position, depth, and bottom characteristics at investigated stations.

Station	Geographical position Lat. N	Long. E	Depth (m)	Type of sediment
OFFSHORE (Bay of Venice)				
SJ-5	45°02.8'	13°19.0'	31	Silty Sand
SJ-6	45°02.0'	13°09.3'	36	Silty Sand
SJ-7	45°01.0'	12°59.7'	33	Clayey-Sandy Silt
SJ-8	44°59.8'	12°49.8'	31	Clayey-Sandy Silt
SJ-9	44°45.4'	12°45.0'	31	Clayey Silt
COASTAL (Limski canal)				
LK-7	45°08.2'	13°42.8'	8	Clayey Silt*
LK-9	45°07.9'	13°40.5'	18	Clayey Silt*
LK-44	45°07.6'	13°36.8'	30	Sandy Silt*

* Data according to Paul (1970)

Meiofauna counting was done after sediment fixation with neutralized 4% formalin and staining with Rose Bengal following elutration and sieving through 100 um and 50 um sieves. Examination was carried out under a dissecting microscope.

Presentation of results: In this report results of the most relevant parameters only are presented in tables and graphs. The number of graphs is limited to those cruises during which the environmental conditions were considered most characteristic for the northern Adriatic offshore waters. Further explanations are given in the text.

3. RESULTS

3.1 Offshore area

During 1982 and 1983 seven cruises along the transect Rovinj - mouth of the Po River were carried out using the RV "Vila Velebita": in October and November 1982, and in January, March, May, August and October 1983.

3.1.1 Pelagic ecosystem

In October and November 1982, at stations facing the Po River mouth, both salinity and temperature of surface layers were lower than in the eastern part of the studied area. Nutrient concentrations in October were also very low in the upper layer, but higher by an order of magnitude near the bottom. In November, however, in the upper layers nutrients were enriched (Fig. 2). A characteristic of bottom layers at the western stations was an absence of oxygen saturation, which at station SJ-9 dropped in November to only 33%. Phytoplankton biomass was however relatively high in the upper layers (2-4 mg chl. a m^{-3}), thus showing its relation to salinity conditions. These phenomena indicated a nutrient remineralization in the bottom layer and the Po River influence in surface layers. It should be noted that in October the phytoplankton biomass at all stations (except SJ-9) consisted mostly of nanoplankton (more than 75%), while in November, according to chlorophyll a, micro- and nanoplankton usually were equally distributed. Microplankton was dominated by diatoms, except for the surface layer at station SJ-9 in which silicoflagellates were characteristic.

The January 1983 cruise showed a complete homogeneity of the water body, vertically and horizontally, within normal values for all parameters (Fig. 3). The nanoplankton dominance surpassed 75% and within microplankton, diatoms dominated by more than 99%.

At the March and May 1983 cruises a phytoplankton bloom at all transect stations was observed (Figs. 4 and 5). According to our data, it started at stations in the vicinity of the Po River mouth, but later its centre shifted eastwards. In March, nutrient concentrations were highest in the surface layer at stations SJ-8 and SJ-9, but very low at other stations at all depths, especially in the upper 10 m layer which was characterized by a relatively high chlorophyll a biomass. It is obvious that the nutrients in this water body which were exhausted, had originated from the Po River plume which was almost completely mixed with sea water. Oxygen saturation showed a similar pattern to chlorophyll a, but in May it somewhat decreased in the bottom layer to less than 70%. At that time of the year, the nanoplankton contribution to the total biomass ranged from 60 to over 75%. It is interesting that at station SJ-9 in March the microplankton photosynthetic activity (85%) was higher than that of the nanoplankton fraction. Within microplankton, diatoms dominated usually by 90-99%. However, in the surface layer of station SJ-5, diatoms were absent in May, and a 100% dinoflagellate population was found.

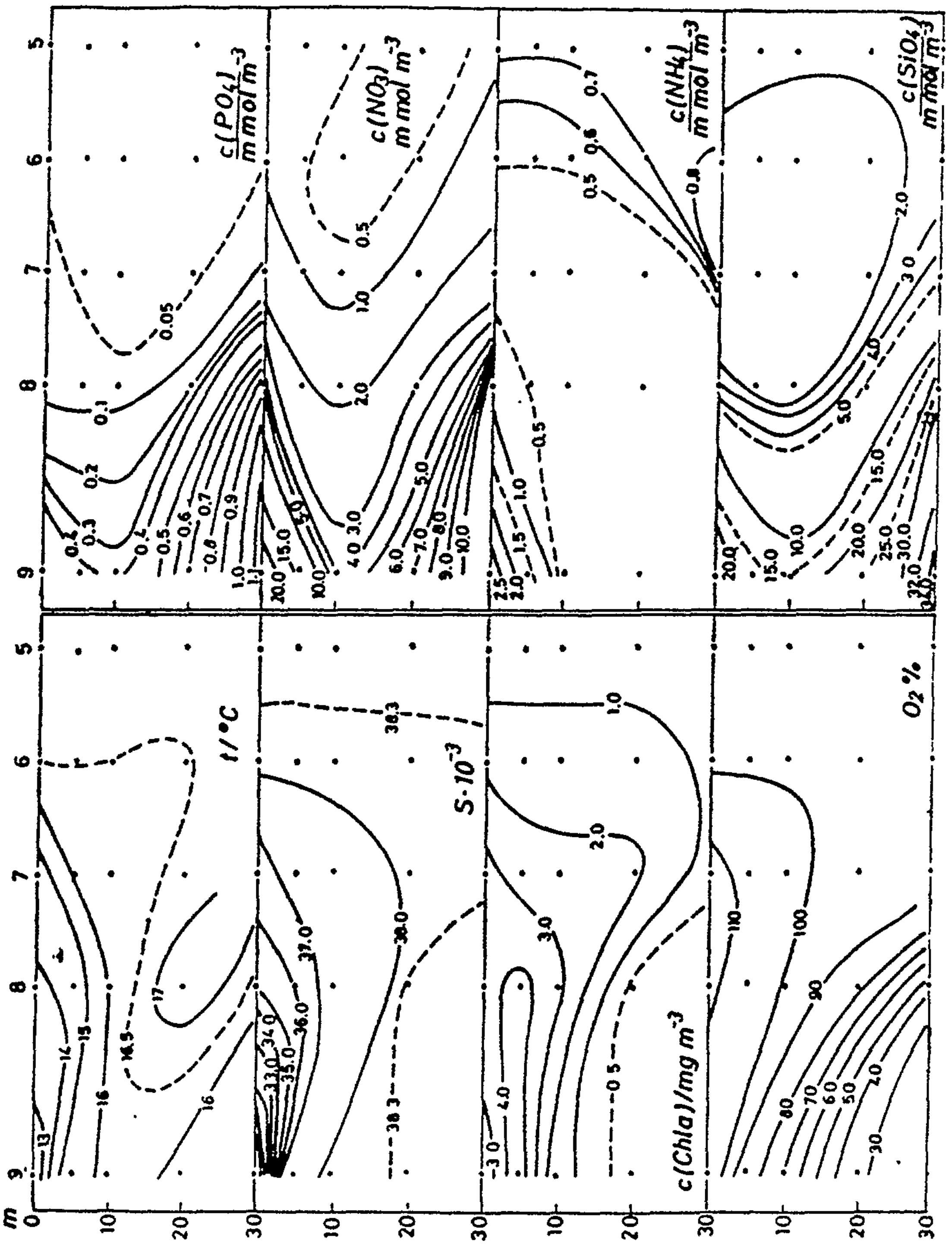

Fig. 2 Basic oceanographic parameters on 22 November 1982 at the SJ stations 5-9

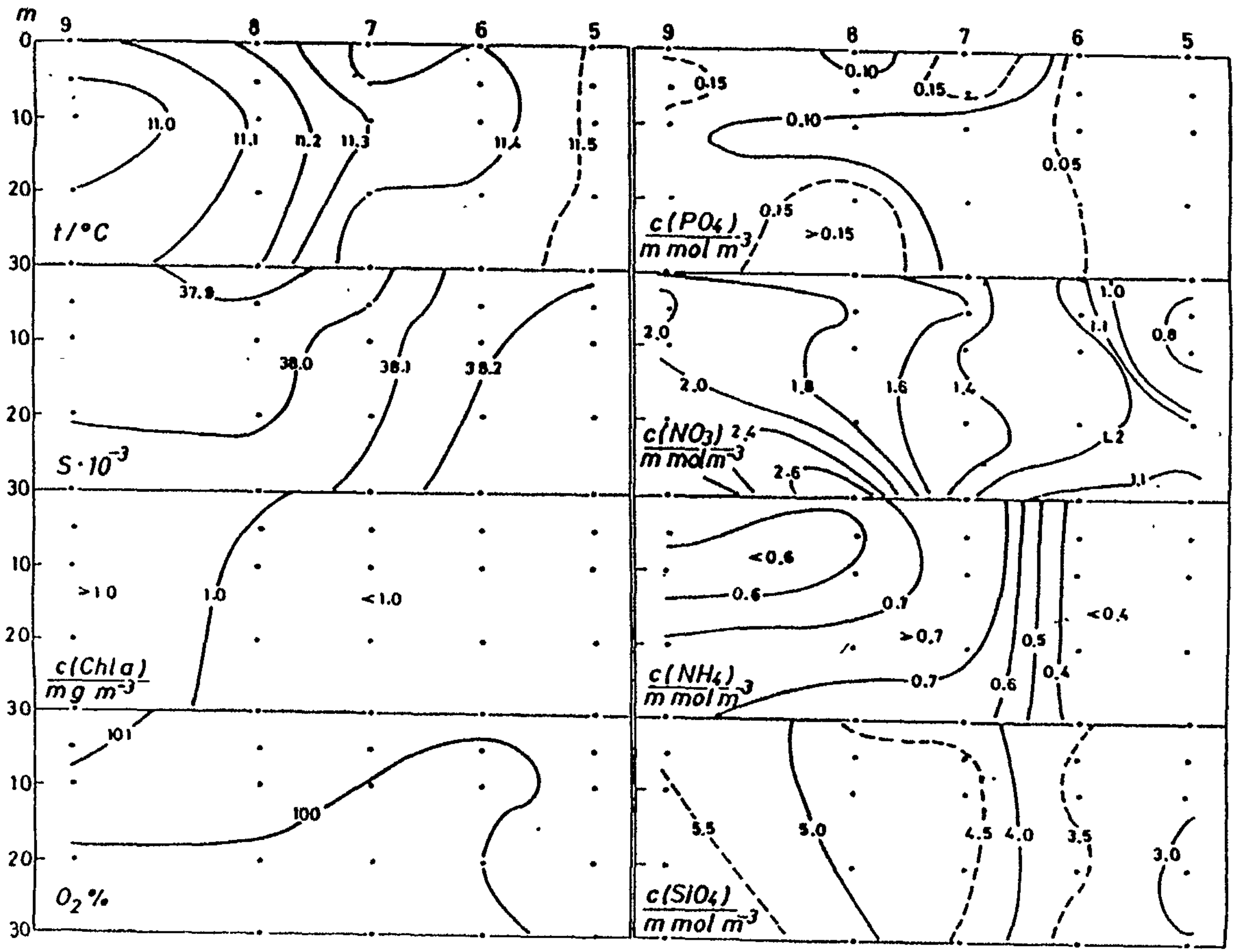

Fig. 3 Basic oceanographic parameters on 25 January 1983 at the SJ stations 5-9

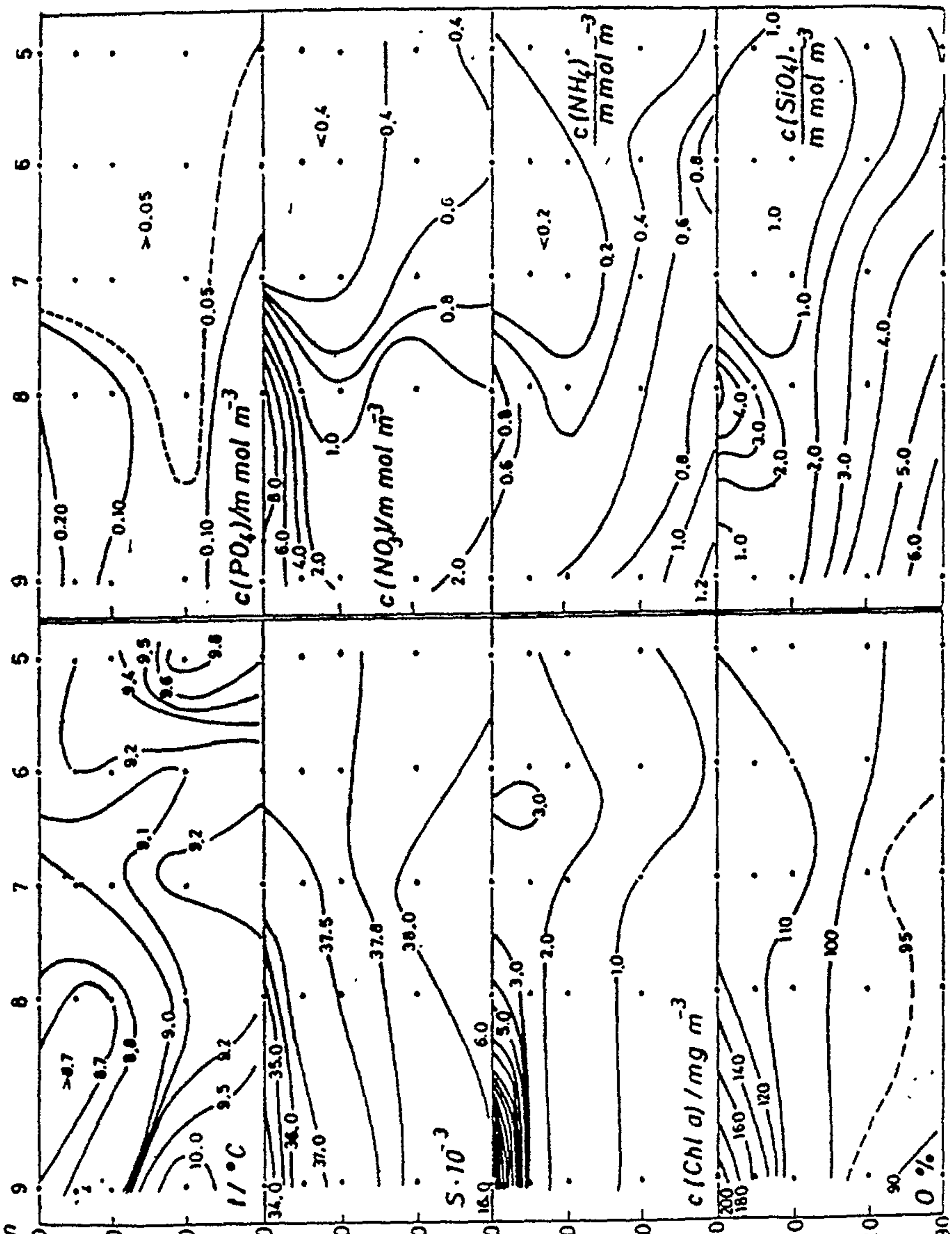

Fig. 4 Basic oceanographic parameters on 10 March 1983 at the SJ stations 5-9

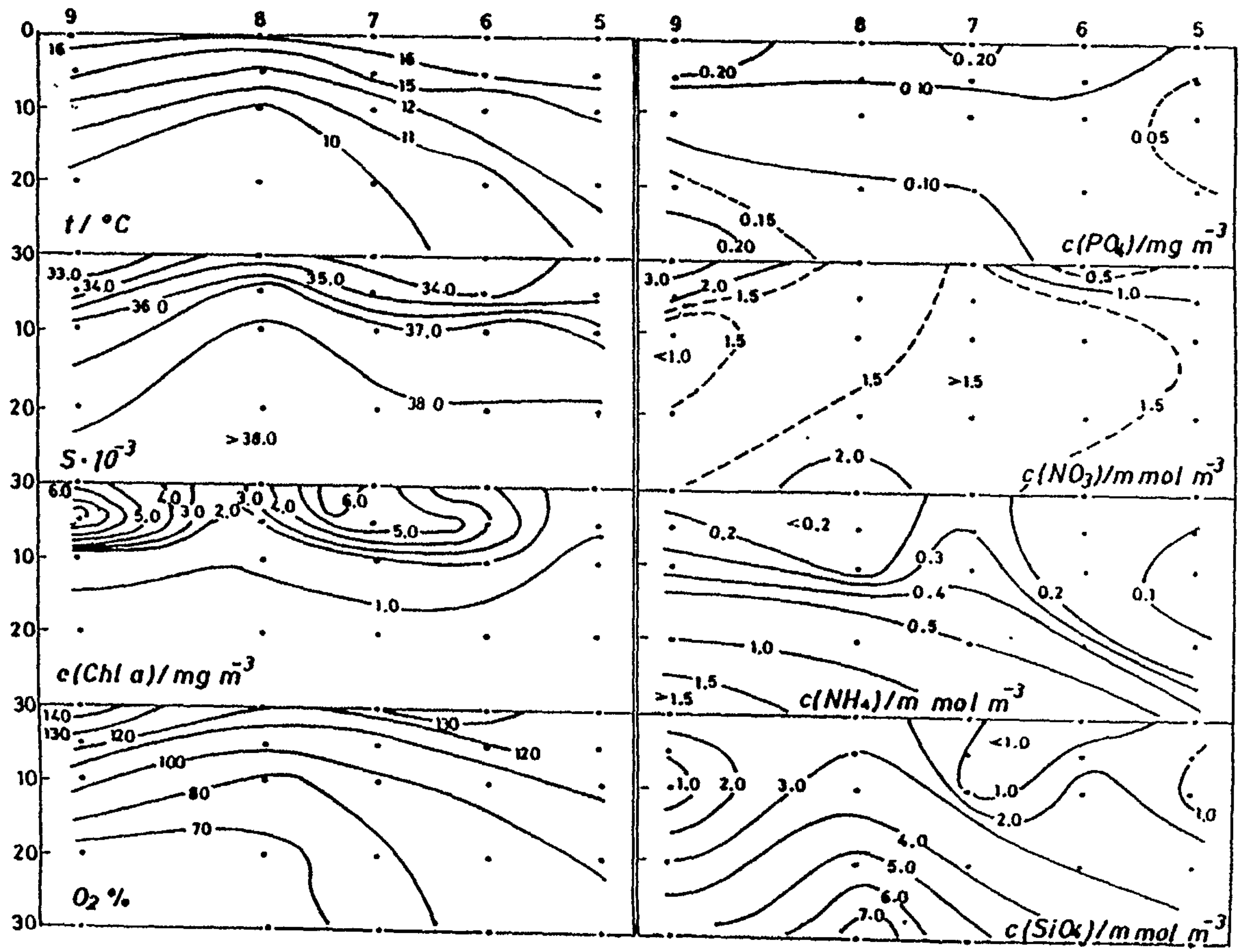

Fig. 5 Basic oceanographic parameters *on* 5 May 1983 at the SJ stations 5-9

In August, the salinity in the surface layer was relatively low, as were also the nutrients, especially phosphorus and nitrate (Fig. 6). This layer was well aerated but near the bottom, oxygen saturation dropped to less than 70%. The temporary high nutrient concentrations in this layer indicated conditions typical of the nutrient regeneration process: low oxygen saturation was coupled with nutrient concentrations. An unusually low phytoplankton biomass was observed at all stations with a nanoplankton contribution of more than 80%. Similar environmental conditions were also observed during the October cruise. However, due to remineralization processes, the oxygen saturation at all stations was less than 60%. In general the phytoplankton biomass was low, except for two surface patches noted at stations SJ-5 and SJ-7. These patches indicated typical phytoplankton bloom conditions: chlorophyll concentrations 2.8 to 4.6 mg chl. a m^{-3}, low salinity, high nutrients and oxygen saturation above 120%. These areas were also characterized by a high contribution of microplankton, and the nanoplankton share in total biomass ranged from 45-67%.

3.1.2 Benthic ecosystem

For technical reasons, the standard oceanographic variables were not measured at the water-sediment interface as well as in the sediment itself. It is believed that the epibenthos at least is exposed to environmental conditions noted in the bottom layer of the water body. Sediment granulometry is however treated as a constant parameter, which under normal conditions is not subject to seasonal alterations. Thus, with regard to sediment characteristics (Table I), at stations located along the transect between Rovinj and the Po River mouth, gradual transitions were noted in community compositions ranging from a typical community of coastal detritic bottom (SJ-5) to a community resembling that of coastal terrigenous ooze (station SJ-8) (Table II). In the westward direction, along the transect, the sediment was characterized by an increased fine particle sedimentation. Therefore, the gradual transition areas between typical benthic communities facies were rather extended and communities were often dominated by non-characteristic, i.e. accompanying species of wide distribution, tolerant of several environmental factors.

Benthos was seasonally surveyed at only three stations facing the Po River mouth, i.e. stations SJ-7, 8 and 9. With regard to abundances, the main groups at these stations were Polychaeta, Echinodermata and Sipuncula. At the species level, the polychaetes *Lumbrineris gracilis*, *Notomastus latericeus* and *Sternaspis scutata*, the molluscs *Turritella communis* and *Corbulla gibba*, the sipunculan *Aspidosiphon sp.* (in all probability *A. kovalevskii*) and the ophiuroids *Amphiura chiajei* and *A. filiformis* were most abundant (Vidakovic and Zavodnik, 1985). On average, during the period investigated, at stations SJ-7 and SJ-8 more than a thousand specimens of macrofauna per square metre were extracted, while at station SJ-9 the mean was 844 spm. m^{-2}.

Most of the macrofauna encountered seemed rather dispersed over the area studied and this was reflected generally in the low species abundance in the samples. Seasonal population dynamics could only be traced for a few dominant species (Table III). The constant dominance of *Notomastus latericeus* and *Amphiura filiformis* was evident at all stations. It should be noted that we did not find recently dead animals in our samples.

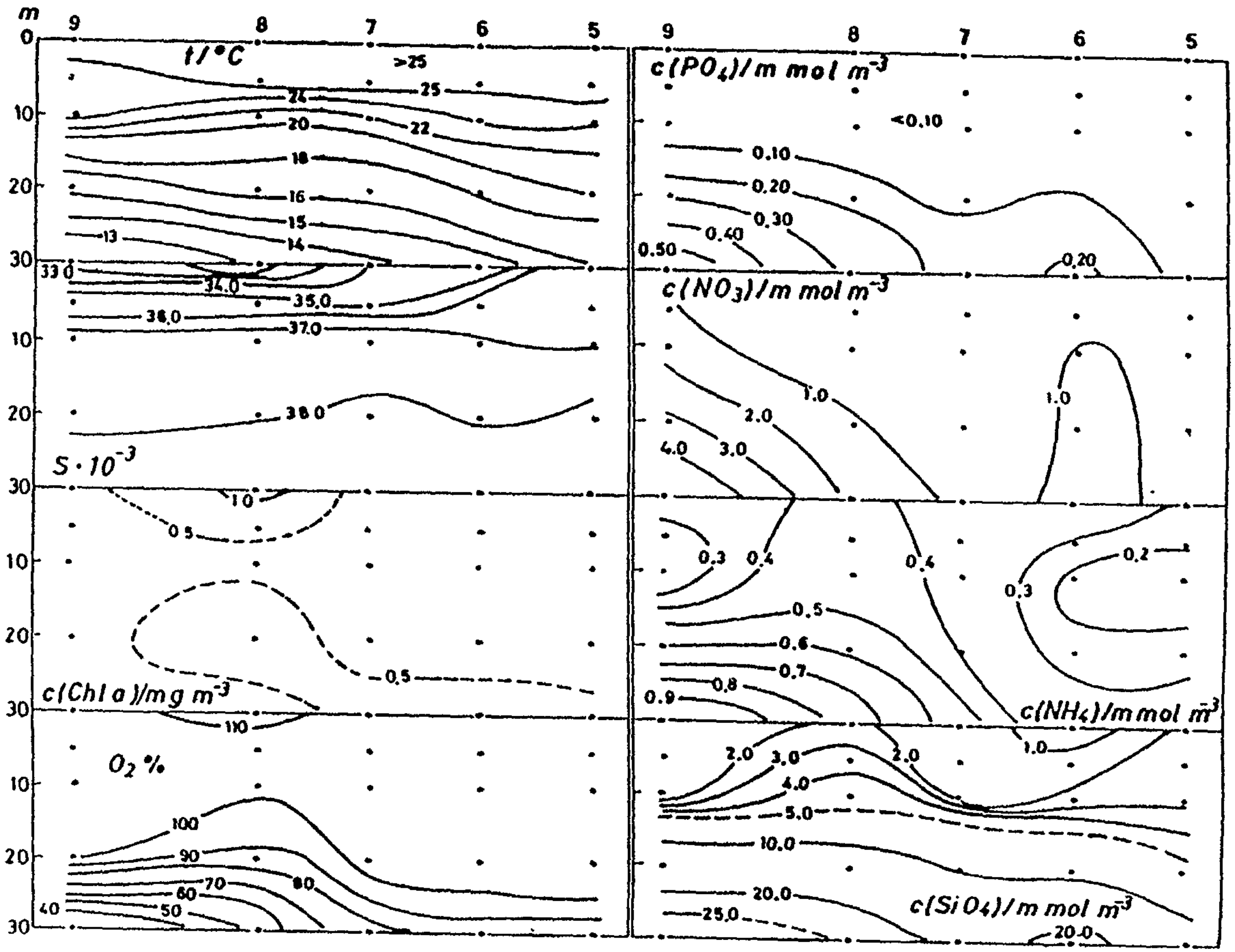

Fig. 6 Basic oceanographic parameters on 24 August 1983 at the SJ stations 5-9

Table II

Macrobenthic communities at investigated stations.

Station	Community
OFFSHORE (Bay of Venice)	
SJ-5	Community of coastal detritic bottom characterized by tubicolous polychaetes, Pitaria rude and some accompanying species (Corbula gibba, Amphiura filiformis, Trachythyone elongata).
SJ-6	Community transitional to coastal detritic bottom mixed with ooze, rich in Turritella communis, Aspıdosiphon kovalevskii and Amphiura filiformis.
SJ-7	Community of coastal detritic bottom mixed with ooze, dominated by Amphiura filiformis and Notomastus latericeus, accompanied by Turritella communis, Aspidosiphon sp. and Sternaspis scutata.
SJ-8	Community of coastal terrigenous ooze characterized by Turritella communis and Sternaspis scutata, accompanied by Corbula gibba and Aspidosiphon sp., and dominated by Notomastus latericeus and Amphiura filiformis.
SJ-9	Community of non-characteristic companion species Abra pellucida, Lumbrineris gracilis and Corbula gibba, relatively rich in Turritella communis and Sternaspis scutata and dominated by Notomastus latericeus, Aspidosiphon sp. and Amphiura filiformis.
COASTAL (Limski canal)	
LK-7	Community of non-characteristic companion species Aporrhais pespelecani, Dentalium dentalis, tubicolous polychaetes and Philocheras sp. and accompanied by Tellinella pulchella, Sternaspis scutata and Astropecten irregularis pentacanthus.
LK-9	Community of coastal terrigenous ooze characterized by Turritella communis, Sternaspis scutata and Labidoplax digitata, accompanied by Dentalium dentalis, tubicolous polycahetes, Processa nouveli, Upogebia tipica and Gourretia minor.
LK-44	Community of coastal terrigenous ooze characterized by Sternaspis scutata, Turritella communis and Labidoplax digitata, accompanied by Tellinella pulchella, Leiostraca subulata, Aspidosiphon kovalevskii, Apseudes latreillei and Amphiura filiformis.

Table III

Seasonal abundance (No. spm. m^{-2}) of Turritella communis, Notomastus latericeus and Amphiura filiformis at offshore stations.

Station	Survey					
	Nov. 82	Jan. 83	Mar. 83	May 83	Aug. 83	Oct. 83
Turritella communis						
SJ-7	4	122	58	36	0	10
SJ-8	22	37	16	10	2	10
SJ-9	6	10	4	5	-	3
Notomastus latericeus						
SJ-7	126	90	182	188	68	40
SJ-8	514	410	326	224	126	203
SJ-9	1224	163	126	33	-	20
Amphiura filiformis						
SJ-7	468	844	490	964	538	640
SJ-8	226	963	770	308	238	1137
SJ-9	26	440	80	140	-	43

The sediment meiofauna was characterized by Nematoda and Copepoda, while members of other groups were not numerous (Table IV). Nematodes were dominant. At stations SJ-7 and SJ-8 the most abundant species was the omnivore enoplid Rhabdodemania mediterranea followed by the chromadorid non-selective deposit feeders Dorylaimopsis mediterranea, Sabatiera ornata and S.punctata. These three species dominated also at station SJ-9, where however, Rhabdodemania no longer was in first place.

3.2 Coastal area

The research in the Limski canal was conducted over two years (October 1982 - October 1984). Three stations were sampled during nineteen cruises, using the MB "Burin": in October and November 1982, in January, March, May, June, July, August, September, October and November 1983, and in February, March, April, May, June, July, September and October 1984.

3.2.1 Pelagic ecosystem

The present hydrographic survey was limited to measurements of temperature, salinity and dissolved oxygen contents in sea water.

Table IV

Meiofauna and heterotrophic bacteria mean abundance at investigated stations.

Station	Meiofauna abundancies (No/10 cm^2) Total	Nematoda	Copepoda	Varia*	Heterotrophic bacteria (No./1 g sediment)
OFFSHORE (Bay of Venice)					
SJ-5	484	452	23	9	1.38×10^5
SJ-6	501	449	40	12	2.02×10^5
SJ-7	1327	1129	136	62	2.08×10^5
SJ-8	1206	996	149	61	2.42×10^5
SJ-9	612	467	96	49	4.03×10^5
COASTAL (Limski canal)					
LK-7	738	474	174	90	1.87×10^5
LK-9	313	197	86	30	1.90×10^5
LK-44	762	571	140	51	2.18×10^5

* Varia: Kinorhyncha, Gastrotricha, Archiannelida, Polychaeta juv., Ostracoda, Isopoda juv., Acari, Bivalvia juv.

In general, no anomalies in these variables were noted. In late autumn (October-November) conditions of a well mixed water column were established. These remained until the beginning of spring (March-April), when a thermocline began to establish itself and surface layers, at least at stations LK-7 and LK-9 became less salty. Low surface salinity was also noted in June at all three stations. Under normal conditions salinity in bottom layers did not decrease.

During the research period a seasonal range of the surface temperature was about 17 °C, to 2 °C lower near the bottom. Slight spatial variations were noted at each survey.

Dissolved oxygen contents showed larger seasonal and spatial variations. In general, the water body in the Limski canal is super-saturated, and the values in surface and bottom layers were usually between about 100 and 110%. The maximum saturation noted was over 121%. In a well mixed water column, in winter-spring time, only insignificant differences in saturation were noted between the surface and bottom layers. During the stratified period these differences were about 10-20%. Extreme differences (about 40%) were noted at station LK-44 in October 1983 and October 1984, and at station LK-9 in September 1984 (about 50%). The oxygen saturation in Limski canal was never less than 65% throughout the surveyed period.

3.2.2 Benthic ecosystem

In the Limski canal silty sediment macrofaunal assemblages were studied from October 1982 to October 1983. The most characteristic animal groups at all stations were Polychaeta, Mollusca and Crustacea. Although taxonomic data for all Polychaeta samples are not yet available, the values of abundance for macrofauna were obviously lower in comparison with the results from the offshore stations. For example, the only species at LK clayey silts for which the mean abundances calculated at some stations exceeded 5 specimens per square metre, were Lunatia alderi, Dentalium dentalis, Sternaspis scutata, Gourretia minor and Upogebia typica. No single species so far identified showed such an extreme dominance as noted at offshore stations. Interesting spatial variations were established, which are probably not due merely to the texture characteristics of the sediments. For example, in clayey silt at station LK-7 a mean of 23.2 specimens of Dentalium dentalis was encountered, while at station LK-9 the calculations resulted in 5 spm.m^2. In no species could any regular seasonal fluctuations be traced by grab sampling; this phenomenon can be evidence of small patchy distribution of animals in the types of sediment studied.

Sediment meiofauna was collected over a period of two years, i.e. from October 1982 - October 1984. The dominance of nematodes was less (63-75%) than was established for silty sediments at offshore stations (Table IV). At all stations, the following four co-dominant species were found: Hypodontolaimus sp., Dorylaimopsis mediterranea, Hopperia sp. and Longicyatholaimus complexus. It seems that nematode associations were stable over the seasons at station LK-44, but at stations LK-7 and LK-9 two species interchanged seasonally in number: at station LK-7 Dorylaimopsis mediterranea was replaced by Hopperia sp., and at station LK-9 the replacer was Hypodontolaimus sp. The most highly expressed dominance of a few species was found at station LK-9, where only three species contributed 67% to the total number of nematode species.

The organic matter content in sediment and the number of heterotrophic bacteria were of the same range at all three coastal stations (Table IV). No correlation was found between the density of nematodes, organic matter content and heterotrophic bacteria in sediments.

Fouling studies at station LK-9, located in the vicinity of a floating net-cage park in which sea fish are cultured, indicated that mariculture activities were not reflected in the composition of the fouling community characteristic for this area (Igic, 1981, 1982). On glass test plates in 1982-1983, in the water column between 0 and 10 metres depth, the green algae settled as usual near the surface. Greater depths were preferred by the bivalve Anomia ephippium, the tube-worm Pomatoceros triqueter, and the bryozoan Bugula simplex. With regard to surface areas, the bryozoan Schizoporella sp. was a dominant fouler at the investigated site.

4. DISCUSSION

The present survey is a further contribution to the understanding of ecosystem balance mechanisms in the shallow northern Adriatic. In spite of important quantities of nutrients and various deposit materials which are constantly discharged by the Po River (Stirn et al., 1972), the decisive influence of remineralisation processes in some hydrographic variables was evident. Oxygen saturation seems to be one of the most important factors controlling the benthic fauna in the studied area: deficiencies in oxygen in the northern Adriatic have repeatedly led to mortality of non-tolerant species (Zavodnik, 1977; Stachowitsch, 1983). Low dissolved oxygen content can also be a secondary effect of phytoplankton and microphytobenthos blooms, which were noted in the northern Adriatic several times during the research period (Smodlaka, 1985).

On the other hand, phytoplankton blooms contributed essentially to seston contents and subsequent sedimentation of organic materials on the bottom. The dominance of suspension or detritus film feeders, such as Amphiura filiformis and several chromadorid nematodes, suggested a high organic seston input from the Po River discharges and periodical unicellular algae blooms. It seems that the temporary population explosion of Notomastus latericeus had little impact on benthic communities at offshore stations, a phenomenon which brings to mind an appearance of Spiophanes bombyx in an area of the New York Bight (Swartz, 1976).

With regard to previous data (Vatova, 1949) at offshore stations the stock of dominant species was subject to important alterations. Besides a population explosion of certain species, the diminution of Turritella communis was most characteristic. The reasons for this phenomenon which has also been noted in other parts of the Adriatic Sea have not yet been identified. Perhaps recent extinctions of this gastropod were a consequence of inorganic (oxygen deficiency) or organic (disease) origin. The mortality of Turritella was probably responsible for the increase of a shell-living sipunculan Aspidosiphon kovalevskii (Vidakovic and Zavodnik, 1985).

The variability of edaphic environmental conditions was reflected in several ways, above all in the patchy distribution of several populations and in the richness of tolerant species of wide ecological distribution. Because of the patchy distribution, of even the most abundant species, the seasonal dynamics were hard to interpret, in spite of the methodology covering surface/volume standards.

The diminution in benthic species numbers and in sediment meiofauna densities at stations SJ-9 and LK-9, when compared to neighbouring areas was most significant. The first station was most often influenced by the plume of the Po River discharges, which are diluted and well mixed in the sea water at the a distance of 13 km from the river mouth. Station LK-9 is located in the close neighbourhood of fish rearing floating cages: the phenomena noted in the structure and the dynamics of benthic communities suggest slight disturbances in ecosystem stability; for the time being they are perhaps limited to the bottom layers only. In general, the Limski canal cannot be considered as a polluted coastal area.

5. CONCLUSIONS

In the period under study (1982-1983) phytoplankton blooms were detected in October-November 1982, in March and May 1983, and patchily also in October 1983. The most intensive phytoplankton blooms occurred in the western part of the shallow northern Adriatic and usually occupied the upper 5-10 m of the water body. Phytoplankton blooms were closely related to specific environmental conditions, especially with regard to salinity and nutrient content which reflected the intensity of the remineralization processes in the area. Oxygen saturation in the bottom layer was often low and, exceptionally, even dropped below 25%. Oxygen saturation in the bottom layer was inversely related to nutrient content and was not affected by oxygen produced in phytoplankton bloom layers.

In the plytoplankton community, the nanoplankton fraction usually prevailed by more than 75%, both in biomass and production. In the microplankton fraction, diatoms nearly always dominated by more than 90%, but occasionally and patchily the complete dominance of dinoflagellates appeared as well.

In the macrobenthic communities, in the area near the Po River mouth, non-characteristic accompanying species tolerant of various edaphic factors were occasionally totally dominant. In this area sediments were very rich in heterotrophic bacteria, but locally, densities of macrofauna and meiofauna were lower. In the land-locked coastal area (Limski canal) the dominance of the most abundant species was less pronounced than those of the offshore stations.

The methods employed were not adequate to trace efficiently seasonal dynamics in macrobenthic assemblages because of a characteristic, small and patchy distribution of populations. No dominant pollution indicator species was identified.

In the meiofauna of the sediments of the surveyed stations, nematodes dominated usually by more than 75%. At some stations seasonal successions in nematode communities were noted.

In the Limski canal no correlation was found between the density of sediment nematodes, organic matter contents and heterotrophic bacteria in sediments. It seems that mariculture activities did not influence the composition of the fouling community established on experimental glass plates.

Macro- and meiofauna densities as well as community structures indicate that both areas in question (the offshore area receiving diluted Po river discharges and the mariculture area in Limski canal) are influenced by inputs but at present they cannot be considered polluted.

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STRUCTURE OF BENTHIC COMMUNITIES OF BRACKISH-WATER MICROHABITATS: SPATIAL AND TEMPORAL VARIATIONS

by

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ABSTRACT

A survey of brackish-water microhabitats of three isles of the Tuscan Archipelago (Elba, Capraia, Giglio) was carried out. Data are compared with three mainland biotopes and with one in Corsica. The population structure of Polychaetes and Molluscs in these biotopes is described. Results reveal a marked heterogeneity among brackish-water microhabitats and their animal communities.

It is possible to distinguish several groups of species, which occur constantly depending on the values of salinity and the type of substratum:

- wide spectrum species: Streblospio shrubsolii, Nereis diversicolor;
- brackish-water species: Perinereis cultrifera, Capitella capitata, Cirriformia tentaculata, Abra ovata, Cerastoderma edule, Parvicardium exiguum and Ventrosia ventrosa;
- transgressive marine species: Syllis mediterranea, Cirrophorus furcatus, Heteromastus filiformis, Exogone gemmifera and Pettiboneia urciensis;
- characteristic species: different in each station.

The presence of these species is connected with stochastic events of colonisation by brackish-water species and local adaptations in the population of true marine species. As a consequence every insular microhabitat has a particular fauna, which reflects both the difficulty of colonization and the structure of nearby benthic communities. Mainland microhabitats have a much more varied fauna (mostly of brackish-water species) depending on their closeness to major brackish-water bodies.

1. INTRODUCTION

The analysis of benthic communities is widely used as a valuable method for the detection of environmental modifications caused by natural and man-made perturbations (Crema and Bonvicini Pagliai, 1981). This kind of analysis, in fact, can reveal long-term effects of pollutants, while a physico-chemical approach can normally give short-term information.

Our research has been mainly devoted to the study of the influence of parameters such as type of substratum and salinity fluctuation on the structure of benthic communities. In order to test this, we focused our attention on brackish-water microhabitats, on account of their distinctive characteristics (small size, low number of species, quick and easy monitoring).

Furthermore, these biotopes are well-suited to colonization studies particularly if they are located in off-shore islands or are at least far away from larger brackish-water areas which can constitute a constant reservoir of potential dwellers. We therefore undertook a monitoring of the microhabitats of the Tuscan Archipelago. The preliminary results (limited to Elba and Capraia) have recently been published (Curini-Galletti et al., 1985). A first account concerning the seasonal fluctuations of Polychaetes in the microhabitats has also been published (Lardicci and Castelli, 1987).

The present report concerns data gathered on three islands of the Tuscan Archipelago and on Corsica, along with data from the examination of comparable sites on the mainland, in order to obtain a clearer picture of the effects of the "geographic isolation" factor.

2. MATERIALS AND METHODS

Extensive samplings in three islands of the Tuscan Archipelago (Capraia, Elba, Giglio) eventually resulted in the detection of several brackish-water microhabitats; in addition, one station in Corsica (in the bay of Calvi) and three in the Italian mainland were chosen (Fig. 1). In some of the stations a more detailed study - with repeated samplings in different seasons - was undertaken, in order to obtain information concerning seasonal modifications of benthic communities.

For each sample 10 litres of sediment were taken and sieved through a 0.5 mm mesh. The material obtained was fixed in 4% formalin and sorted in the laboratory. The salinity was measured with a Beckman Salinometer. In the statistical analysis of data we adopted two methods currently used for the detection of the affinity degree among different stations: the Sorensen similarity index (S.i) and the Kulczynski similarity index (K.i.). Numerical data were arranged in two dendrograms.

The structural analysis concerning seasonal fluctuations of Polychaetes was performed using multivariate ordination techniques (Fresi and Gambi, 1982; Zurlini, 1983). Data were elaborated by factorial analysis of correspondence (Benzecrì, 1982) on a set of species ordinated in three kinds of matrices:

- "matrix des états", describing the seasonal conditions of the samples on the basis of simultaneous variation of the species.
- "matrix des histoires", describing the "history" of each species in the two samples.
- "matrix des états (II)", in which the vector of the changes in the abundance of species is split into several vectors, to emphasize the relationship among the abundance changes of such species.

Significance of the axes was tested by the method of Lebart (1975).

3. DESCRIPTION OF THE STATIONS

3.1 Elba Island

- Salina (Fig. 2, site 1)

The area includes a small inlet separated from the open sea by a small breakwater and the mouth of a stream, completely dry in summer, which flows into the inlet. Two sites were chosen for sampling: S1 in the mouth of the stream, about 200 m from the sea. S2 within the inlet, 50 m from the sea.

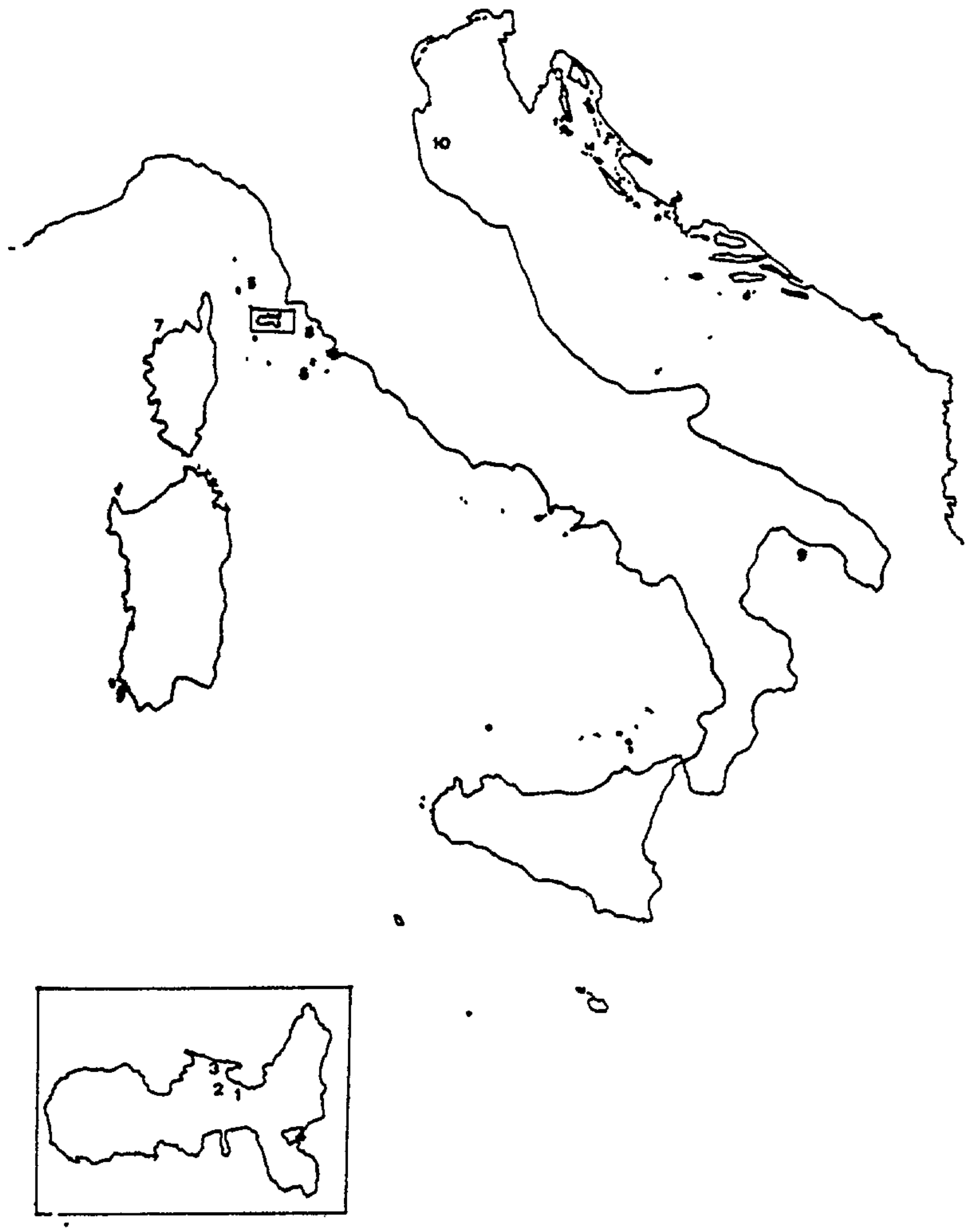

Fig. 1 Sampling sites

1. Cantiere Navale (Cn)
2. Capitano (Cp)
3. Capraia (Ca)
4. Figarella (Fg)
5. Giglio (Gi)
6. Madonnina (Ma)
7. Mola (Mo)
8. Punta Marina (Pm)
9. Salina (S)
10. San Leopoldo (Se)

Samplings were taken in April 1983 (Ap83), October 1983 (Oc83), October 1984 (Oc84), April 1985 (Ap85), May 1985 (Ma85), July 1985 (Ju85), September 1985 (Se85) and November 1985 (No85).

- Madonnina (Fig. 2, site 2)

The area sampled lies at the mouth of a stream with concrete embankments which is dry in summer. There were two sampling sites:
Ma1 100 m from the outlet.
Ma2 10 m from the outlet.
Samples were taken in October 1983 (Oc83) and October 1984 (Oc84).

- Cantiere Navale (Fig. 2, site 3)

This is a small artificial basin with concrete banks, collecting water from a system of drainage channels also connecting the streams flowing to the above stations. Samples (Cn) were taken in October 1984 (Oc84).

- La Mola (Fig. 2, site 4)

The area lies in the outer region of a system of artificial channels. One of the channels was sampled:
Mo1 in the upper part, 80 m from the outlet.
Mo2 in the lower part, about 20 m from the outlet.
Samples were taken in October 1983 (Oc83), October 1984 (Oc84).

3.2 <u>Capraia island</u> (Fig. 3, site 5)

Two stations were chosen inside a complex of drainage channels:
Ca1 in the main channel, close to the outlet.
Ca2 in a side-channel.
Samples were taken in May 1984 (Ma84) and November 1985 (No85).

3.3 <u>Giglio island</u> (Fig. 3, site 6)

This area is an artificial outlet of a small stream with concrete banks. Samples (Gi) were taken about 10 m from the outlet itself in December 1985 (De85).

3.4 <u>Corsica island</u> (Fig. 3, site 7)

The station (Fg) was situated in a very small side-channel flowing into the river Figarella, close to its mouth in the Bay of Calvi.
Samples were taken in April 1985 (Ap85).

3.5 <u>Italian Mainland</u>

- San Leopoldo (Toscana) (Fig. 4, site 8)

The station was situated at a silted mouth of a channel draining the swamps of Castiglione della Pescaia. Samples (SL) were collected at a depth of about 1 m, in December 1985 (De85).

- Capitano (Puglia) (Fig. 4, site 9)

The station was situated in a karstic dolina close to the sea with subterranean infiltrations of sea water. Samples (Cp) were taken with the aid of a grab at a depth of about 5 m, in November 1984 (No84).

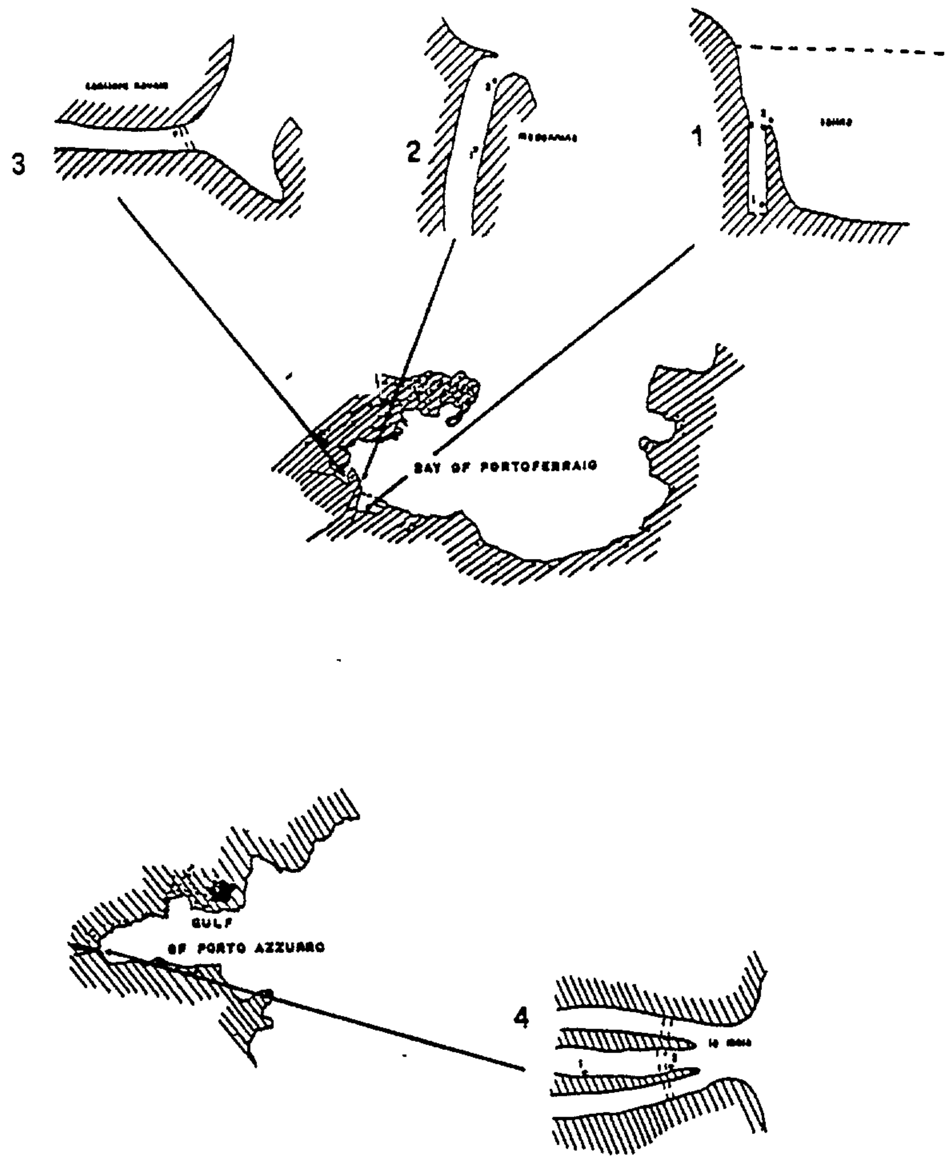

Fig. 2 Map of sites 1, 2, 3 and 4 on Elba

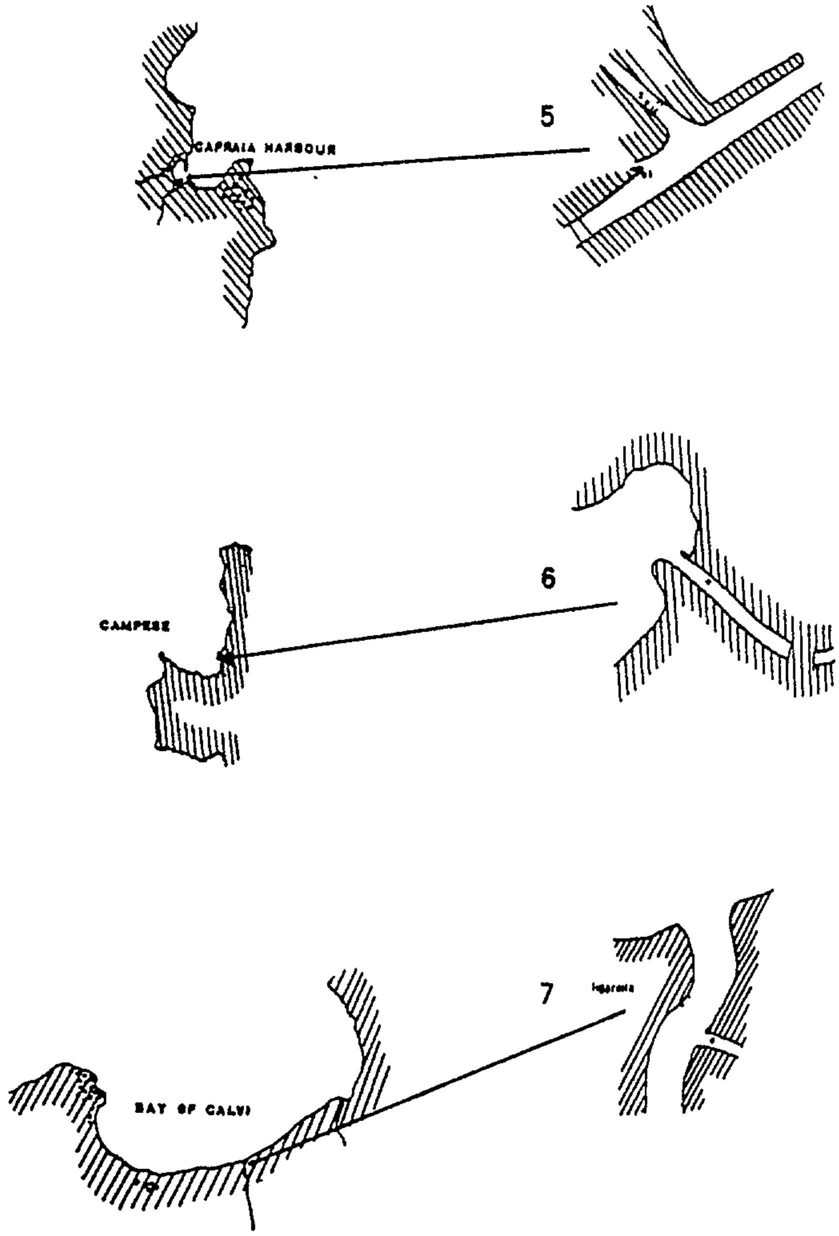

Fig. 3 Map of sites 5, 6 and 7 on the islands of Capraia, Giglio and Corsica

- Punta Marina (Emilia-Romagna) (Fig. 4, site 10)

This is a drainage channel flowing into the Adriatic sea.
Two stations were chosen:
PM1 - 150 m from the outlet.
PM2 - 50 m from the outlet.
Samples were taken in June 1985 (Jn85), September 1985 (Se85), October 1985 (Oc85) and December 1985 (De85). During September the mouth was silted.

4. RESULTS

4.1 Abiotic data

A brief description of the type of substratum, with the values of salinity recorded during samplings, is reported in Table I.

4.2 Biotic data

A list of the Polychaetes and Molluscs found in the samples is given in Table II(a) and (b). It is worth noting that these two groups are among the most representative benthic organisms. The analysis of the distribution of these two taxa is considered as providing good information about the characteristics of the whole environment (Fresi and Gambi, 1982).

4.3 Statistical analysis

The results of the Sorensen (S.i.) and Kulczynski (K.i.) similarity indices are given in Tables III and IV. The relevant dendrograms are presented in Figs. 5 and 6. In the dendrogram based upon the S.i., three groups of stations are clearly distinguished:

a. Punta Marina, Madonnina 1, Capitano, Figarella, S. Leopoldo. These stations all have very low values of salinity at least for part of the year (Punta Marina). Their substrate is predominantly muddy.

b. Mola, Madonnina 2, Salina, Capraia and, with a lower level of affinity, Cantiere Navale. In all these stations the salinity hardly falls below 25°/oo. Only the upper part of Salina (Station 1) has much lower values in winter, but during the dry season, with values around 30°/oo, it harbours a fauna comparable to the other stations. Furthermore, in most of the stations the substratum has a significant fraction of coarse sand and gravel in addition to the mud.

c. Giglio, with one station only, harbours a very poor fauna and has a substratum entirely lacking in mud.

The k.i. was evaluated on samples collected from October 1984 onward, from which quantitative data are available.

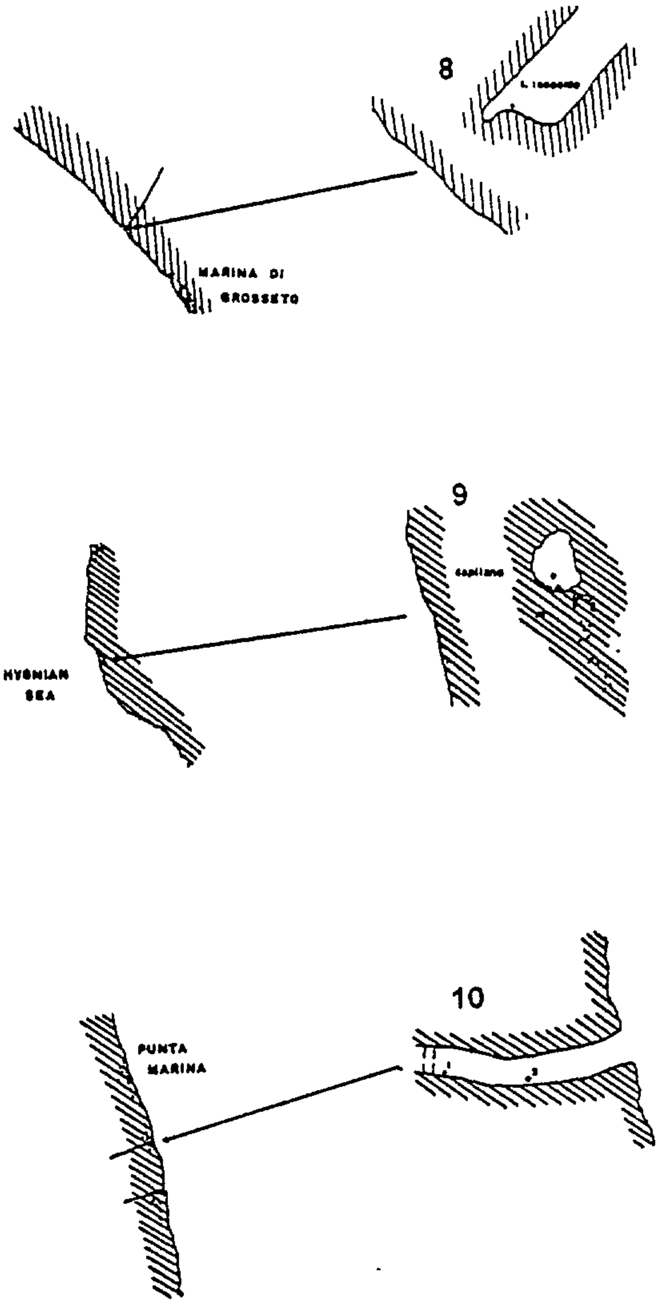

Fig. 4 Map of mainland sites 8, 9 and 10

Table I

Abiotic data.

	SUBSTRATUM	SALINITY
Salina		
St.1	mud with vegetal debris	Ap83: 0.5°/oo; Oc83, Oc84: 31°/oo Ap85: 0.5°/oo; Ma85: 30.1°/oo Ju85, Se85: 38°/oo; No85: 27.4°/oo
St.2	muddy coarse sand	Ap83: 30°/oo; Oc83, Oc84: 31°/oo Ap85: 14.2°/oo; Ma85: 35.2°/oo Ju85, Se85: 38°/oo; No85: 35.5°/oo
Madonnina		
St.1	mud with vegetal debris	Oc83: 20.2°/oo
St.2	muddy coarse sand	Oc83: 35.7°/oo; Oc84: 38°/oo
Mola		
St.1	mud with vegetal debris	Oc83: 35.2°/oo; Oc84: 34.6°/oo
St.2	mud with pebbles and vegetal debris	Oc83: 38°/oo; Oc84: 38°/oo
Cantiere Navale		
	muddy coarse sand	Oc84: 29.7°/oo
Capraia		
St.1	slightly muddy coarse sand	Ma84: 32.7°/oo; No85: 33°/oo
St.2	" " "	Ma84: 28.2°/oo; No85: 30.5°/oo
Giglio		
	coarse sand	De85: 33.8°/oo
Corsica		
	mud with vegetal debris	Ap85: 0.5°/oo
San Leopoldo		
	muddy fine sand with vegetal debris	De85: 7.1°/oo
Capitano		
	mud with vegetal debris	No85: 4°/oo
Punta Marina		
St.1	clay	Jn85: 35.8°/oo; Se85: 40.2°/oo Oc85: 10.3°/oo; De85: 2°/oo
St.2	muddy fine sand with vegetal debris	Jn85: 31.6°/oo; Se85: 45.3°/oo Oc85: 18°/oo; De85: 8.3°/oo

Table II(a)

List of species: (a) quantitative data; (b) qualitative data
p = Polychaetes, m = Molluscs.

Specie	Sloc84	S2oc84	Slap85	S2ap85	Slma85	S2ma85	Slju85	S2ju85	Slse85	S2se85	Ma2oc84	Cnoc84	Moloc84
p Aricidea catherinae	0	0	0	0	0	0	0	0	0	0	0	0	0
p Brania oculata	0	53	0	0	0	3	0	1	0	1	0	0	0
p Brania pusilla	0	1	0	0	0	0	0	0	0	0	0	0	0
p Capitella capitata	3	24	0	36	2	96	0	818	9	180	51	12	16
p Cirriformia tentaculata	2	198	0	6	0	31	0	47	0	253	0	0	2
p Cirrophorus furcatus	0	20	0	0	0	1	0	11	0	7	0	78	0
p Desdemona ornata	0	0	0	0	0	0	0	0	0	1	7	0	0
p Eusyllis assimilis	0	53	0	0	0	0	0	15	0	36	0	0	0
p Exogone gemmifera	0	2	0	0	0	0	0	0	1	0	0	0	0
p Fabricia sabella	0	0	0	0	0	0	0	0	0	0	0	0	0
p Ficopomatus enigmaticus	0	0	0	0	0	0	0	0	0	0	0	0	0
p Heteromastus filiformis	0	0	0	0	0	0	0	3	0	0	0	12	0
p Hydroides elegans	0	0	0	0	0	0	0	0	0	0	0	3	0
p Malacoceros fuliginosus	0	27	0	18	0	49	0	60	0	40	0	0	0
p Marphysa sanguina	0	1	0	0	0	0	0	0	0	0	0	0	0
p Nereis caudata	0	0	0	0	0	0	0	0	0	0	0	0	0
p Nereis diversicolor	11	0	38	10	167	7	41	3	15	0	0	0	0
p Nereis succinea	0	0	0	0	0	0	0	0	0	0	0	0	0
p Parapionosyllis elegans	0	0	0	0	0	0	0	0	0	0	0	0	0
p Parapionosyllis labronica	0	0	0	0	0	0	0	0	0	0	0	0	0
p Perinereis cultrifera	0	32	0	92	0	28	0	69	0	46	0	0	2
p Perinereis oliveirae	0	4	0	0	0	0	0	6	0	3	0	0	0
p Pettiboneia urciensis	0	0	0	0	0	0	0	1	0	0	0	0	6
p Phylo foetida	0	0	0	0	0	0	0	0	0	0	0	0	0
p Pionosyllis pulligera	0	0	0	0	0	0	0	0	0	0	0	0	0
p Polycirrus medusa	0	0	0	0	0	0	0	0	0	0	0	0	0
p Polydora ciliata	0	0	0	0	0	0	0	0	0	0	0	0	0
p Pseudobrania clavata	0	0	0	0	0	0	0	0	0	0	0	0	0
p Sphaerosyllis hystrix	0	2	0	0	0	0	0	0	0	0	0	0	0
p Spio decoratus	0	0	0	12	0	12	0	36	0	16	30	3	0
p Spiophanes bombyx	0	1	0	0	0	0	0	3	0	0	0	0	0
p Streblospio shrubsolii	123	156	584	38	708	354	699	420	1050	316	0	0	1296
p Syllides edentata	0	0	0	0	0	0	0	0	0	0	0	0	28
p Syllides edentula	0	0	0	0	0	0	0	0	0	0	0	0	0
p Syllis hyalina	0	0	0	0	0	0	0	0	0	0	2	0	0
p Syllis mediterranea	0	0	0	0	0	0	0	0	0	0	0	0	0
p Syllis prolifera	0	0	0	0	0	0	0	0	0	0	0	0	0
m Abra ovata	4	0	0	12	3	128	0	0	0	0	3	0	12
m Bornia sebetia	0	0	0	0	0	2	0	0	0	0	0	0	0
m Cerastoderma edule	0	0	0	0	1	0	0	5	0	0	2	0	0
m Hydrobia acuta	0	0	0	0	0	0	0	0	0	0	0	0	0
m Lentidium mediterraneum	0	0	0	0	0	0	0	0	0	0	0	0	0
m Loripes lacteus	0	0	0	0	0	0	0	0	0	0	0	0	8
m Melaraphe neritoides	0	0	0	0	0	0	0	0	0	0	0	0	0
m Monodonta articulata	0	0	0	1	0	0	0	0	0	0	0	0	0
m Parvicardium exiguum	0	1	0	0	0	3	0	0	0	1	0	0	4
m Potamopyrgus jenkinsi	0	0	0	0	0	0	0	0	0	0	0	0	0
m Scrobicularia plana	0	0	0	0	0	0	0	0	0	0	0	0	0
m Tapes aurea	0	0	0	3	0	0	0	0	0	0	0	0	2
m Tapes decussata	0	1	0	9	0	6	0	6	0	8	9	0	0
m Theodoxus fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0
m Turbonilla lactea	0	0	0	0	0	0	0	0	0	0	0	6	0
m Ventrosia ventrosa	0	0	0	0	0	0	0	0	1	0	2	0	30

Table II(a) (continued)

List of species: (a) quantitative data; (b) qualitative data
p = Polychaetes, m = Molluscs.

	Specie	Mo2oc84	Ca1ma84	Ca2ma84	Ca1no85	Ca2no85	Gide85	Cyno84	Fgap85	Pm1jn85	Pm2jn85	Pm1se85	Pm2se85	Slde85
p	Aricidea catherinae	1	0	0	0	0	0	0	0	0	0	0	0	0
p	Brania oculata	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Brania pusilla	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Capitella capitata	34	2	0	141	150	0	0	0	0	14	9	215	0
p	Cirriformia tentaculata	2	0	0	0	0	0	0	0	0	0	0	0	0
p	Cirrophorus furcatus	20	0	0	0	0	0	0	0	0	0	0	0	0
p	Desdemona ornata	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Eusyllis assimilis	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Exogone gemmifera	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Fabricia sabella	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Ficopomatus enigmaticus	0	0	0	0	0	0	0	0	0	0	0	0	36
p	Heteromastus filiformis	0	6	12	0	0	0	0	0	0	0	0	0	0
p	Hydroides elegans	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Malacoceros fuliginosus	0	0	0	66	12	0	0	0	0	0	0	0	0
p	Marphysa sanguina	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Nereis caudata	14	24	0	0	0	0	0	0	0	0	0	0	0
p	Nereis diversicolor	0	0	54	0	0	0	10	11	4	35	0	3	351
p	Nereis succinea	0	0	0	0	0	0	0	0	160	13	1	2	0
p	Parapionosyllis elegans	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Parapionosyllis labronica	0	0	0	0	6	0	0	0	0	0	0	0	0
p	Perinereis cultrifera	0	0	0	12	51	2	0	0	0	0	0	0	0
p	Perinereis oliveirae	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Pettiboneia urciensis	8	0	0	0	0	0	0	0	0	0	0	0	0
p	Phylo foetida	6	0	0	0	0	0	0	0	0	0	0	0	0
p	Pionosyllis pulligera	0	3	0	0	0	0	0	0	0	0	0	0	0
p	Polycirrus medusa	0	0	0	0	4	0	0	0	0	0	0	0	0
p	Polydora ciliata	0	0	0	0	0	0	0	0	0	184	111	468	4
p	Pseudobrania clavata	0	0	0	0	1	0	0	0	0	0	0	0	0
p	Sphaerosyllis hystrix	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Spio decoratus	0	0	0	0	0	0	0	0	10	27	0	0	0
p	Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Streblospio shrubsolii	118	0	0	0	0	0	28	0	4825	1168	4	0	0
p	Syllides edentata	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Syllides edentula	0	0	0	0	0	0	0	0	0	0	0	0	18
p	Syllis hyalina	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Syllis mediterranea	0	0	0	0	51	4	0	0	0	0	0	0	0
p	Syllis prolifera	0	6	0	0	0	0	0	0	0	0	0	0	0
m	Abra ovata	16	0	0	0	0	0	0	0	0	0	0	0	9
m	Bornia sebetia	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Cerastoderma edule	0	0	0	0	0	0	0	0	0	18	14	143	9
m	Hydrobia acuta	0	0	0	0	0	0	0	0	2	8	11	42	0
m	Lentidium mediterraneum	0	0	0	0	0	0	0	0	0	0	18	48	0
m	Loripes lacteus	26	3	9	3	0	0	0	0	0	0	0	0	0
m	Melaraphe neritoides	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Monodonta articulata	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Parvicardium exiguum	2	6	3	3	0	0	0	0	0	0	0	0	0
m	Potamopyrgus jenkinsi	0	0	0	0	0	0	0	28	0	0	0	0	0
m	Scrobicularia plana	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Tapes aurea	2	3	0	0	0	0	0	0	1	0	0	0	0
m	Tapes decussata	2	0	9	0	0	0	0	0	0	0	0	0	0
m	Theodoxus fluviatilis	0	0	0	0	0	0	35	0	0	0	0	0	0
m	Turbonilla lactea	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Ventrosia ventrosa	4	0	0	0	6	0	48	0	0	0	0	0	86

Table II(b)

List of species: (a) quantitative data; (b) qualitative data
p = Polychaetes, m = Molluscs.

	Specie	sl	s2	ma1	ma2	cn	mo1	mo2	ca1	ca2	gi	fg	sl	cp	pm1	pm2
p	Aricidea catherinae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
p	Brania oculata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Brania pusilla	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Capitella capitata	1	1	0	1	1	1	1	1	1	0	0	0	0	1	1
p	Cirriformia tentaculata	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0
p	Cirrophorus furcatus	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
p	Desdemona ornata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Eusyllis assimilis	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
p	Exogone gemmifera	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Fabricia sabella	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Ficopomatus enigmaticus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
p	Heteromastus filiformis	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0
p	Hydroides elegans	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
p	Malacoceros fuliginosus	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
p	Marphysa sanguina	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Nereis caudata	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
p	Nereis diversicolor	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1
p	Nereis succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
p	Parapionosyllis elegans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Parapionosyllis labronica	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
p	Perinereis cultrifera	0	1	0	1	0	1	0	1	1	1	0	0	0	0	0
p	Perinereis oliveirae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Pettiboneia urciensis	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
p	Phylo foetida	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
p	Pionosyllis pulligera	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
p	Polycirrus medusa	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
p	Polydora ciliata	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
p	Pseudobrania clavata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
p	Sphaerosyllis hystrix	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
p	Spio decoratus	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1
p	Spiophanes bombyx	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p	Streblospio shrubsolii	1	1	1	1	0	1	1	0	0	0	0	0	0	1	1
p	Syllides edentata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
p	Syllides edentula	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
p	Syllis hyalina	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
p	Syllis mediterranea	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
p	Syllis prolifera	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
m	Abra ovata	1	1	0	1	0	1	1	0	0	0	0	1	0	0	0
m	Bornia sebetia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Cerastoderma edule	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1
m	Hydrobia acuta	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
m	Lentidium mediterraneum	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
m	Loripes lacteus	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
m	Melaraphe neritoides	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Monodonta articulata	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
m	Parvicardium exiguum	0	1	0	1	0	1	1	1	1	0	0	0	0	0	0
m	Potamopyrgus jenkinsi	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
m	Scrobicularia plana	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
m	Tapes aurea	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0
m	Tapes decussata	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0
m	Theodoxus fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
m	Turbonilla lactea	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
m	Ventrosia ventrosa	1	0	0	1	0	1	1	0	1	0	0	1	1	0	1

Table III

Results of S.i. (% of similarity).

	S1	S2	Ma1	Ma2	Cn	Mo1	Mo2	Ca1	Ca2	Gi	Fg	SL	Cp	Pm1	Pm2
S1		41	36	50	13	60	58	21	36	0	18	46	38	33	32
S2			12	44	22	39	49	35	33	6	6	12	12	26	25
Ma1				15	12	15	12	0	13	0	0	67	22	36	33
Ma2					12	55	46	29	42	15	0	27	33	40	38
Cn						19	15	25	21	0	0	0	0	13	12
Mo1							69	48	42	15	0	27	22	20	19
Mo2								40	36	0	0	21	18	17	16
Ca1									52	0	0	11	0	10	27
Ca2										13	0	24	20	18	17
Gi											0	0	0	0	0
Fg												33	22	18	17
SL													36	31	29
Cp														38	35
Pm1															95

Two main groups of stations can be distinguished:

a. Mo2Oc84; S1Oc84; S2Ma85, Se85, Oc84, Ju85; S1Ma85, Ju85, Ap85, Se85; Mo1Oc84; Pm2Jn85, with similarity values above 20%. All these stations are characterized by a very high abundance of the species S.shrubsolii (100 $<$ n $<$ 1500). Within these, a further grouping is possible:

(i) S1Ma85, Ju85, Ap85, Se85, Mo1Oc84; Pm2Jn85, with a very high degree of similarity ($>$ 65%) and low values of salinity

(ii) Mo2Oc84; S1Oc84; S2Ma85, Se85, Oc84, Ju85, with higher values of salinity

Table IV

Results of K.i. (% of similarity).

	Sloc84	S2oc84	Slap85	S2ap85	Slma85	S2ma85	Slju85	S2ju85	Slse85	S2se85	Ma2oc84	Cnoc84	Moloc84
Sloc84		36	35	30	27	32	30	16	22	24	5	2	17
S2oc84			26	29	22	42	24	31	20	65	7	10	18
Slap85				11	83	54	91	40	71	41	0	0	58
S2ap85					9	34	10	22	9	29	35	7	9
Slma85						46	91	36	74	36	1	0	62
S2ma85							49	52	41	65	17	3	37
Slju85								38	79	38	0	0	65
S2ju85									33	56	11	3	30
Slse85										33	2	2	85
S2se85											15	4	29
Ma2oc84												11	3
Cnoc84													2

	Mo2oc84	Calma84	Ca2ma84	Calno85	Ca2no85	Cpno84	Fgap85	Pmljn85	Pm2jn85	Pmlse85	Pm2se85	SLde85	Gide85
Sloc84	63	2	10	2	1	29	12	5	17	5	1	5	0
S2oc84	40	1	1	16	16	8	0	6	17	3	3	0	1
Slap85	27	0	11	0	0	10	3	21	59	1	0	7	0
S2ap85	36	3	12	29	38	21	7	2	9	6	7	5	2
Slma85	27	0	11	0	0	8	2	24	64	1	1	25	0
S2ma85	36	1	4	34	27	8	8	13	35	3	12	8	1
Slju85	24	0	10	0	0	9	3	24	67	1	0	7	0
S2ju85	19	1	2	25	24	4	0	13	32	2	18	1	0
Slse85	19	0	3	1	1	7	2	35	84	2	1	2	0
S2se85	28	1	2	34	35	5	0	11	29	2	20	0	0
Ma2oc84	22	3	9	31	27	2	0	0	5	8	10	2	0
Cnoc84	17	10	12	7	6	0	0	0	2	6	2	0	0

Table IV continued

	Mo2oc84	Calma84	Ca2ma84	Calno85	Ca2no85	Cpno84	Fgap85	Pmljn85	Pm2jn85	Pmlse85	Pm2se85	SLde85	Gide85
Moloc84	20	2	1	3	3	8	0	40	82	2	1	4	0
Mo2oc84		15	7	16	14	17	0	4	15	6	6	3	0
Calma84			17	6	1	0	0	0	0	2	0	0	0
Ca2ma84				4	0	10	17	0	5	0	1	18	0
Calno85					65	0	0	0	2	5	25	0	2
Ca2no85						3	0	0	2	4	25	2	4
Cpno84							12	1	5	3	1	18	0
Fgap85								0	1	0	1	4	0
Pmljn85									37	0	0	0	0
Pm2jn85										18	19	5	0
Pmlse85											30	4	0
Pm2se85												2	0
SLde85													0
Gide85													

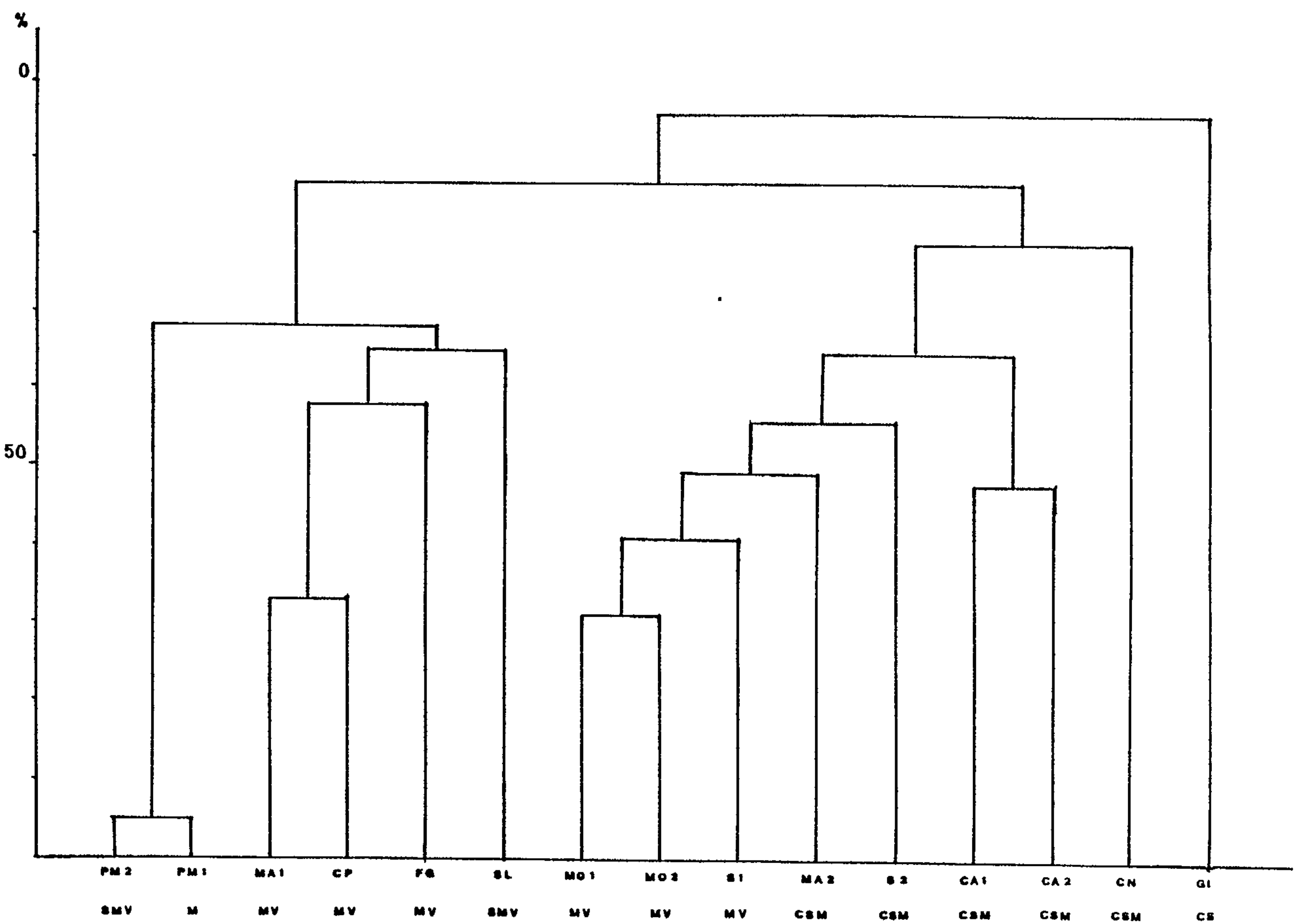

Fig. 5 Dendrogram based upon S.i. Kind of substrate is reported for each station: S = sand; CS = coarse sand; M = mud; V = vegetal debris

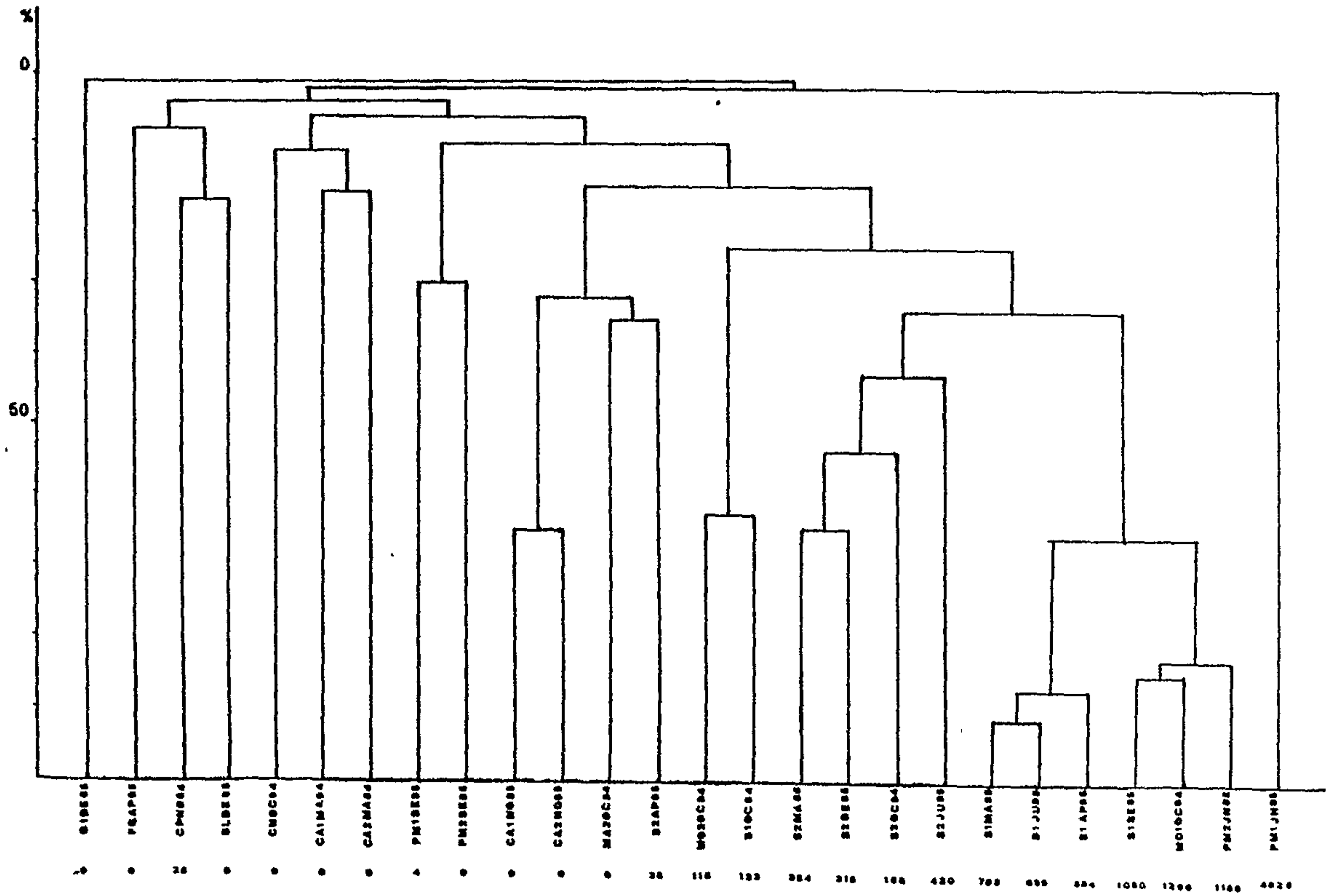

Fig. 6 Dendrogram based upon K.i. The numbers of specimens of *Streblospio shrubsolii* are reported for each station

b. FgAp85; CpNo84; SLDe85; CnOc84; Ca2Ma84; Pm1Se85; Pm2Se85; Ca1No85; Ca2No85; Ma2Oc84; S2Ap85. This group is composed of different blocks of stations, grouped together by roughly similar values of salinity. Generally, in all the stations of this group, S.shrubsolii is either very rare or absent.

Two stations showed very low values of similarity compared with all the others: GiDe85 and Pm1Jn85. Giglio was sharply separated from the other stations in the S.i and its poor fauna, lacking in Molluscs, also distinguished it here. Punta Marina is different in its overwhelming predominance of S.shrubsolii (4825 spm m^{-2}), that strongly characterizes the structure of this animal community.

The seasonal study of the fluctuation of Polychaetes in Salina resulted in the finding of 20 species belonging to 8 families. Some species such as N.diversicolor and S.shrubsolii were very abundant in the upper station, while in the lower station species such as E.assimilis, B.oculata, P.cultrifera, C.tentaculata and S.shrubsolii were well represented. The number of species up-channel was always lower than in the inlet during the whole period of study.

In the analysis performed on the "matrix des états(I)" only the first two axes are significant and account for 81.14% of the total variance. The ordination model obtained on the plane of the two factors is shown in Fig. 7. The first axis sharply separates the inner samples from the outer ones over the whole period of study. On the second axis the seasonal fluctuations are developed particularly as far as the inner samples are concerned.

In the analysis performed on the "matrix des états(II)" it is again only the first two axes that are significant and account for 56.26% of the total variance. As far as the station points are concerned, the ordination model obtained (Fig. 8) is very similar to that previously described. The trend of abundance vectors of the species points is well related to those of the stations. N.diversicolor, linked to the upper stations, shows a variable trend along the second axis. This trend is linked to time variability. In fact this species shows an increase in abundance when the salinity is lower (spring samples). S.shrubsolii, C.tentaculata and C.capitata show some fluctuations in abundance along the first axis, which is interpreted in both models as a gradient reflecting changes of abiotic parameters from up-channel to beyond the outlet.

In the analysis performed on the "matrix des histoires" only one factor was enucleated and the total variance of the system is linked to this axis. Therefore, an axis including the sampling periods was placed perpendicular to the first axis in order to represent the data more clearly (Fig. 9). Four groups of species points were obtained:

- The first, consisting of S.shruboslii, the only species located always in the intermediate zone between the upper and lower stations.

- The second, consisting of N.diversicolor, is linked to the upper zone, except for April 1985 when it lies in the intermediate zone.

- The third, consisting of C.capitata and C.tentaculata, fluctuates from the upper to the lower zone in autumn, whereas it is linked to the lower zone in the spring periods.

- Finally, the fourth, consisting of the remaining species, is entirely linked to the lower zone.

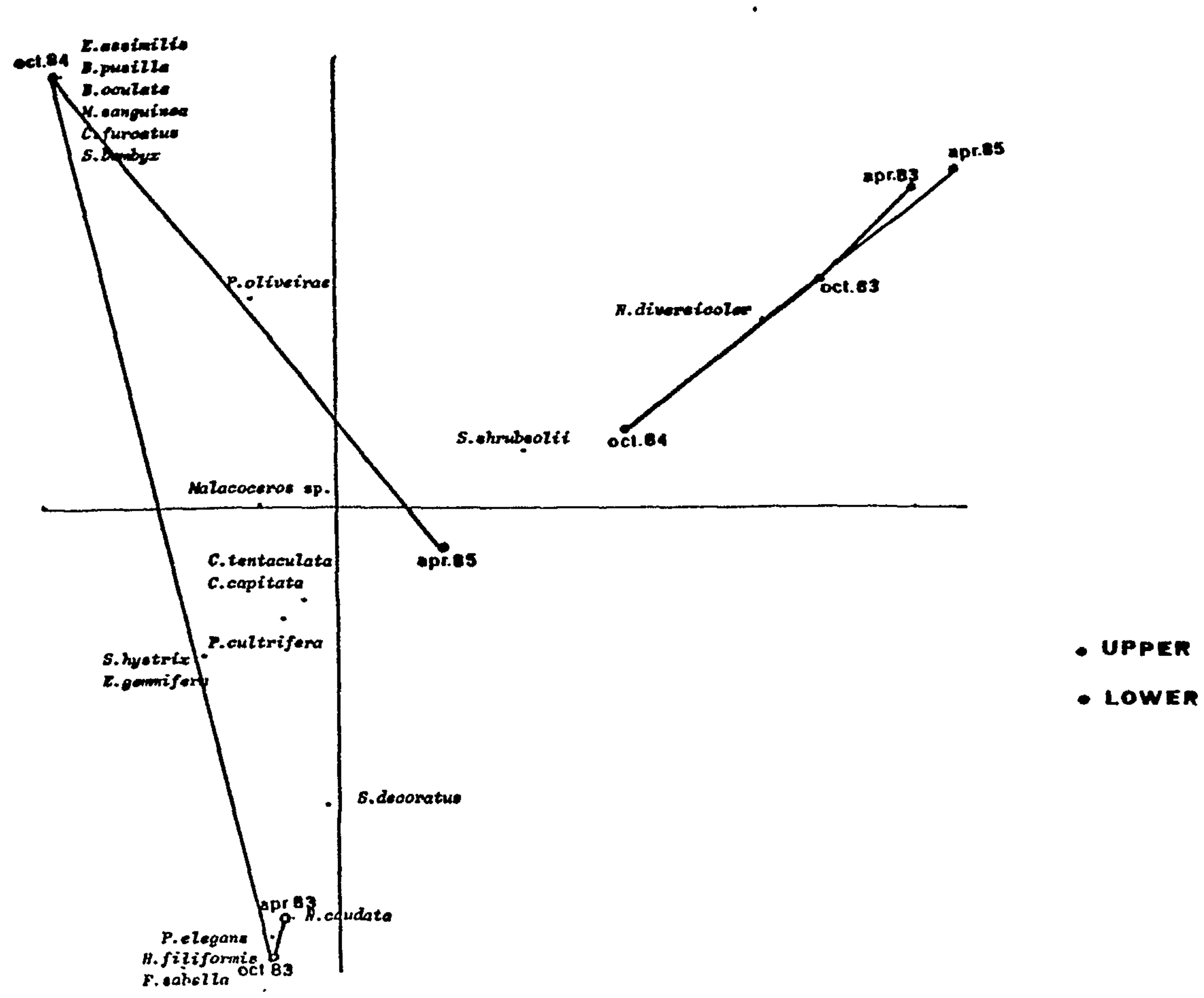

Fig. 7 Ordination model based upon "matrix des états I"

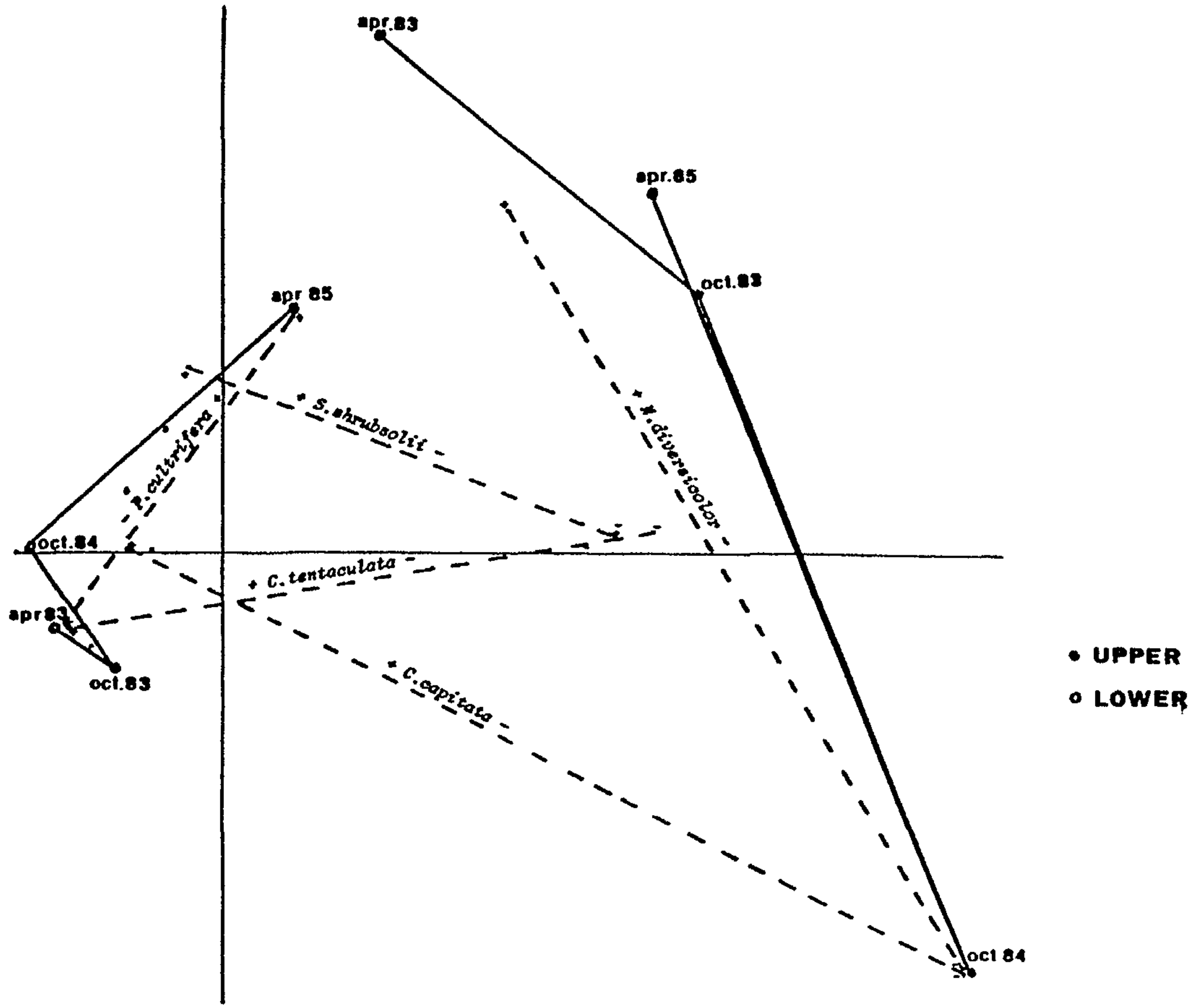

Fig. 8 Ordination model based upon "matrix des états II"

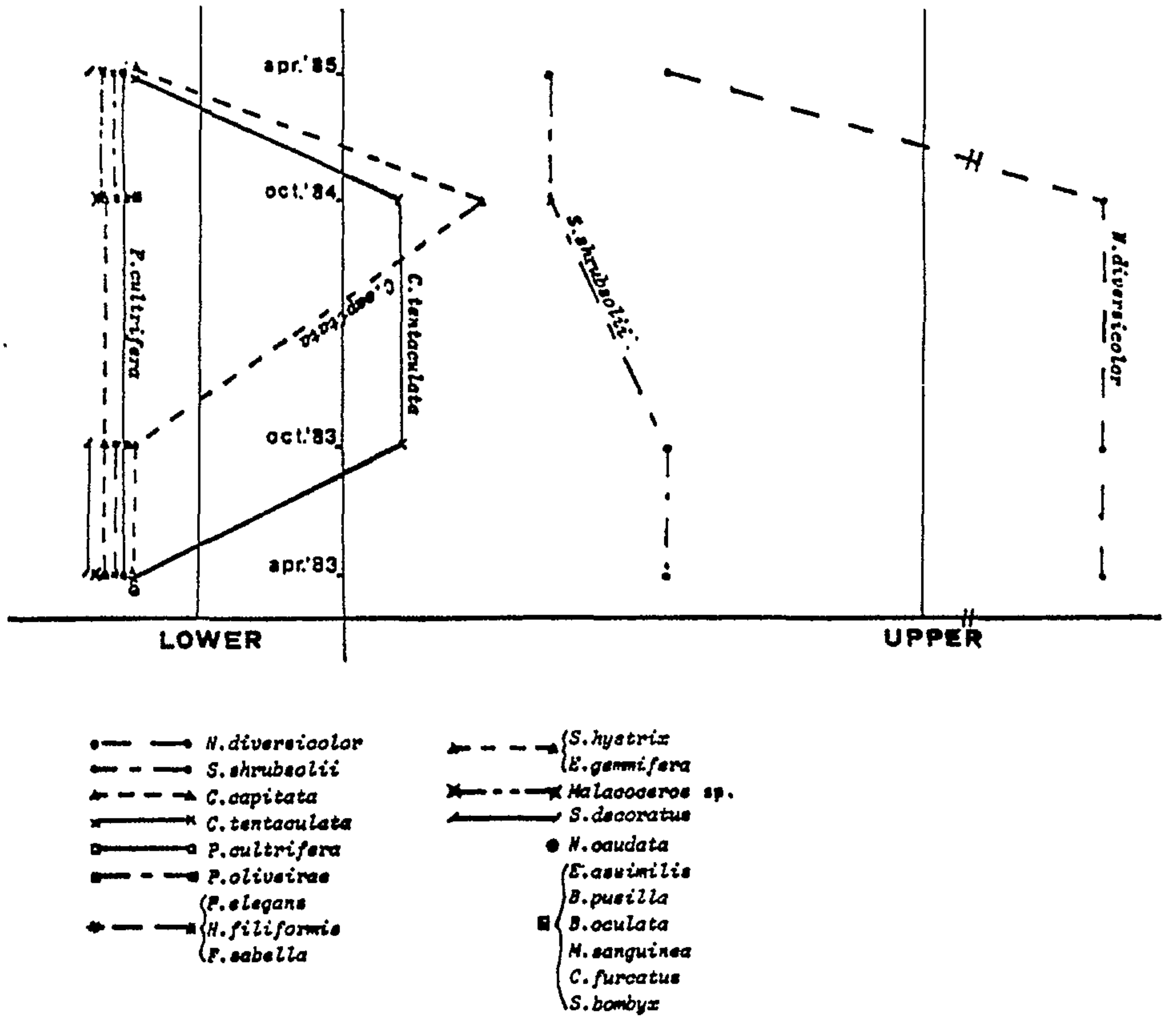

Fig. 9 Ordination model based upon "matrix des histoires"

5. DISCUSSION

5.1 Heterogeneity of chemical and physical parameters

The microhabitats studied, which by definition have in common reduced size and reduced salinity at least during part of the year, nevertheless differ in other parameters such as:

(a) Type of substratum:

Essentially this varies in the amount of mud or in the presence/absence of vegetal debris. The type of substratum can strongly influence the distribution of benthic organisms. In our samples, species such as Abra ovata are absent in coarse sand bottoms, preferring muddy substrata. Among Polychaetes also some deposit-feeders, such as S.shrubsolii and N.diversicolor, are affected in their distribution by the presence of muddy sediment preferably with vegetal debris.

(b) Salinity:

Only one of the microhabitats (Capitano) shows no appreciable seasonal range of fluctuation of salinity (Annichiarico, 1978). All the other stations show a more or less marked seasonal range. A preliminary division can be made between:

(i) stations with a moderate range of fluctuations with values of salinity never dropping below 15°/oo and very rarely below 25°/oo;

(ii) stations with wide fluctuations, ranging from zero values (around 0°/oo) to 38°/oo or hyperhaline values (up to 45°/oo at Punta Marina).

As a rule, the upper stations when present show values around 0°/oo during the rainy season. Such low values have on the contrary never been recorded in the lower stations. This implies a sharp diversification of their respective animal communities, mainly due to the amount of species unable to tolerate (for reasonably long periods of time) salinities lower than 20-25°/oo. Salinities in the region of 20°/oo appear to represent a boundary for many true marine species in larger coastal lagoons also (Barnes, 1980).

In the dendrogram based on the K.i., (Fig. 6) salinity constitutes the secondary ordinative factor and the upper stations are consistently separated from the lower ones.

5.2 Heterogeneity of animal communities

The results of the S.i. clearly indicate that a low level of similarity exists among the various stations. It is noteworthy that the dendrogram based upon the S.i. reveals a structure attributable to two main ordinative factors: type of substratum and salinity.

The K.i. index, which evaluates the affinities among stations on the basis of the community structures adds a further ordinative factor: the abundance of the species S.shrubsolii. The relevant dendrogram (Fig. 6) is in fact divided into two blocks: stations where the Polychaete is largely dominant and stations where the species is absent or present in very low numbers. Within these blocks, the salinity, as has been already shown, is a further ordinative factor separating the upper from the lower stations.

Statistical analysis therefore strongly suggests the existence of different groups of species, tending to occur with a certain constancy in the various microhabitats, according to different values of salinity and type of substratum:

- Wide spectrum species:

Streblospio shrubsolii: it occurs in stations with muddy substrata, often with heavy sedimentation and rich in vegetal debris. In the stations characterized by strong fluctuations of salinity this species can be very abundant and it can be one of the few organisms present.

Nereis diversicolor: it is a typical euryhaline species, which tolerates low oxygen levels, high concentrations of heavy metals and high variability in temperature values (Muus, 1967; Bryan and Hummerstone, 1971). It is prevalent in muddy stations. In these areas which have a range of salinities, the species occurred only in the low salinity stations. It is in fact well known as a rather non-competitive species: its abundance in stations with wide fluctuations is presumably due to the difficulties that more competitive species encounter in colonizing such areas.

- Brackish-water species:

Those species generally occur widely in the microhabitats although with a lesser degree of tolerance than the first group. They can be assumed to constitute the basic stock of species of this environment:

Perinereis cultrifera: it is present in stations with a moderate range of salinity. This species, although similar to N.diversicolor in its food requirements, tends to avoid silty and muddy substrata, and stations with a wide range of salinity. It is therefore prevalent in the outer area of the microhabitats.

Capitella capitata: it is a typical r-selected species: it can reproduce both by means of planktonic and benthic larvae, has a short life-cycle and reaches maturity from the egg in about three weeks. It can therefore continuously repopulate sediments subject to organic pollution. This species adapts to continuous disturbance of its environment by continuous reproduction (Gray, 1981). C.capitata does not tolerate low salinity values and is only present in stations with a moderate range of fluctuations.

Cirriformia tentaculata: it is a saprobic species typical of environments with high organic content, such as harbours or polluted areas (Bellan, 1968; Cognetti and Taliercio, 1969). Its life history and reproductive strategy are similar to that of C.capitata. It is only present in stations with a moderate salinity range and a muddy substratum.

Abra ovata: it is well known in Mediterranean and Atlanto-Lusitanic coastal lagoons, where it prefers very muddy sediments with 80% of particles less than 50 um in size (Glémarec, 1964). It is widely distributed in the microhabitats with adequate substrata.

Cerastoderma edule: it is questionable whether the specimens collected belong to this species or to its sibling species C.lamarcki. Morphological analyses carried out on shells do not allow any conclusive determination. The two species however are known to tolerate wide ranges of salinity values (more C.lamarcki than C.edule) (Tebble, 1966). Specimens of this genus are very common in two continental microhabitats (San Leopoldo, Punta Marina) and are occasionally also found in the Salina, in Elba Island, but do not appear to succeed in establishing themselves in insular microhabitats.

Parvicardium exiguum: it occurs frequently in stations with a moderate range of fluctuations. The larvae of this species are able to settle in waters of about $20^{o}/oo$ or more (Rasmussen, 1973), but the adult is known to withstand slightly lower salinities (Tebble, 1966).

Ventrosia ventrosa: it is frequently found in the stations with moderate fluctuations and rich in vegetal debris. It is known to withstand a large spectrum of values of salinity, from $6\text{-}7^{o}/oo$ up to hyperhaline values (Torelli, 1982), and to prefer sheltered habitats (Cherrill and James, 1985).

- Transgressive marine species:

Several species of general occurrence in coastal biocenoses in normal sea water are widely distributed in the microhabitats: Syllis mediterranea, Cirrophorus furcatus, Heteromastus filiformis, Exogone gemmifera, Pettiboneia urciensis.

Their presence reveals the existence of independent and successful colonization events as already suggested by Cognetti (1982), both for brackish and polluted environments.

- Characteristic species:

A few species had an extremely narrow distribution occurring in one station only, albeit sometimes in large numbers and thus may be said to characterize the environment.

For each station these are:

San Leopoldo : Ficopomatus enigmaticus, Syllides edentula

Punta Marina : Nereis succinea, Hydrobia acuta, Lentidium mediterraneum, Cyclonassa neritea, Scrobicularia plana

Cantiere Navale : Turbonilla lactea

Capitano : Theodoxus fluviatilis

Salina : Brania oculata, Brania pusilla, Marphysa sanguinea, Spiophanes bombyx, Bornia sebetia, Melaraphe neritoides

Mola : Aricidea catherinae

Capraia : Parapionosyllis labronica, Pseudobrania clavata

Figarella : Potamopyrgus jenkinsi

It is noteworthy that this stock of species is highly heterogeneous including:

a. typical brackish-water species (F.enigmaticus, P.jenkinsi, H.acuta, C.neritea, S.plana and, to a lesser extent, T.fluviatilis which cannot withstand values above 10-15°/oo (Torelli, 1982).

b. true marine species (B.oculata, B.pusilla, S.bombyx, A.catherinae, P.labronica, P.clavata, T.lactea, B.sebetia), with a similar requirement to those already noted for the transgressive marine species.

5.3 Seasonal fluctuations

The results of the statistical analysis (matrix des "états" I and II, matrix des "histoires"), suggest several considerations that can be summarized as follows:

- a sharp discontinuity between the lower and upper area exists during the whole period of study.

- species richness is always higher in the lower zone.

- the species moving between the upper and lower zones are mainly three: N.diversicolor, C.capitata, and C.tentaculata.

Examination of the trend concerning each species during the study period, shows that three patterns are recognizable as a response to environmental changes:

- species characterizing the seasonal fluctuation of the whole community by their spatial shiftings (N.diversicolor, C.capitata, and C.tentaculata).

- species present both in the upper and lower zones without any change in abundance (S.shrubsolii). This species appears to tolerate both competition and environmental variability.

- stenohaline species linked to the outer zone (P.cultrifera, M.fuliginosus). We can include here some marine species which appeared only after summer, with the rising of salinity values (E.assimilis, B.oculata, B.pusilla, C.furcatus).

The existence of marked seasonal fluctuations in the organisms of the microhabitats is therefore well documented. Since these animals tend to inhabit areas suitable for their ecological requirements, seasonal fluctuations may be interpreted as a progressive change of the various environments of the microhabitats themselves, each with its group of species.

5.4 Comparisons with continental macrohabitats

The data obtained from the examination of the microhabitats of the Tuscan Archipelago can be usefully compared with what is known from the large brackish basins of the facing Tuscan coast. At present a large amount of data concerning the Orbetello and Burano lagoons is available (Bonvicini Pagliai and Cognetti, 1982; Cognetti et al., 1978).

The following observations can be made:

a. All brackish-water species present in the microhabitats (although with scattered distribution) are present in the coastal lagoons.

b. Further brackish-water species lacking in the insular microhabitats are present: Haminoea navicula, Cyclonassa neritea, Ficopomatus enigmaticus, Aricia foetida, Armandia cirrosa.

c. At Orbetello (due to the marked heterogeneity of the environment, with a strictly marine outer zone) several marine species succeeded in colonizing part of the lagoon. However, the marine component of the fauna constituting the insular microhabitats contains several species not found in the lagoon. This shows the existence of independent processes of colonization by marine species in each brackish-water body, provided there are areas with compatible values of salinity (Cognetti, 1982).

6. CONCLUSIONS

It is possible to sum up the characteristics of the benthic communities of these microhabitats briefly, some of which, we believe, hold good for any brackish-water body:

a. There is a basic stock of species which can be expected to occur in any brackish-microhabitat located in the central basin of the Mediterranean. Those species include S.shrubsolii, N.diversicolor, C.capitata, A.ovata, P.exiguum. This stock constitutes the characteristic fraction of that environment. However, the type of substratum and the range of salinity fluctuations can prevent some of the species from permanently colonizing part of the microhabitats.

b. A small number of marine species, different in the various stations, is generally present in the microhabitats. These generally rely upon independent colonization events by species from the neighbouring marine communities. As a rule, such colonization is limited to the outer area of the stations and is most likely to occur during the dry season. These species are generally a characteristic feature of the single microhabitats, and closely reflect the composition of nearby benthic communities.

c. On the basis of the fluctuations of the salinity values, occurring as a rule in the microhabitats, most of the species expand or reduce their distribution, according to their ecological requirements.

d. The existence of stochastic factors affecting the distribution of the species in the microhabitats must be emphasised. Most of the insular stations are difficult to colonize. Not only must such potential inhabitants go through a planktonic larval stage, but the larvae must happen on, and settle in, areas sometimes no larger than a few square metres. On this basis, the total absence in the insular biotopes of well known brackish-water species, such as F.enigmaticus, S.plana, H.navicula or the scarcity of C.edule/lamarcki is understandable. All of these are abundant in larger brackish-water bodies and generally occur in the mainland microhabitats, which are as a rule much easier to colonize.

The effects of stochasticity may eventually lead to a low level of biological pressure of brackish-water species in at least some of the microhabitats. This establishes the conditions for repeated invasions of stenohaline species, resulting in the presence of many species of Molluscs and Polychaetes never found in brackish waters. It is possible therefore to define the structure of the benthic communities of the microhabitats as a unique event which depends on the chemical and physical parameters of the environment, on the species that succeeded in colonizing them and on the relationships that are likely to exist between them which would then inhibit further settlement. Finally, these areas differ from larger brackish-water bodies in the importance of stochastic factors which determine the presence/absence of some species in environments which seem to be exactly similar.

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ACTUAL STATE OF THE BENTHIC BIOCENOSES OF THE LIGURIAN SHELF AND THE ISLANDS OF THE TUSCAN ARCHIPELAGO

by

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ABSTRACT

This study deals with the first faunal, bionomic and zoogeographical description of the soft bottom macrobenthic communities in the Tuscan Archipelago. It is part of a more extensive research carried out on the macrobenthos of the Ligurian shelf and of the Tyrrhenian Sea insular systems. The samples were collected with a van Veen grab during five oceanographic cruises on the Capraia, Pianosa, Giglio, Montecristo, Giannutri and Elba shelves. The analysis of the samples shows considerable differences in faunal, bionomic and quantitative features of the macrobenthic populations of the six islands. The high number of species allows one to draw some conclusions on the zoogeography of the benthos of the Tuscan Archipelago, confirming the great affinity of this area to the boreal-lusitanian Atlantic one. Moreover the data, mostly faunal-bionomic, represent the basis of reference for future evaluations of environmental changes caused by human activities.

1. INTRODUCTION

The terrestrial flora and fauna of the minor insular systems of the Italian Seas (Tuscan, Pontine, Egadi and Eolie Archipelagoes) have always aroused great scientific interest and numerous studies have been carried out on these subjects. On the contrary, the marine organisms living on the bottom sediments of such insular systems have been neglected; research is lacking and information is scanty. The problems concerning the bottom fauna of soft sediments around insular shelves have been tackled at the Institute of Marine Environmental Science of the University of Genova since 1976.

On a preliminary basis, the primary aim of the research was to give a faunal, bionomic and zoogeographical description of the insular systems as well as to evaluate, from the quantitative point of view, the macrobenthic populations. Moreover the research, which involved comparing the macrobenthic populations of different islands and different insular systems with those of the neighbouring continental shelves, is intended to clarify some features relating to isolation phenomena. In the insular environment such phenomena are different for marine and terrestrial species. The data and observations on the biocoenoses of the sea bed of the Archipelagoes will represent finally the first references for future evaluations of environmental changes on a large scale basis.

2. MATERIALS AND METHODS

The samples were collected during five oceanographic cruises carried out by Gruppo Ricerca Oceanologica-Genova (G.R.O.-G.) on the vessels "L.F.Marsili" (1976, 1977, 1978, 1982) and "Bannock" (1980). The sampling stations, placed between 35 and 200 m depth, were on lines vertical to the coast and where possible all around the island (Fig.1). Every station is represented by two samples taken with a van Veen grab (surface 726cm^2; volume 12l); at Pianosa moreover, two stations were sampled with a dredge. The sediment was sieved through a 1.8mm mesh and the remaining sediment fraction on the sieve was subsequently examined in the laboratory. During both operations the macrobenthic organisms were collected and fixed with formalin solution.

The first part of the research was supported by a C.N.R. grant. (Sottoprogetto "Inquinamento Marino", Progetto Finalizzato "Oceanografia e fondi marini"). Since October 1982 the research has been financed through the Mediterranean Trust Fund.

3. RESULTS

The first results of the research concern the macrobenthos of the Tuscan Archipelago (Capraia, Pianosa, Montecristo, Giannutri and Elba). The faunal analysis shows that a great number of species characterizes the macrobenthic populations of each island (Albertelli et al., 1983, 1984). Polychaetous Annelids are the major components of the populations of every island except Pianosa (Drago et al., 1980) where Molluscs are equally abundant. It has to be pointed out that some species of Crustaceans and Polychaetous Annelids are new for the Mediterranean or Tyrrhenian macrobenthic fauna (Drago et al., 1978; Cattaneo et al., 1978).

Despite the high diversity, one might be led to think that the number of species is underestimated due to the sampling methods, whereas the results emphasize that each island can be considered an entity with marked faunal individuality and as such different from the others. This individuality can clearly be seen from the fact that the percentage of species which are common to the sea beds of the six islands of the Tuscan Archipelago is only equal to 2%, while the percentage of species collected on each island shelf is, on the average, 50% of all species collected, that is 522 species (Table I).

The only biocoenosis common to all islands is the coarse sand with Posidonia meadow. This biocoenosis is located around the islands on shallow stations (Fig.1), while on deep stations detritic-like and muddy-like biocoenoses have been found. The former were located on the Capraia, Pianosa and Montecristo shelves; the latter on the Giannutri, Giglio and Elba shelves. The occurrence of such biocoenoses allows one to distinguish between the islands near the continental shelf which are more influenced by terrigenous inputs and those subjected to more marked hydrodynamic phenomena due to the system of currents in the Tyrrhenian Sea.

The mean density of the macrobenthic populations of the Tuscan Archipelago is 174 organisms per square metre which is lower than that of the Ligurian continental shelf sampled with the same methods over the same period (222 organisms per m^2), (Albertelli et al., 1981).

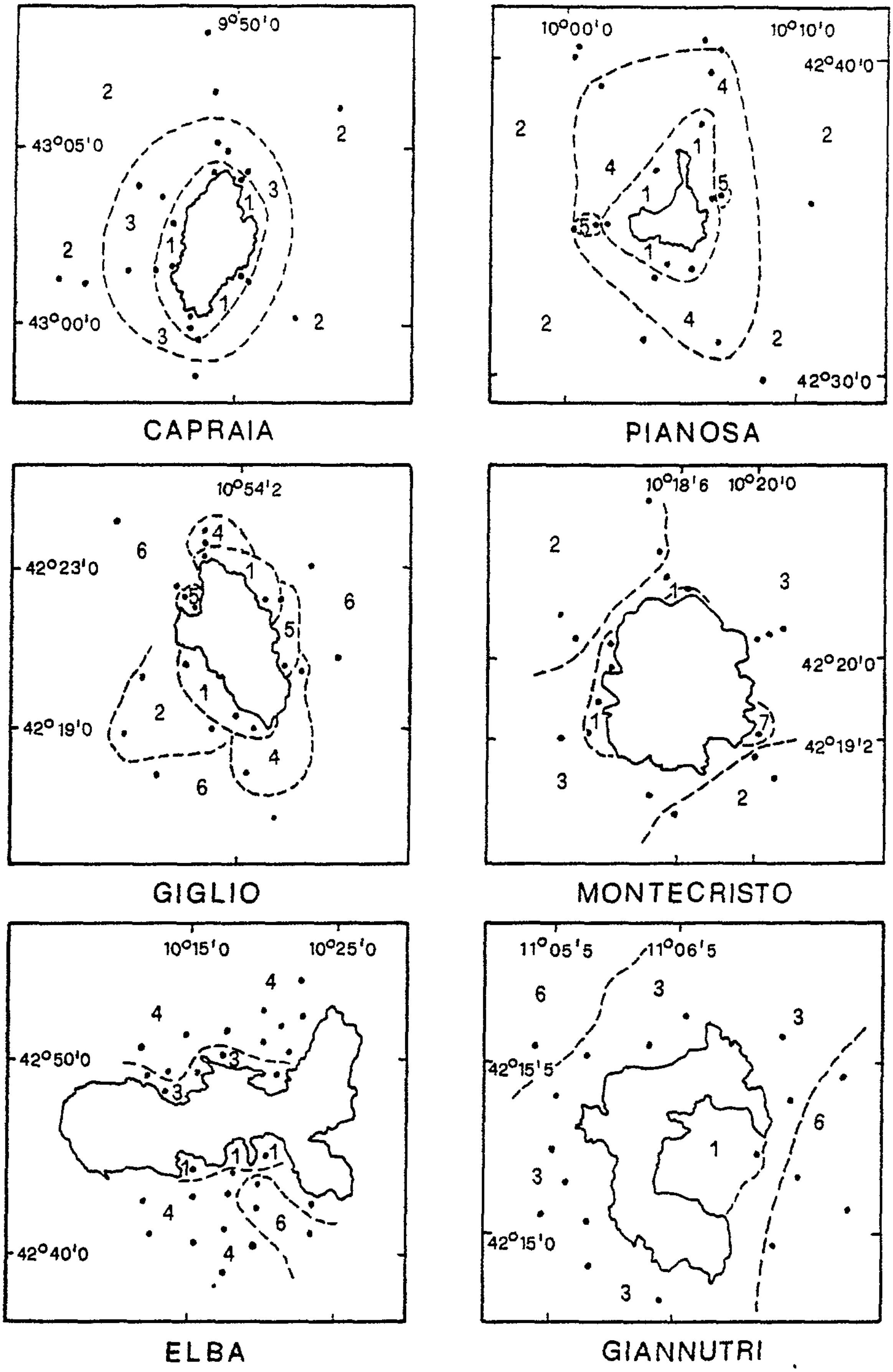

Fig. 1 Sampling area around each island: 1. Biocoenosis "Coarse Sand with Posidonia meadow", 2. Shelf-Edge Detritic, 3. Coastal Detritic, 4. Detritic-Muddy bottoms, 5. "Fond de decantation" (decantation bottom), 6. Terrigenous Mud, 7. Precoralligenous bottom

It is interesting to note that from the zoogeographical point of view the macrobenthic populations of the Tuscan Archipelago show a great affinity with the boreal-lusitanian Atlantic ones. The similarity is shown in each systematic group studied (Table II). Molluscs and Echinoderms show many species common to the West African coasts (South of Green Cape) while Polychaetous Annelids are represented in a high percentage of Indopacific species: the majority of these is also present in the Atlantic regions.

With regard to the endemic species of the Mediterranean Sea, it should be noted that Crustaceans have the highest percentage; in this taxonomic group there are many species which have been collected and described only in these last few years and these show high frequency and wide distribution in the Tuscan Archipelago.

This report gives only limited information and does not refer at all to the results of several cruises carried out around the islands of the other Tyrrhenian Archipelagoes.

Table I

Number and percentage of macrobenthic species common to the Tuscan Archipelago, (after Albertelli *et al.*, 1984). (Pol.= Polychaetous Annelids; Cru.= Crustaceans; Mol.= Molluscs; Ecm.= Echinoderms).

Species common to	Pol.		Cru.		Mol.		Ecm.		Total	
the sea beds of	no.	%	no.	%	no.	%	no.	%	no.	%
1 island	91	45	91	58	65	54	19	43	266	51
2 islands	51	25	34	22	30	25	9	20	124	24
3 islands	32	16	21	13	13	11	7	16	73	14
4 islands	12	6	6	4	8	7	2	5	28	5
5 islands	10	5	4	3	3	2	5	11	22	4
6 islands	6	3	-	-	1	1	2	5	9	2

Table II

Number and percentage of the macrobenthic species collected in the Tuscan Archipelago and grouped according to their zoogeographical distribution (after Albertelli et al., 1984).
(Pol.= Polychaetous Annelias; Cru.= Crustaceans; Mol.= Molluscs; Ecm.= Echninoderms).

SPECIES	Pol.		Cru		Mol		Ecm.		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%
Endemic	21	11	40	33	10	10	9	19	80	17
Mediterranean lusitanic	46	24	19	16	13	13	10	21	88	19
boreal	71	38	38	31	40	41	14	29	163	36
boreal and West African	7	4	15	12	25	26	8	16	55	12
tropical	4	2	-	-	5	5	6	12	15	3
Indopacific lusit.	13	7	1	1	1	1	-	-	15	3
Indopacific boreal	16	8	2	2	2	2	-	-	20	4
Indopacific West African	8	4	-	-	-	-	-	-	8	2
Cosmopolitan	3	2	7	6	1	1	1	2	12	3
Total	189		122		97		48		456	

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EFFECTS OF POLLUTION ON THE BENTHIC AND PELAGIC ECOSYSTEMS OF THE IZMIR BAY (TURKEY)

by

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ABSTRACT

This investigation concerns the effects of pollution on the benthic and pelagic ecosystems of Izmir Bay. Towards this aim 12 stations were selected for comparative investigation, 6 located in the heavily polluted inner bay (domestic sewage of over 2 million people plus the effluents of 1250 factories) and 6 located in the unpolluted Gülbahçe Bay. Physicochemical parameters and biological results obtained during the investigation period between the years 1983-1985 are described below.

Both bay waters are quite similar in respect to temperature although the surface waters of the inner bay are slightly warmer. The pollution-free waters of Gülbahçe Bay are much more transparent (secchi disc 1030-1330 cm) in comparison to the inner bay waters (secchi disc 121-357 cm) but the amount of seston (1.8-6.4 mg l^{-1}) is much less than in the inner bay (5-50 mg l^{-1}). Gülbahçe Bay is slightly more saline than the inner bay. Dissolved oxygen levels are quite stable in Gülbahçe Bay waters, ranging from 7.0-7.6 mg l^{-1} whereas in the inner bay they fluctuate between 3.2 and 8.5 mg l^{-1}. The pH values are rather similar in both bays. Inner Bay waters are richer in nutrients i.e. average values in the inner bay range from 3.1-12.1 ug N l^{-1} for nitrite; 14.1-40.6 ug N l^{-1} for nitrate and 23.6-60.7 ug P l^{-1} for phosphate whereas the range in Gülbahçe bay is between 0.5-0.9 ug N l^{-1} for nitrite, 13.7-40.1 ug N l^{-1} for nitrate and 2.3-4.0 ug P l^{-1} for phosphate.

In both bays the plankton species belonging to Diatomophyceae, Silicoflagellata, Dinoflagellata, Ciliata, Annelida (larvae), Mollusca (larvae) and Crustacea were found. Quantitavely, the inner bay is much richer in phytoplankton ($7.8x10^5$ cells l^{-1}) and zooplankton ($7x10^3$ ind. l^{-1}) than Gülbahçe Bay (phytoplankton $8x10^2$ cells l^{-1}, zooplankton 27 ind. l^{-1}). Gülbahçe Bay is richer both qualitatively and quantitatively than the inner bay in respect of benthic organisms. The number of species, individuals and diversity indices range between 5-66, 152-1524 and 0.81-5.20 respectively in the inner bay stations whereas the ranges for the Gülbahçe stations are 69-101, 1305-1684 and 5.5-5.86 respectively. The inner bay is quantitatively richer whereas Gülbahçe Bay is qualitatively richer in respect of fish population.

1. INTRODUCTION

The population of the city of Izmir situated around the bay of Izmir is about 4.4% of the population of Turkey. According to the 1985 census, Izmir is one of the most rapidly developing cities in Turkey. Parallel to the increase in population, there is a rapid increase in fisheries, industrial and commercial activities. The industrial and domestic wastes of this densely populated settlement enter the bay water, the wastes not undergoing any pretreatment. All these wastes dumped into the sea have an adverse effect both on the organisms and the water quality. Izmir Bay has become an important pollution focus point in Turkey.

The bay began to be heavily polluted in the 1960's; however this pollution was not noticed until the 1970's. For this reason, research on the effects of pollution on the bay waters and biota started after the 1970's. The effects of pollution on the bay waters have been studied by Geldiay et al. (1979) and Büyükisik (1986); plankton by Ozel (1979), Mater (1979) and Koray (1985); benthos by Kocatas (1979, 1981a, 1981b), Ergen (1979), Kocatas and Geldiay (1980), Kocatas et al. (1985), and Güner (1981); fish by Geldiay (1969).

If the pollution of the bay were to continue at the same rate, the region would soon die.

2. SOURCES OF POLLUTION

The main sources of pollution are organic substances, suspended matter, hydrocarbons, heavy metals and pathogenic microorganisms. These pollutants reach the bay in many ways, which are:

- Domestic and industrial wastes (50%)
- Rainfall (15%)
- Bay activities and sea traffic (4%)
- Rivers and streams (10%)
- Erosion (8%)
- Agricultural pesticides and fertilisers (10%)
- Other sources (3%)

2.1 Domestic and Industrial Discharges

The daily waste of the inhabitants of Izmir consisting of factory discharges and sewage (leather, textiles, food, detergents, beverages, chemicals etc.) are dumped into the bay waters through 128 canals and 10 streams. For 1985 this amount has been determined on 338,000 m^3 day^{-1} and of this amount 245,000 m^3 consists of domestic waste, and 93,000 m^3 of industrial waste (Table I).

Table I

Amount of industrial and domestic waste water discharge in the Izmir Bay (Uslu et al., 1985).

Years	Population	Domestic waste water (m^3 day^{-1})	Industrial waste water (m^3 day^{-1})	Total (m^3 day^{-1})
1977	1,054,870	127,000	-	-
1978	1,122,200	139,000	-	-
1979	1,193,809	154,000	-	-
1980	1,270,000	169,000	-	338,000
1985	1,595,650	245,000	93,000	338,000

With these waste waters an important amount of organic matter, suspended matter, nutrients and heavy metals enters the bay water. The amount of organic substances, suspended matter, nitrogen, phosphorus and heavy metals are given in Table II. If no steps for prevention are taken, there will be a very large amount of accumulation of pollutants in the future which will lead to an irreversibly polluted bay resulting in a totally azoic lagoon.

Table II

The amounts of BOD, suspended matter, nutrients and heavy metals in the bay waters, in 1985 (Uslu *et al*. 1985).

Type	Domestic ($kg\ day^{-1}$)	Industrial ($kg\ day^{-1}$)	Total ($kg\ day^{-1}$)
BOD	112,000	102,000	214,000
Suspended matter	117,000	40,000	166,000
Nitrogen	6,125	2,325	8,450
Phosphorus	1,960	140	2,100
Heavy metals	-	7,595	7,595

2.2 Wastes Caused by Ships and Sea Traffic

The Bay of Izmir is one of Turkey's most important bays. Izmır is a very busy bay, used by large ships, tankers, fishing and ferry boats which are one of the main sources of oil pollution.

2.3 Drainage From Land

A new road around the coast is being constructed in the inner bay and large coastal regions are being filled in, to gain space, with consequent building construction along the coast. As a result of these activities wastes are introduced into the bay waters directly or through run-off.

3. THE METEOROLOGIC CHARACTERISTICS OF THE REGION

Reports on temperature, rainfall and wind for the region which have a direct or indirect effect on the bay waters have been obtained from Ciglı weather forecast centre.

3.1 Temperature

The average temperature for the Izmir region is around 17 $^{\circ}C$. In summer it is usually hot and for July which is the hottest month the average temperature is 25.96 $^{\circ}C$. In January, the coldest month, the average temperature is 7.62 $^{\circ}C$ (Table III).

3.2 Rainfall

The region where Izmir is situated receives a fair amount of rain: Turkey as a whole is considered to receive a medium amount of rainfall. The average amount of rainfall per month and per day varies between 1.60-104.41 mm. (Table IV). Much of the rainfall is in winter (50%).

3.3 Wind

Although winds in this region may vary, the main winds are from a north and south eastern direction (Fig. 1). In summer however, there are westerly winds in the coastal regions during daytime and during the night there are off-shore winds.

Table III

Monthly averages of daily average temperature values recorded during 1976-1984.

Months	Average temperature (°C)	Standard deviation
January	7.62	0.92
February	8.24	2.00
March	10.75	1.00
April	14.46	0.83
May	19.23	0.81
June	24.20	0.77
July	25.96	0.71
August	25.05	0.92
September	21.60	1.06
October	17.38	1.55
November	12.57	1.49
December	9.55	1.46

Table IV

Monthly averages of daily average rainfall values (mm water column) recorded during 1971-1984.

Months	Average rainfall	Standard deviations
January	104.41	97.63
February	78.89	51.37
March	54.35	40.58
April	48.26	30.64
May	23.40	18.15
June	10.83	16.72
July	2.86	0.35
August	1.60	3.52
September	7.30	15.88
October	42.91	33.43
November	76.90	35.52
December	91.76	61.76
Total	543.47	

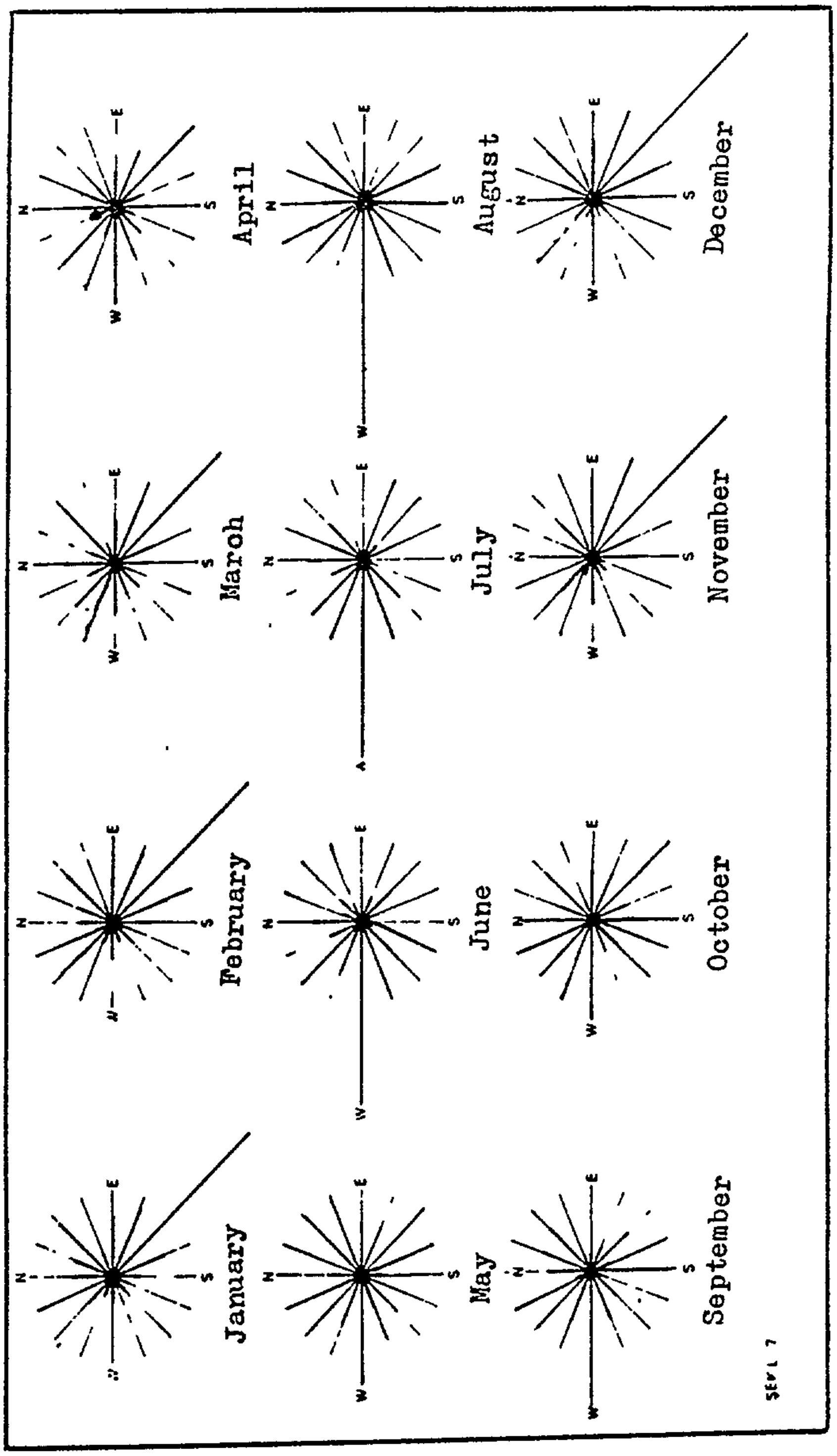

Fig. 1 Monthly distribution of winds in Izmir region

4. GENERAL CHARACTERISTICS OF THE BAY

Izmir bay, situated in the western coast of the Aegean sea, lies between the latitudes 38°20'-38°42' N and longitudes 29°25'-27°10' E. From the topographic and hydrographic point of view, it is divided into the inner and outer bay regions (Fig. 2).

The Yeni Kale lighthouse divides the bay into two, the inner bay on the eastern side being connected to the outer bay by a narrow channel. The length of the coast is 55 km, 13 km being the length of the inner coast; the width varies between 2.5-6.4 km, the area being 65.5 km^2 and the volume $636.2x10^6$ m^3. On the coast of the inner part of this lagoon-like bay the city of Izmir and important district suburbs (Karsiyaka, Bornova, Narlidere, Buca etc.) and industrial centres are located. The outer part of the bay with an area of 354.3 km^2 and volume of 9476.3 km^3 has some factories and settlement centres (Foça, Karaburun etc.) with several thousand inhabitants.

The average depth is about 20-25 m. The inner bay which is shallower reaches a maximum depth of about 20 m, whereas the outer bay which is deep reaches a maximum depth of 70 m (Fig. 2).

5. MATERIALS AND METHODS

Sampling in 12 stations located in the inner bay and outer bay (Gülbahçe) was carried out to determine the effects of pollution on the benthic and pelagic ecosystem of the Izmir Bay between the years 1983-1985 (Fig. 3).

Physico-chemical parameters of the bay waters such as temperature (YSI model 33 SCT-Metre), transparency (Secchi-disc) and oxygen (Winkler method) were measured on board ship, whereas salinity, pH and nutrients values were determined in the laboratory. For this purpose water samples, often collected with a Hydrobios Universal Series Water sampler, were transferred in polyethylene bottles to the laboratory for analysis. In the laboratory, salinity was determined with a salinometer (Beckman model RS7B), the pH with a portable pH meter, phosphates according to the method of Strickland and Parsons (1972), and nitrites and nitrates according to Wood (1975).

Plankton samples were collected with a Hydrobios plankton net (mesh size 55 um) for qualitative analysis and with a 5 l Hydrobios Universal Series water sampler for quantitative analysis. Samples collected for quantitative analysis were fixed with 4% formalin according to Semina's (1978) procedure in 1 l glass bottles so as to result in a final concentration of 2-4 % and after sedimentation, were counted using the reverse filtration method. After fixation, determination of species and counts were made using an inverted plankton microscope equipped with a phase contrast. The Sedwick-Rafter chamber was used for microplankton and zooplankton group counts.

In benthic sampling an orange-peel grab with a capacity of 4-5 litres was used. At each station a total of 9-10 litres of sediment was sampled and sieved through a 2 mm mesh. The material obtained was preserved after fixation with 4% formalin.

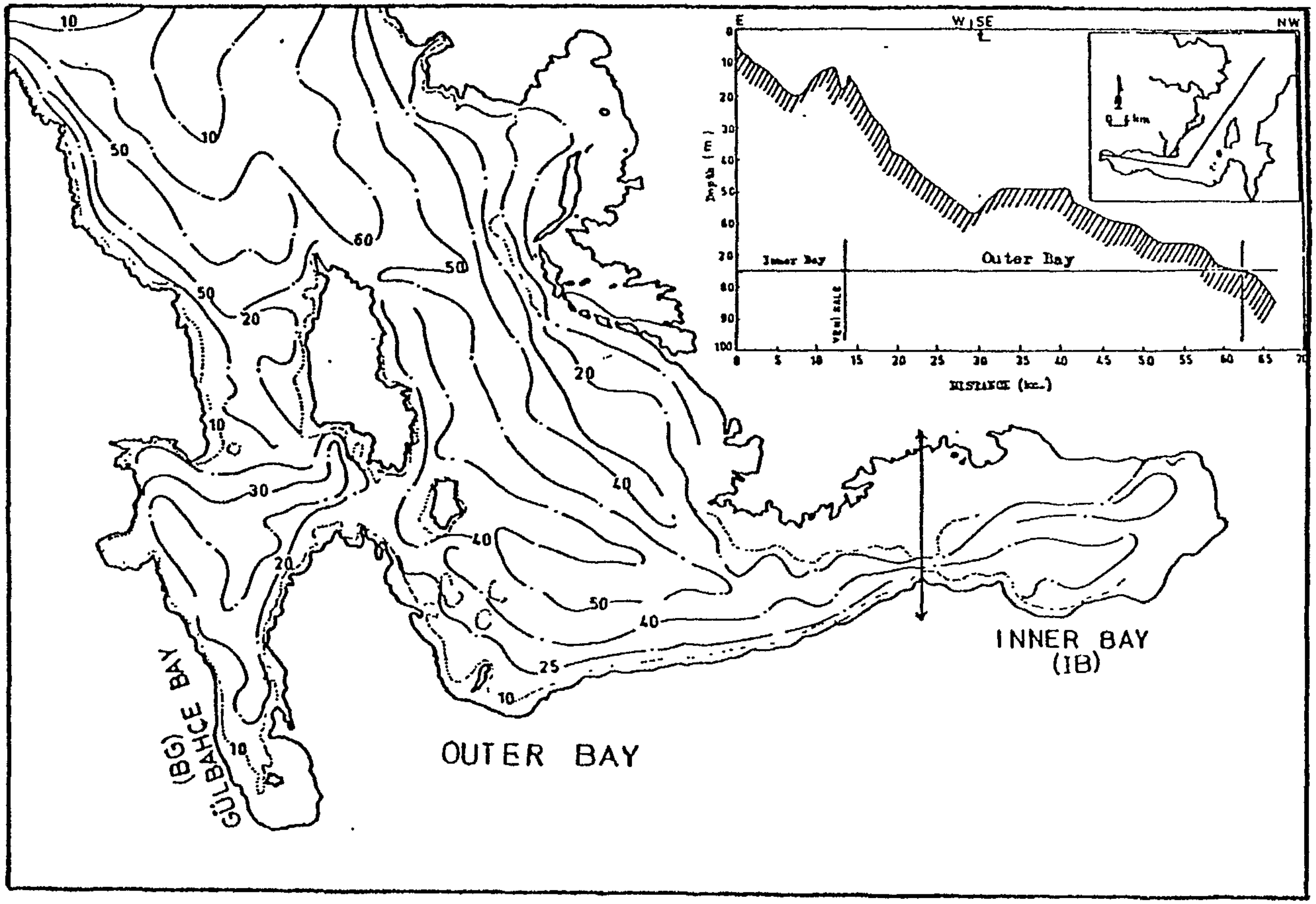

Fig. 2 Bottom topography of Izmir Bay

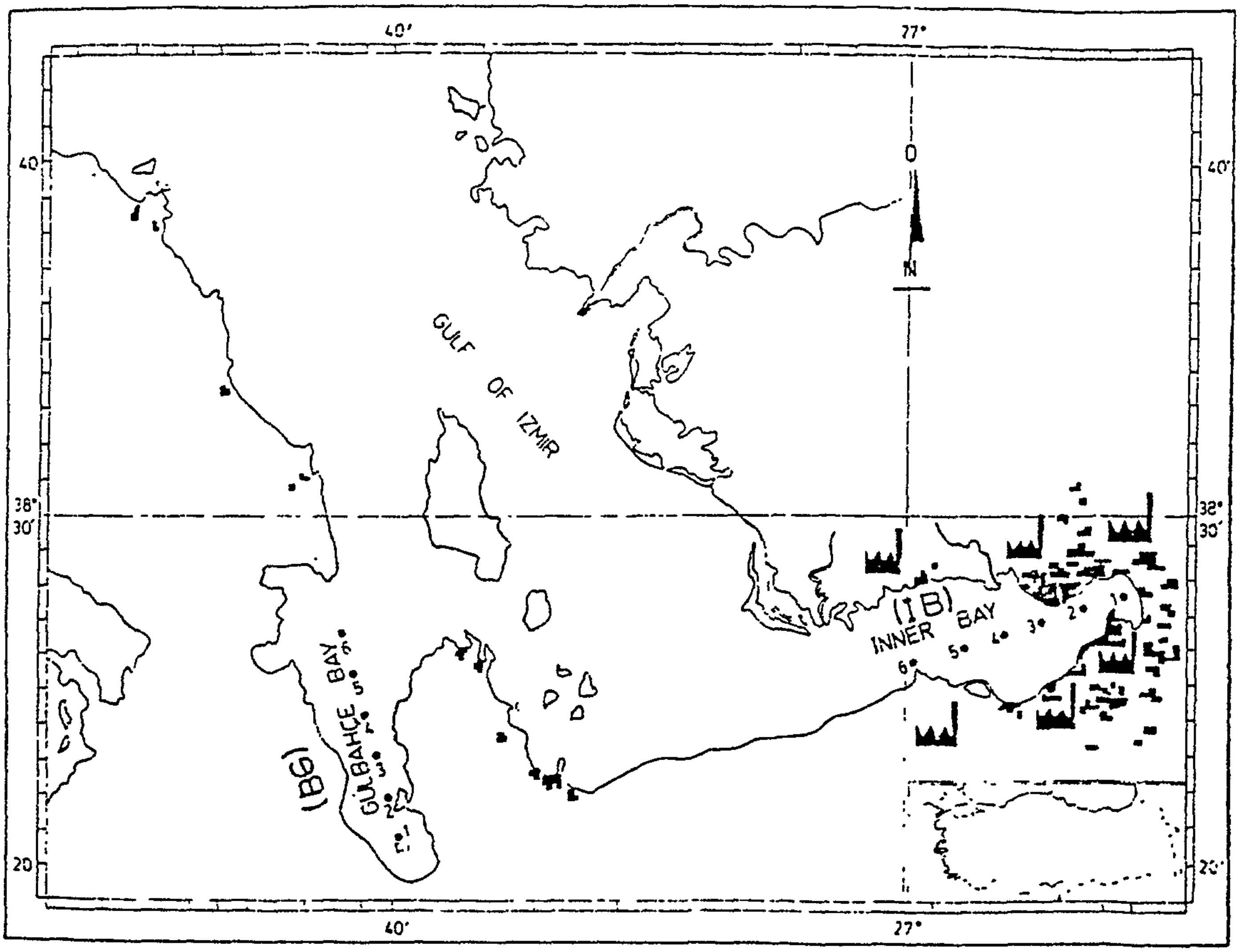

Fig. 3 Sampling stations in the Bay of Izmir

Fish were collected with fishing nets.

Richness of species was determined using Margalef's (1958) formula:

$$\left(d = \frac{S-1}{\ln N}\right)$$

and Shannon-Wiener information statistic (Shannon and Weaver, 1949):

$$\left(D' = - \sum_{l=1}^{s} pi \log_2 pi\right)$$

for determination of the diversity index.

6. RESULTS AND DISCUSSION

6.1 Environmental Conditions

Temperature

Observations on regional variations in bay water temperatures showed no important change; however, seasonal variations range between 9 °C (January in Gülbahçe) and 27 °C (July in inner bay). The surface waters of Gülbahçe bay are colder when compared with the inner bay; however, the temperature of the deeper waters decreases in a regular pattern from the coast towards the bottom waters where station 5 is located (Fig. 4).

Transparency

Transparency (secchi disc) shows a regional and seasonal variation in the bay waters. The seasonal range is between 70 cm (September, inner bay) and 1830 cm (June, Gülbahçe bay). The mean values for the inner bay range between 121-357 cm, whereas the values in Gülbahçe bay range between 1030-1330 cm (Fig. 4). Apart from this, a regular increase in the secchi disc values in stations of both regions from the coast towards the deeper region is detectable.

Seston

Similar changes to those of transparency were observed in the bay waters. As an example, in November 1984 the amount of seston in the inner bay varied from 1-16 mg l^{-1} whereas in the outer bay (Gülbahçe) it varied from 2.4-4.8 mg l^{-1}.

Salinity

Measurements showed that the salinity of the outer bay is higher than that of the inner bay (Fig. 4). Seasonal variations are quite important in the inner bay and show differences in different stations with regular increases towards the outer part of the Izmir bay whereas there are fluctuations in average salinity values between stations of Gülbahçe bay.

Dissolved Oxygen (DO)

DO concentrations show important seasonal (0-12.4 mg l^{-1}) and regional (3.2-8.5 mg l^{-1}) changes especially in the inner bay waters (Fig. 4). In the outer bay (Gülbahçe) values lie in the range between 7.0-7.6 mg l^{-1} which is rather a narrow range when compared with variations in the inner bay. Although Gülbahçe bay shows similarity between the surface and bottom water dissolved oxygen (DO) levels the inner bay waters show important variations.

pH

The mean pH values of both regions (outer and inner bay waters) were found to be quite similar. In other words the range in the inner bay lies between 7.46-7.80 and that of Gülbahçe between 7.70-7.86 (Fig. 5). The seasonal minimum value (6.35) was observed in July in the bottom waters and the maximum (8.40) in the surface waters of the inner bay.

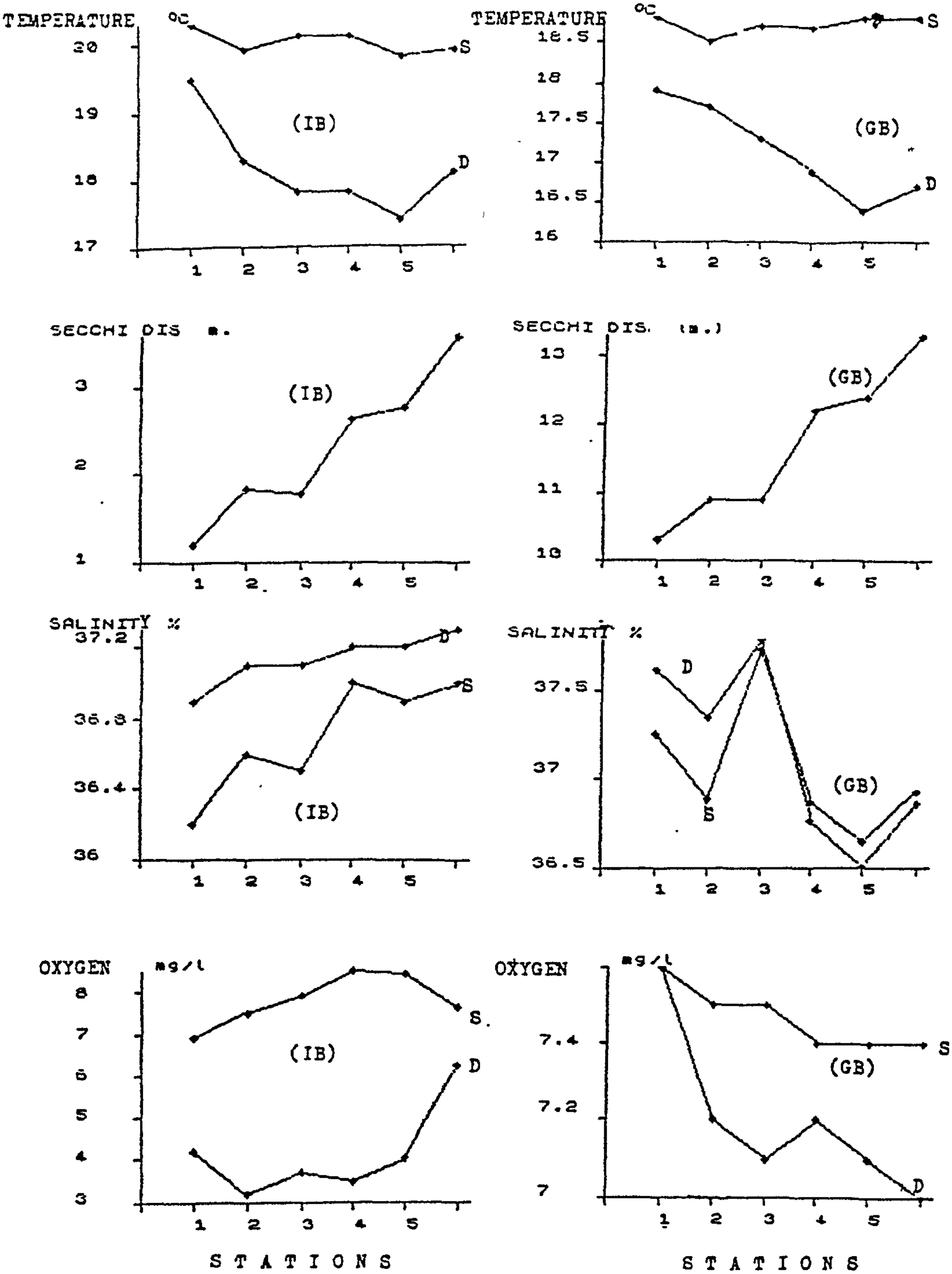

Fig. 4 Mean values of temperature, transparency, salinity and DO at stations in surface (S) and deep (D) waters of the inner bay and Gülbahçe Bay

Nitrites

Nitrite determinations showed that the inner bay bottom waters are richer than the Gülbahçe bay surface waters. The average nitrite values in the surface waters of the inner bay stations range between 3.1-12.1 ug N l^{-1} whereas in Gülbahçe bay the average values lie between 0.5-0.9 ug N l^{-1} (Fig. 5). There is also a regular decrease in the nitrite content of both regions towards the deeper waters of the Izmir Bay. Seasonal variations are between 0-45 ug N l^{-1}.

Nitrates

The average nitrate concentrations of the Izmir bay waters show major variations in stations of both regions investigated. The average values in the inner bay are between 14.1-40.6 ug N l^{-1} whereas in Gülbahçe region they lie between 13.7-40.1 ug N l^{-1} (Fig. 5). The range for seasonal variations is between 0-166.0 ug N l^{-1}.

Phosphates

As with other nutrients, the inner bay waters had higher levels of phosphates than the outer region (Gülbahçe).

The surface waters of the inner part of Izmir bay contain about 23.6-60.7 ug P l^{-1} whereas the mean concentration of phosphates in the Gülbahçe region shows a variation between 2.3-4.0 ug P l^{-1} (Fig. 5). The bottom waters of the inner bay are richer in phosphates than the surface waters though there is no major variation in Gülbahçe; seasonal variations are between 0-522 ug P l^{-1}.

6.2 Plankton

When the species composition of the inner bay and Gülbahçe bay are compared, an obvious difference is observed especially in the number of diatom and ciliate species (Fig. 6). Diatoms are represented with a larger number of species in Gülbahçe bay when compared with the number in the inner bay whereas ciliate species are more diverse in the inner bay. No difference in the number of species of dinoflagellates and zooplankton was observed. This may be due to the fact that only 1 litre water samples were analysed and therefore the apparent similarity between the number of species, in both the outer and inner bay regions may not be valid.

However, it is quite interesting that no difference between the species composition of the dinoflagellate communities was observed and probably members of this taxon make use of nitrogen in any form and thus they are more resistant to hypertrofication.

A larger number of ciliate species members observed in the inner bay in comparison to the outer region (Gülbahçe) is probably the consequence of weak currents flowing towards the inner bay in a northeast direction (anti-clockwise) thus causing an accumulation in the inner bay.

In Fig. 7, the average number of primary producers (nannoplankton, diatoms and photosynthetic dinoflagellates) and secondary producers (ciliates and microzooplankton) have been comparatively summarized. As can be easily seen from the figure the number of phytoplankton and zooplankton is always much higher in the inner bay than in the Gülbahçe region. Phytoplankton which

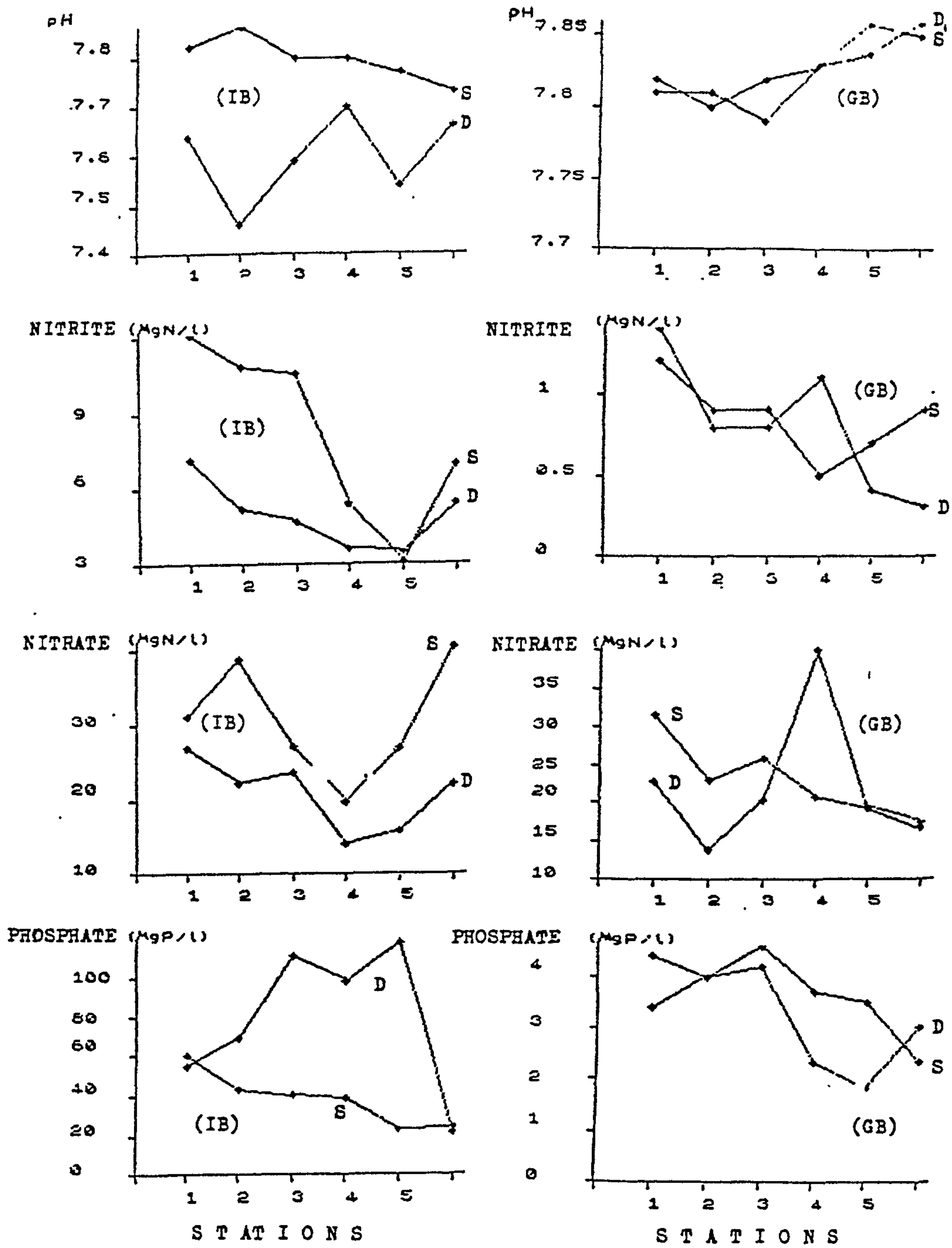

Fig. 5 Mean values of pH, nitrite, nitrates and phosphates in the surface (S) and deep (D) waters of the inner bay and Gülbahçe Bay

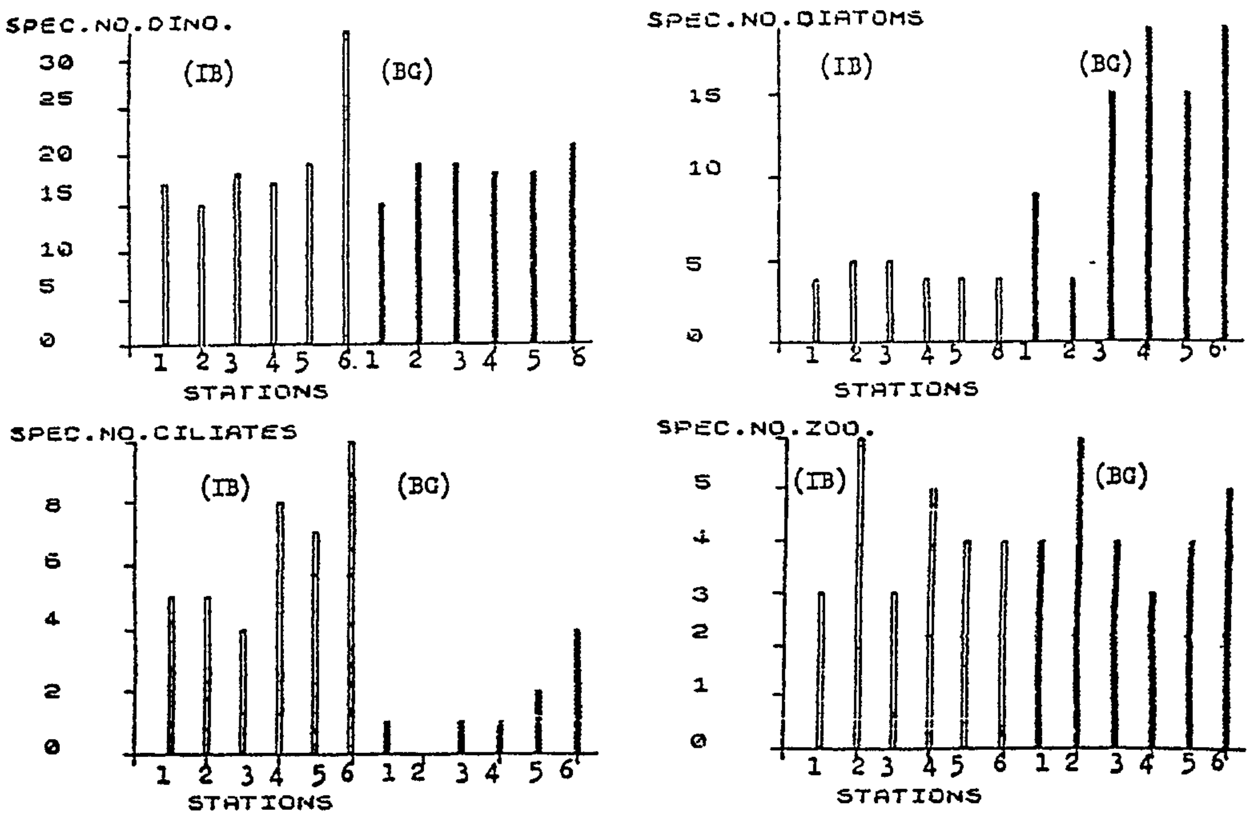

Fig. 6 Diatom, dinoflagellate, ciliate and zooplankton species in the inner bay and Gülbahçe Bay

shows an average density of 7.8×10^5 cells. l^{-1}, in the inner bay reaches only about 0.1% of this value (avg 8×10^2) in Gülbahçe bay. A similar situation also occurs with zooplankton. The average number of individuals in the inner bay is 7×10^3 individuals l^{-1}, while values in the Gülbahçe region hardly reach 0.4% of this.

The species richness (Margalef's formula) of diatom, dinoflagellate and zooplankton communities in the inner bay region which has undergone eutrophication and ecological alterations, was compared to the oligotrophic Gülbahçe bay which was characterised by higher species richness, thus highlighting the differences between the two areas. Such contrast in the structure of the ciliate communities is not evident: low values are observed in the inner stations of the Gülbahçe bay which are oligotrophic in character. In connection with this, an explanation for the lower richness values for ciliates in Gülbahçe bay must be found, an explanation which will not concern the dominance but rather the decrease in the number of species and individuals (Fig. 8).

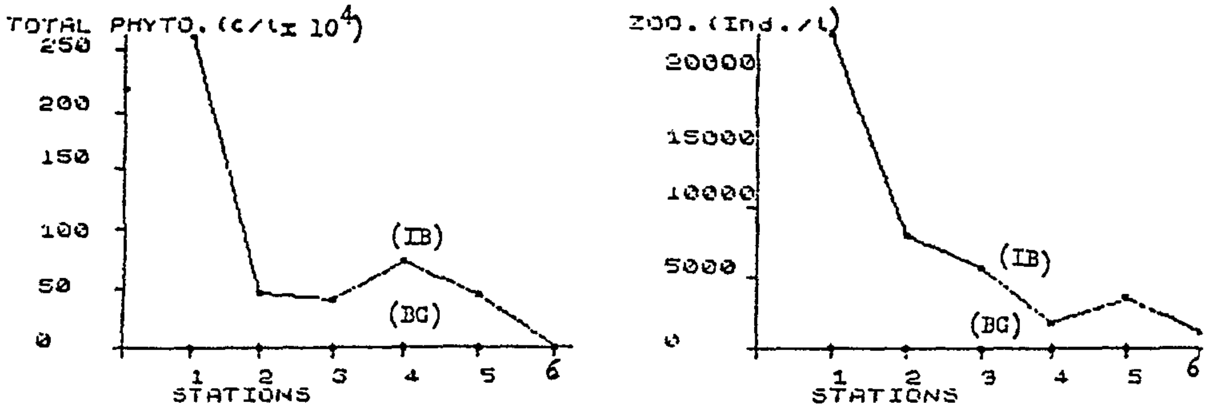

Fig. 7 Average quantitative variations in primary producers and secondary producers observed in the inner and outer regions of the Izmir Bay

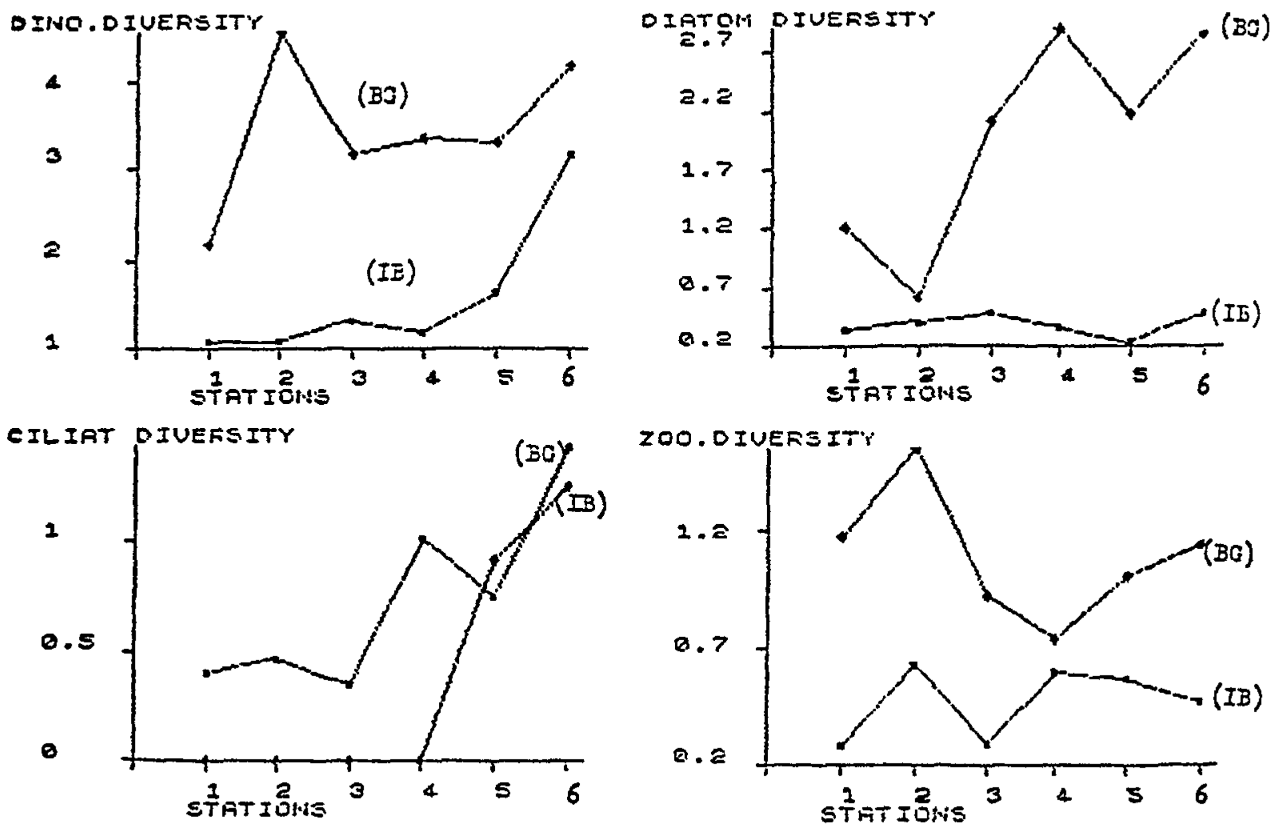

Fig. 8 Richness of diatom, dinoflagellate, ciliate and zooplankton species in the inner bay and Gülbahçe Bay

It is possible to differentiate the inner bay, which undergoes hypertrofication occasionally, from Gülbahçe bay which is partly oligotrophic, from the microplankton community composition excluding the ciliates. However, care should undoubtedly be taken to bear in mind the plankton patchiness.

As can be seen in Fig. 9, all microplankton community parameters as a whole can be used as data in the Shannon Weaver index and still trace the differences between the inner bay and Gülbahçe bay. Nevertheless, it is interesting that the most distant station in both bays (St. no.6) shows a similarity in community structure. Similarity is also observed in both bays at stations where there are fresh water entrances (St. no.1). Marked differences have been observed between the other stations.

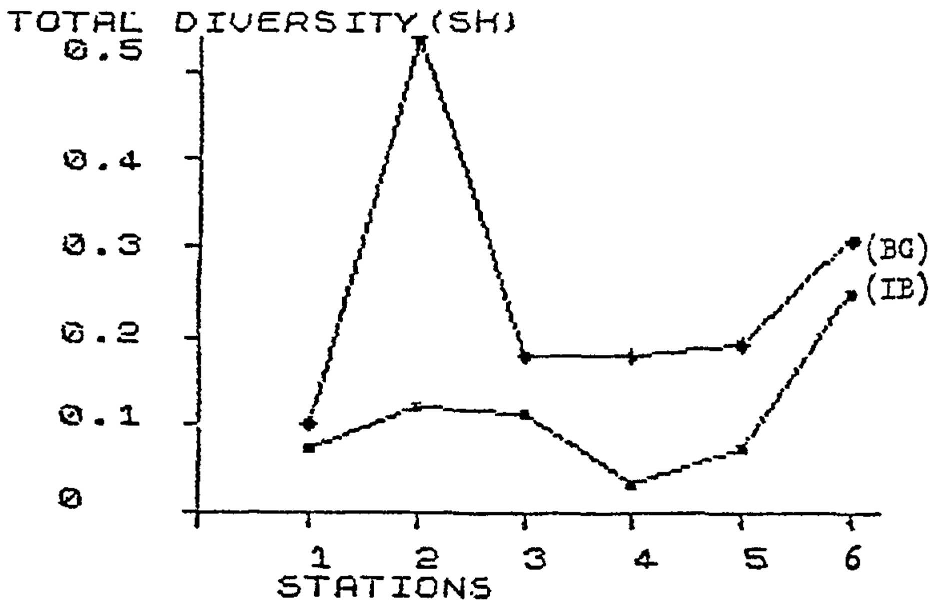

Fig. 9 Total diversity determined by the quantitative characteristics of diatom, dinoflagellate, ciliate and zooplankton groups in stations of inner bay and Gülbahçe Bay

6.3 Benthos

Benthic sampling revealed 75 species and 3814 individuals in the inner bay, whereas the corresponding numbers in Gülbahçe bay were 179 and 9113 (Table V).

Both regions are dominated by Polychaeta which rank first both in diversity of species and number of individuals. Next comes the Mollusca group in the inner bay, while the diversity of Crustacea in Gülbahçe is higher (Table V). On the whole there is a wide diversity between stations in both regions. With the exception of station 6, polychaetes which rank high in both regions show a lower diversity index in the inner bay stations when compared with those in Gülbahçe (Fig. 10). The same pattern is found for the Mollusc and Crustacean groups. Although Echinodermata are found in all stations of the Gülbahçe region, they are only found in station 6 of the inner bay.

Number of species, number of individuals and diversity index for each station in both regions, are shown in Table VI. The corresponding ranges in the inner bay are 5-66, 152-1524 and 0.81-5.20, whereas in the Gülbahçe region they are 69-101, 1305-1684 and 5.15-5.86.

Table V

Total number of species and individuals of different groups found in inner bay and Gülbahçe Bay.

GROUPS	Inner Bay		Gülbahçe Bay	
	Species number	Number of individuals	Number of Species	Number of individuals
Polychaetes	47	2628	79	6375
Molluscs	15	1119	41	1542
Crustaceans	8	51	46	772
Others	5	16	13	454
Total	75	3814	179	9143

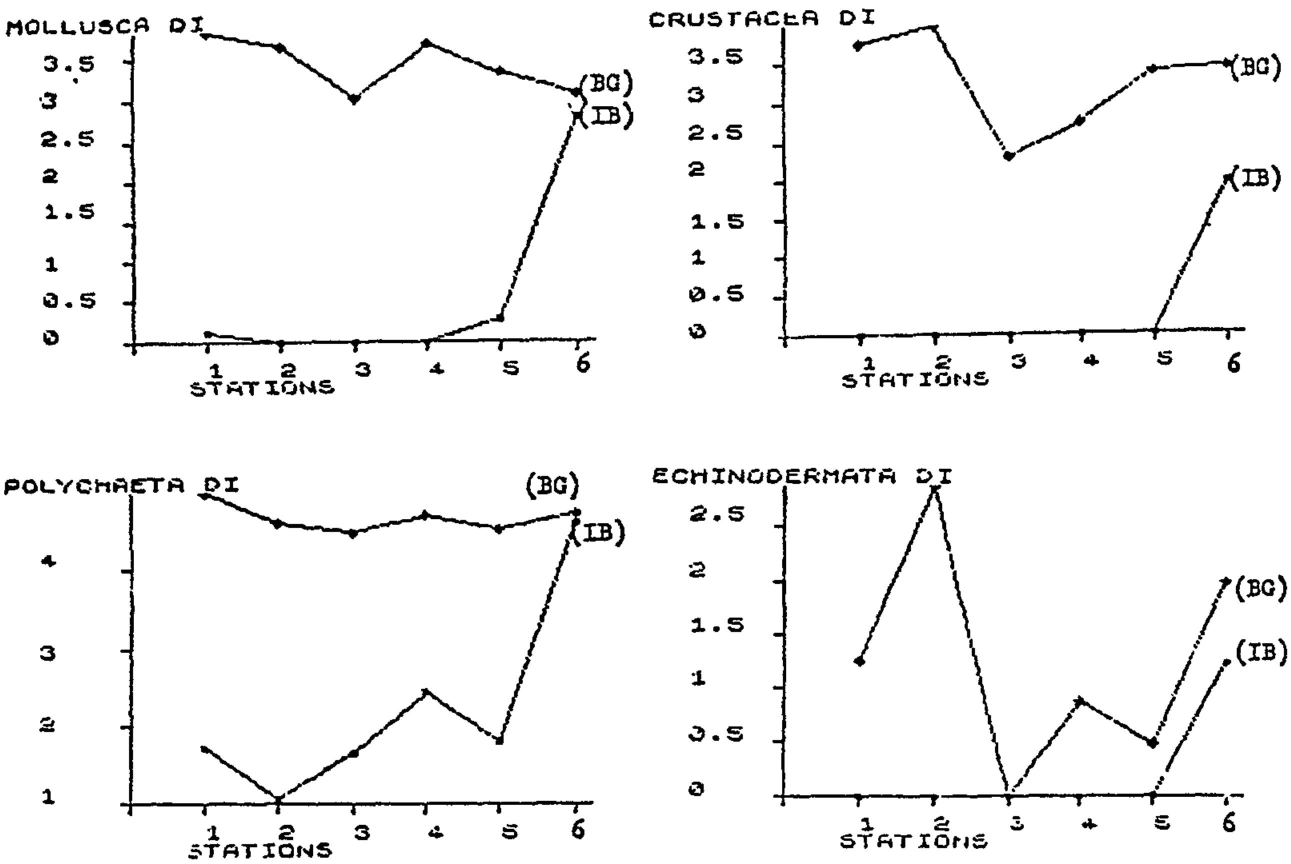

Fig. 10 Diversity indices of different groups in stations of inner bay and Gülbahçe Bay

Table VI

The number of species (NS) and individuals (NI) with diversity indices (DI) of different groups found in stations of inner bay and Gülbahçe Bay.

GROUPS		Polychaetes			Molluscs			Crustaceans			Echinoderms			TOTAL		
	STATIONS	NS	NI	DI	NS	NI	DI	NS	NI	DI	NS	NI	DI	NS	NI	DI
INNER BAY	1	7	1452	1.72	2	71	0.11	1	1	-	-	-	-	10	1524	1.98
	2	4	56	1.06	1	96	-	-	-	-	-	-	-	5	152	1.34
	3	7	386	1.65	1	16	-	1	6	-	-	-	-	9	408	1.91
	4	9	78	2.44	1	286	-	-	-	-	-	-	-	10	346	1.32
	5	4	38	1.79	4	436	0.29	-	-	-	-	-	-	8	474	0.81
	6	41	618	4.60	14	232	2.81	6	46	1.99	3	12	1.25	66	920	5.20
GULBAHCE BAY	1	49	1048	4.98	22	242	3.82	27	288	3.74	3	12	1.25	101	1592	5.86
	2	45	1086	4.60	24	314	3.65	22	138	3.97	8	22	2.86	99	1562	5.56
	3	42	859	4.49	16	214	3.03	10	94	2.32	1	22	-	69	1305	5.15
	4	44	1096	4.69	22	330	3.69	11	86	2.77	4	144	0.88	81	1656	5.45
	5	39	982	4.50	15	204	3.33	15	92	3.41	3	96	0.48	72	1324	5.26
	6	46	1262	4.70	19	224	2.08	17	70	3.48	9	128	1.99	91	1684	5.40

As can be seen from the results discussed above, there is an uneven pattern of species richness in the inner bay stations under the effect of heavy pollution whereas in the outer region (Gülbahçe) stations a homogeneous situation can be observed (Fig. 11).

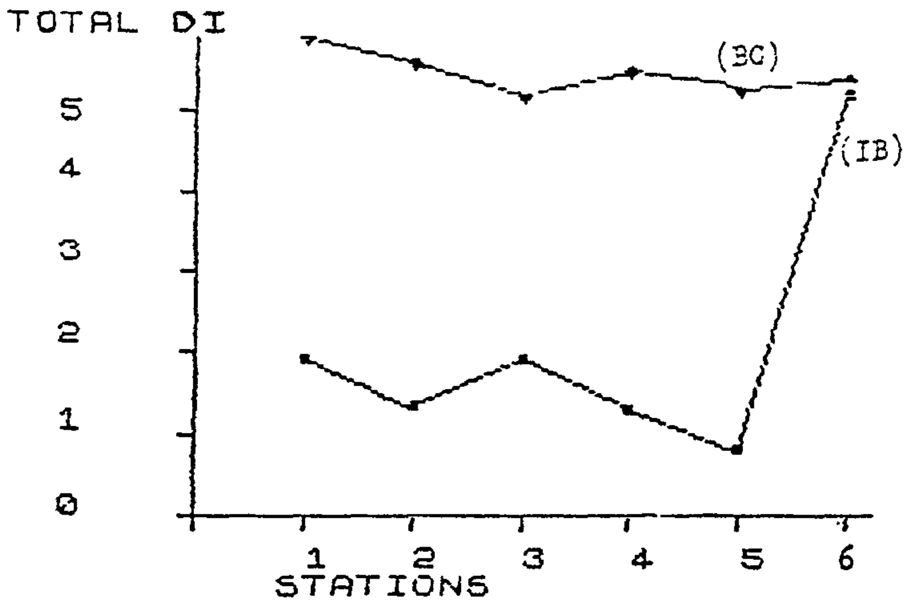

Fig. 11 Total diversity in each of the stations (both bays)

6.4 Fish

There is a regular increase in the number of species from the interior towards the exterior part of the inner bay whereas a fluctuation is observed in stations of the Gülbahçe Bay (Fig. 12). However, when we compare the two qualitatively, Gülbahçe Bay is richer. When we compare the two regions quantitatively, the inner bay is richer due to the abundance of anchovy especially in stations 2 and 3.

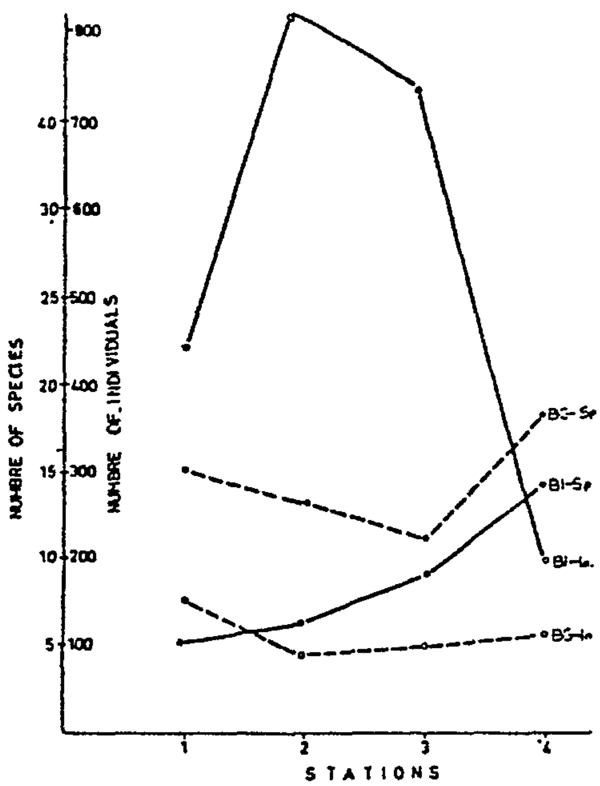

Fig. 12 Distribution of number of species and individuals in stations of both bays

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EVALUATION OF THE CONDITIONS OF SOME *Posidonia* MEADOWS IN THE NORTH-WESTERN MEDITERRANEAN SEA AND EVENTUAL EFFECTS OF POLLUTANTS ON THE ASSOCIATED FAUNA

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ABSTRACT

A survey of the *Posidonia* meadows at Bogliasco off the coast of Genoa was carried out in order to evaluate the environmental effect of a small sewage outlet. A numerical assessment of the density of the bundles of *Posidonia* was carried out by divers, along a series of stations taken at different distances from the outfall. Examination of the meadow condition, according to bundle density shows a very restricted negative effect along a narrow strip on either side of the effluent. Additional examination of the epiphytic populations of hydroids and bryozoans and statistical treatment of the data was not conclusive enough to indicate a pollution effect on these populations. The general condition of the *Posidonia* meadow at this locality may be considered as satisfactory. However, as there are no previous data available for comparison, one cannot draw a final conclusion as to the evolution of the meadow in relation to the degree of pollution.

1. INTRODUCTION

Each benthic biocoenosis which is strictly dependent on a complex of environmental factors (such as water conditions, geological characteristics of the bottom, hydrodynamics of the area etc.) may display important variations corresponding to changes in these factors. The variation of a single or several parameters usually determines an alteration - in a short time - of the original population which may be directly proportional to the intensity of the variation. That is what occurs in the proximity of polluting outlets, where extremely reduced populations - mainly formed by a few pollution resistant species - often increase abnormally due to the absence of competition from other organisms.

To evaluate correctly the environmental effect of a polluting outlet, a complete knowledge of the original population which was present in the area is obviously necessary. When these data are lacking it is usually possible to refer to the population of one or more spots in the same geographical area which are free from polluting phenomena.

The *Posidonia oceanica* meadow, which is a rather well-known Mediterranean marine ecosystem (Panayotidis, 1980), is well developed along the Ligurian coasts. The variations of the previously cited environmental factors may cause a more or less marked regression of the meadow or - when the environmental changes are particularly important - its complete disappearance with serious consequences for the whole littoral system. The discharge of sewage or industrial effluents into the sea can certainly alter the balance of the ecological factors affecting the life and development of a *Posidonia* meadow, (Geraci and Cattaneo, 1980; Balduzzi *et al.*, 1984).

2. MATERIALS AND METHODS

To evaluate the effect of a small sewage outlet (Fig.1) on Posidonia, the meadow existing off Bogliasco, a small coastal town east of Genoa, was studied.

In each sampling station a series of density counts, counting the number of bundles on a surface of 900 cm^2, was carried out by divers. The counts were repeated three times in each station. Data were subsequently referred to a standardised surface of one square metre (Table I).

Table I

Density of the meadow as number of bundles per square meter.

Station	Density
PB	181
1N	226
1S	178
1E	189

In another station (station D) a more detailed surveying method was employed. In this place, the meadow shows signs of extensive degeneration in the proximity of the pipe outlet. In this case the density counts were made at increasing distances and on both sides of the pipe along a transect crossing its axis (Table II).

Table II

Density of the meadow as number of bundles per square meter in the proximity of the pipe outlet.

Location	Density
1 m E	-
2 m E	-
5 m E	177
10 m E	144
15 m E	189
1 m W	-
2 m W	-
5 m W	144
10 m W	122
15 m W	167

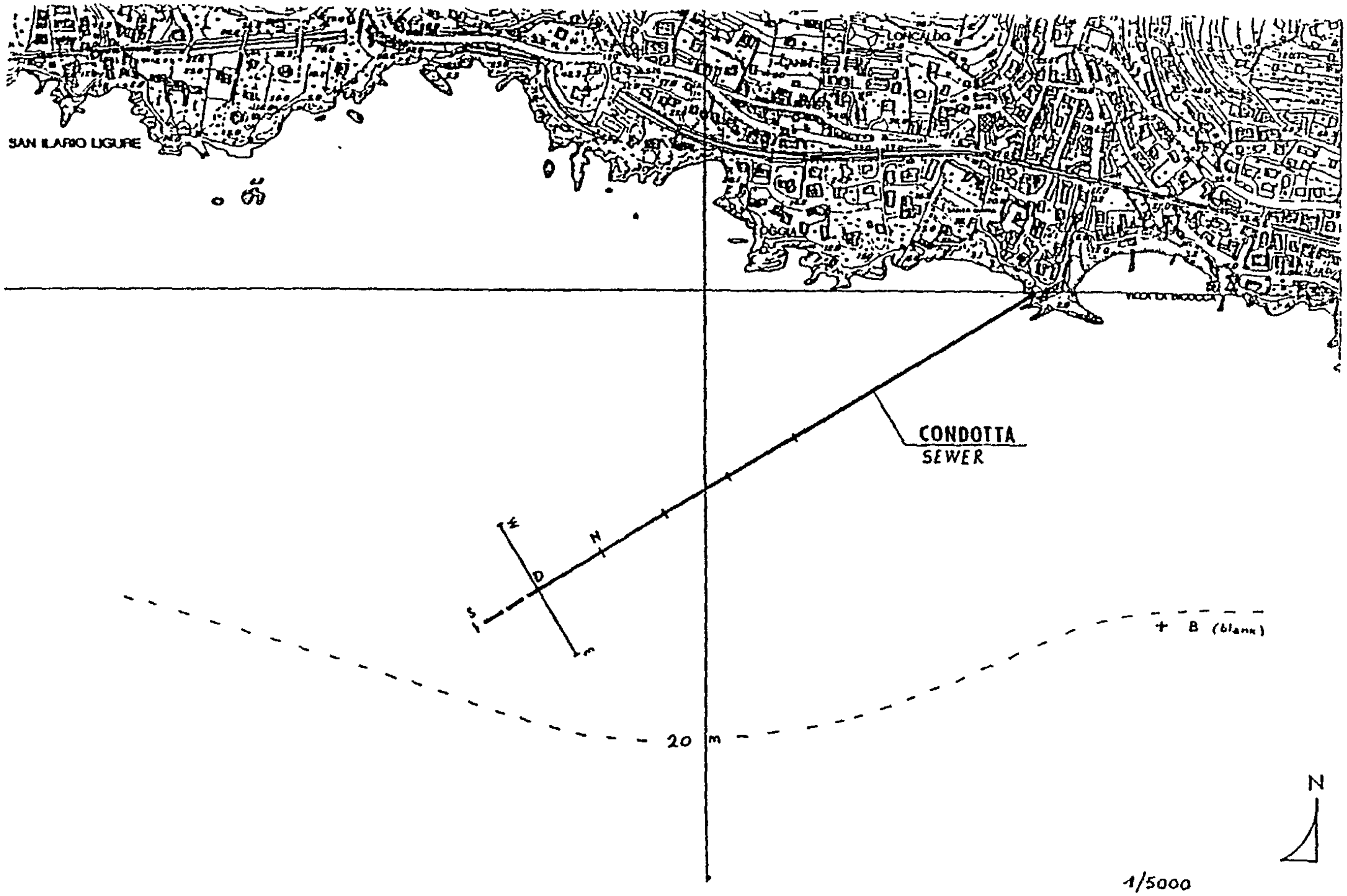

Fig. 1 Location of sampling sites

3. RESULTS AND DISCUSSION

3.1 The Posidonia meadow

The meadow, according to the density values observed and to Giraud's (1977) classification, has to be considered as "very rarefied" in all the examined stations. Despite the low density values and the lack of comparative data on the history of the examined area, the present situation may be considered as normal. Comparable data from literature on similar areas support this assumption.

The remarkable uniformity of the values recorded among the various stations suggest that the effect of this sewage outlet is not considerable. Special attention was given to the conditions of the meadow close to the outlet. Posidonia plants are completely absent on both sides of the end part of the pipe over an area at least two metres wide. The most probable causes of their disappearance are the extremely localized salinity drop due to the freshwater outflow and a probable modification of the edaphic characteristics. The meadow condition, according to bundle density, appear normal at a distance of only 5 m from the outlet, suggesting a very restricted negative effect of the effluent.

However, in a strip 30-40 m wide on both sides of the sewer, it is possible to detect by direct observation a remarkable reduction in the mean length of the leaves. This phenomenon may be related to an early loss of the leave's apical part, because of a more rapid and intense covering by vegetable epiphytes. This is probably due to a nutrient increase close to the outlet which affects the development of epiphytic algae.

3.2 Epiphytic populations of hydroids and bryozoans of the considered meadow: a statistical analysis

In order to show possible differences in the benthic populations living in the meadow due to the presence of the outlet, the hydroid and bryozoan epifauna was studied. These taxa represent the most abundant component of the sessile fauna on Posidonia beds, both qualitatively and quantitatively, and that is why they were chosen for this study. The list of the identified species with presence-absence data for each station, is given in Table III. The data were classified according to the well-known differences between leaf and rhizome populations.

None of the identified species can be considered as indicating the presence of pollution. Among 48 identified taxa, only Schizoporella longirostris, Schizoporella dunkeri and Turbicellepora avicularis had never before been recorded on Posidonia. However, since these are species that commonly thrive in different environments, we do not attribute any special significance to their presence.

If we compare our data with data reported by other authors on various meadows, (Kerneis, 1960; Harmelin, 1973; Hayward, 1974; Relini Orsi et al., 1977; Geraci and Cattaneo, 1980; Boero, 1981; Balduzzi et al., 1983; Fresi et al., 1983), the total number of identified taxa seems to be rather high. In order to show similarities in the specific composition among the sampling stations, the presence-absence data were statistically treated by the factorial analysis of correspondences, (Benzecrì, 1982). In this analysis the similarity among various stations is a function of the distance that separates the sample points shown individually on the factorial plane. The different species are thus associated with a single station or a group of stations according to the ecological characteristics of the latter.

Table III

List of species identified in the sampling stations on *Posidonia* leaves and rhizomes. Presence-absence data.

Species	FD	RD	FN	RN	FE	RE	FS	RS	FB	RB
HYDROIDS										
1. *Aglaophenia harpage* von Schenck, (1965)	+				+		+			
2. *Campanularia sp.*	+									
3. *Clytia haemisphaerica* (L., 1767)	+		+		+		+			
4. *Ectopleura larynx* (Wright, 1863)	+									
5. *Halecium pusillum* (M.Sars, 1857)	+						+		+	
6. *Obelia dichotoma* (L. 1758)	+									
7. *Stylactis inermis* (Allman, 1872)	+									
8. *Clava sp.*			+							
9. *Cordylophora pusilla* (Mots-Kossowska, 1905)			+		+				+	
10. *Plumularia obliqua* (Johnston, 1847)			+						+	
11. *Sertularia perpusilla* (Stechow, 1919)			+				+			
12. *Coryne sp.*									+	
BRYOZOANS										
Ctenostomes										
13. *Nolella dilatata* (Hincks, 1860)	+			+	+	+	+	+		
14. *Nolella gigantea* (Busk, 1856)					+	+				
15. *Pherusella tubulosa* (Ellis & Solander, 1786)				+						+
Chilostomes										
16. *Electra posidoniae* (Gautier, 1954)	+		+		+		+		+	
17. *Beania mirabilis* (Jonhston, 1839)	+				+		+			

Table III (cont.)

Species	Stations									
	FD	RD	FN	RN	FE	RE	FS	RS	FB	RB
18. *Beania hirtissima* (Heller, 1867)										+
19. *Beania robusta* (Hincks, 1881)										+
20. *Aetea sica* (Couch, 1844)	+	+	+	+	+	+	+	+	+	
21. *Cellaria salicornioides* (Lamouroux, 1816)		+								
22. *Bugula sp.*							+			
23. *Chlidonia piriformis* (Bertoloni, 1810)								+		
24. *Copidozoum tenuirostre* (Hincks, 1880)				+		+				+
25. *Scrupocellaria scrupea* (Busk, 1851)										+
26. *Cribrilaria innominata* (Couch, 1844)					+					
27. *Collarina balzaci* (Audouin, 1826)	+		+				+		+	
28. *Puellina gattyae* (Landsborough, 1852)							+			
29. *Chorizopora brongniartii* (Audouin, 1826)	+	+	+	+	+		+	+	+	+
30. *Haplopoma impressum* (Audouin, 1826)	+		+		+	+	+		+	
31. *Haplopoma graniferum* (Jonston, 1847)										+
32. *Escharina vulgaris* (Moll, 1803)	+		+		+		+		+	
33. *Celleporina hassallii* (Johnston, 1847)	+		+		+		+		+	
34. *Fenestrulina malusii* (Audouin, 1826)	+	+		+		+		+		+
35. *Fenestrulina joannae* (Calvet, 1902)			+		+					
36. *Rhynchozoon sp.*		+								
37. *Pentapora ottomulleriana* (Moll, 1803)	+		+				+		+	
38. *Schizoporella longirostris* (Hincks, 1886)		+								

Table III (cont.)

Species	Stations									
	FD	RD	FN	RN	FE	RE	FS	RS	FB	RB
39. *Schizoporella dunkeri* (Reuss, 1848								+		
40. *Schizomavella auriculata* (Hassali, 1842)						+				+
41. *Schizobrachiella sanguinea* (Norman, 1868)				+		+				
42. *Hippotoa divaricata* (Lamouroux, 1821)	+									
43. *Microporella ciliata* (Pallas, 1766)					+		+		+	
44. *Arthropoma cecilii* (Audouin, 1826)						+		+		
45. *Cryprosula pallasiana* (Moll, 1803)						+				
46. *Turbicellepora avicularis* (Hincks, 1880)			+							
47. *Turbicellepora sp.*	+									
Ciclostomes										
48. *Crisia spp.*	+					+				

Figure 2, which is the graphic result of this analysis, can be briefly commented upon. Along the first factor axis (the x axis) which shows the highest per cent variance of the system, what is most evident is a clear separation between leaf and rhizome stations. This is not surprising, since it is in accordance with literature data which attribute well-marked differences to the populatons of these two layers. Some authors even attribute the leaf and rhizome strata to different biocoenoses respectively.

The distribution of the station points on the factorial plane indicates also that the leaf population appears much more uniform than the rhizome population; the rhizome stations in fact display a remarkable scattering along the second factor axis (the y axis). Indeed, the *Posidonia* leaves, represent a distinctive substrate which selects a very specialized population. On the other hand, the rhizomes, which are far less specific, can host a more differentiated epiphytic population. Station RB however which represents the blank point, clearly differs from all other stations and particularly from station RD. Such a distribution may suggest the existence of a gradient of an unidentified environmental factor along the RD-RB direction.

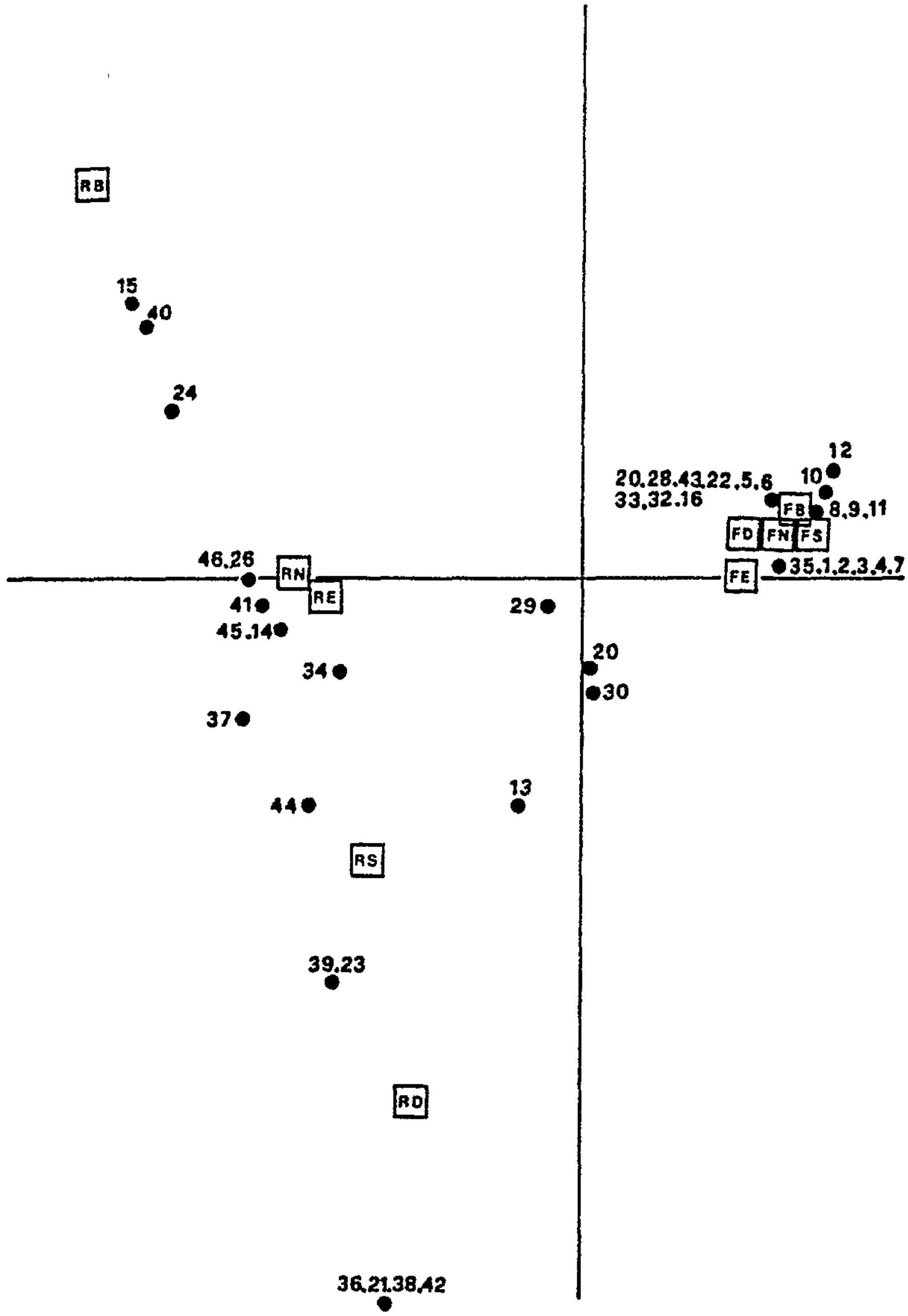

Fig. 2 Factorial analysis of correspondences. The graphic represents the statistical treatment of presence-absence data of species in the examined stations, separating the leaf layer (F) from the rhizome layer (R).
Explained per cent variance: I axis: 24,4%, II axis 16,7%

In order to eliminate the disturbance generated by the naturally existing differences between leaf and rhizome populations, the statistical treatment was repeated using only rhizome population data. (Fig.3).

The results of this analysis confirm the previous one at a higher significance level. Indeed, on the first factor axis the same station point distribution pattern that was observed along the second factor in the previous analysis is perfectly evident.

Along the second factor axis a scattering of the stations which are close to the outlet is found. This phenomenon is rather difficult to explain with the data available and in any case it militates against the hypothesis of a continual gradient between stations RB and RD.

On the basis of the results obtained, a direct effect of the studied outlet on the epiphytic population of the rhizomes of station RD can be assumed. It may be caused by a variation of the physico-chemical parameters close to and on the bottom, which can produce a selection when larvae try to settle on the rhizomes. The data obtained however do not permit the exclusion of the possibility that the observed distribution could be completely random. This distribution pattern may be connected with either the well-known phenomenon of patchiness in the settling of epiphytes or with other environmental factors - so far unknown - and not necessarily connected with the disposal of sewage.

4. CONCLUSIONS

The environmental effects of the presence of the outlet on the benthic communities seem to be rather small according to the observations and analyses carried out. The destructive effect of the sewage disposal on the Posidonia meadow appears to be restricted to a narrow strip on both sides of the sewer. Furthermore, the photosynthetic surface reduction of Posidonia bundles is limited to a strip not more than 30-40 m wide along the pipe trail. The negative effects of the effluent may be restricted to a slight and extremely localized reduction of environmental productivity. The general condition of the Posidonia meadow off Bogliasco, on the basis of the analyses and direct observations carried out, may be considered to be satisfactory: the lack of historical data for comparison, however does not permit us to draw a final conclusion.

5. AKNOWLEDGEMENTS

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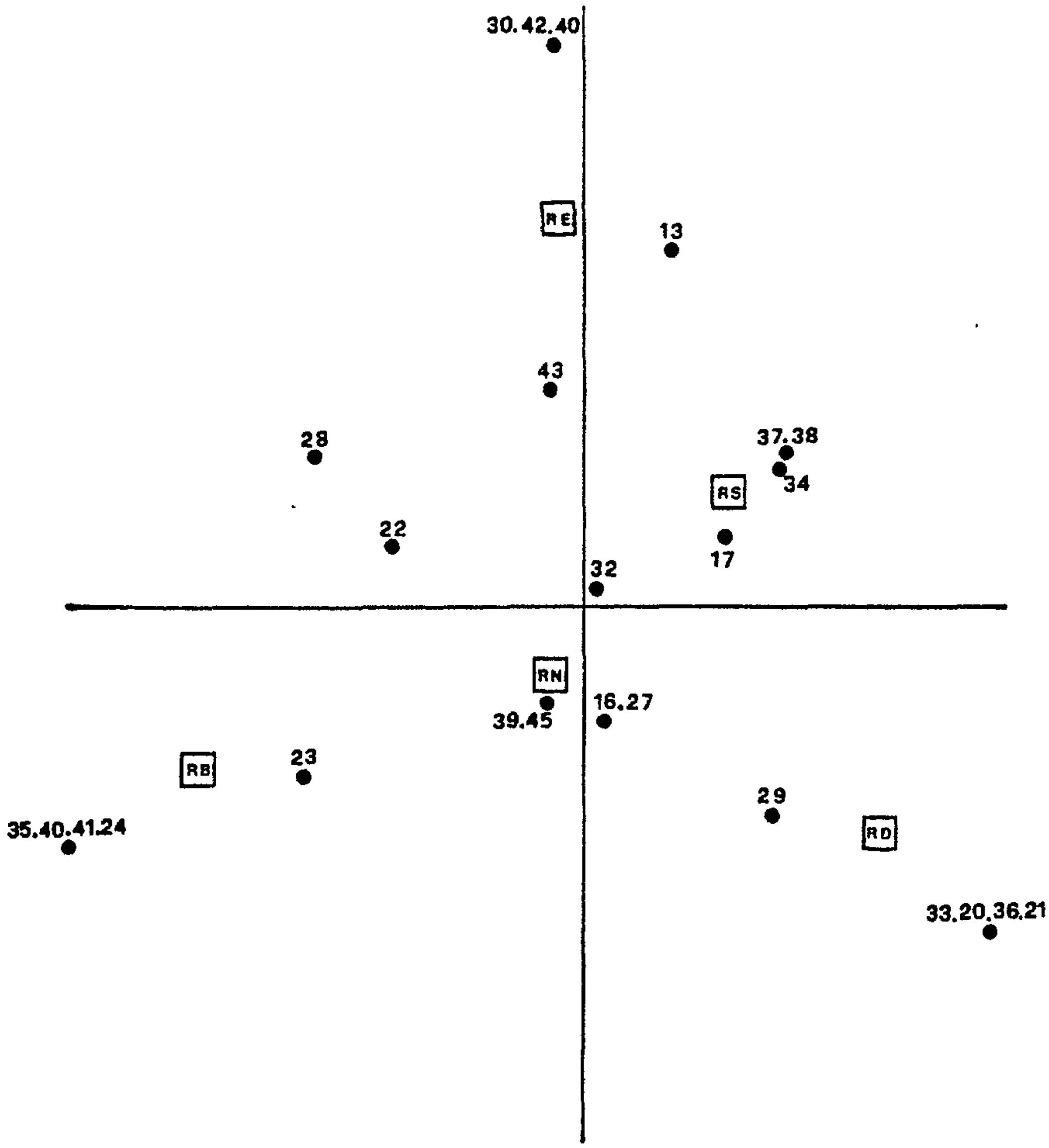

Fig. 3 Factorial analysis of correspondences. The graphic represents the statistical treatment of presence-absence data of species in the examined stations, taking into account the rhizome (R) layer only. Explained per cent variance: I axis: 31,6%, II axis: 28,5%

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ETUDE DE L'IMPACT DE LA POLLUTION SUR LES HERBIERS DE Posidonia oceanica (LINNAEUS) DELILE, DANS LE GOLFE SARONIKOS (MER EGEE, GRECE)

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R E S U M E

La distribution et la phenologie de la phanerogame marine Posidonia oceanica (Linaeus) Delile, ainsi que la bioaccumulation des ions métalliques Cd, Cr et Ni par les racines, rhisomes et feuilles de la plante, ont été étudiées dans le Golfe Saronikos de juin 1984 à juillet 1985.

Les résultats de cette étude ont montré que les herbiers de P. oceanica sont bien développés dans le secteur extérieur du Golfe Saronikos, tandis que dans le secteur ouest ils sont pratiquement absents. Le secteur intérieur du golfe peut être considéré comme une zone de transition.

La rareté des herbières dans le secteur ouest du golfe ne semble pas être liée aux activités humaines mais aux conditions hydrologiques (faible renouvellement naturel des eaux).

L'impact de la pollution est important dans le secteur intérieur du golfe qui se trouve au contact de la zone industrielle et de l'émissaire centrale de la ville d'Athènes. En plus, sur les côtes de l'Attique qui appartiennent à ce secteur, une série de constructions a modifié la quasi totalité du rivage naturel. Le résultat de ces activités humaines fut néfaste pour le développement des herbiers: sur une grande surface de ce secteur il n'y a actuellement que de "matte" morte, tandis que là où l'herbier résiste encore, sa densité au m^2 et son indice foliaire sont faibles. Néanmoins nous n'avons pas observé des modifications du cycle de renouvellement des feuilles de P. oceanica, fait qui nous permet de considérer que sous le régime actuel de pollution les herbiers du secteur intérieur ne risquent pas de disparaître brutalement.

En ce qui concerne la bioaccumulation des ions métalliques dans les différentes parties végétatives de P. oceanica, les concentrations mesurées dans l'ensemble du golfe sont faibles et ne présentent pas des variations importantes ni dans le temps ni dans l'espace.

1. INTRODUCTION

Le golfe Saronikos situé en gros entre les latitudes 37° 30' N et 38° N et les longitudes 23° E et 24° E, appartient à une zone biogéographique favorable au développement des herbiers de Posidonia oceanica (Linnaeus) Delile (Peres et Picard, 1958). Les marges de variation de la salinité (de 38 à 39 pour mille) et de la température (de 13° C à 23° C) sont telles que la présence de P. oceanica ne semble pas être a priori exclue d'une partie du golfe.

Le problème de la pollution dans le golfe Saronikos a fait l'objet de nombreuses études physicochimiques (Friligos, 1975; Ignatiades et Mimicos, 1977; Friligos, 1976) et biologiques (Moraitou-Apostolopoulou et Ignatiades, 1977).

La végétation du golfe a été aussi étudiée (Diapoulis, 1983) mais le problème de l'impact de la pollution sur les herbiers de P. oceanica n'a pas été abordé.

Les herbiers de P. oceanica dans le golfe Saronikos sont menacés par des activités humaines telles que la pêche aux engins traînants (ex. gangui) et le mouillage aussi bien que la pollution par les rejets urbains et industriels.

Le but de cette étude est d'estimer l'impact des différents types de pollution sur la distribution des herbiers, d'obtenir des données sur leur vitalité et de mesurer la bioaccumulation de certains polluants.

2. TRAVAIL DE RECHERCHE

2.1 Etude sur le terrain

2.1.1 Méthodologie. Durant la période comprise entre juin 1984 et juillet 1986, nous avons fait des observations et des mesures par bateau ou en plongée autonome, sur une grande partie du golfe Saronikos (Fig. 1 et 2).

Les côtes situées au nord du golfe sont accessibles par la route. Par contre, les côtes des îles de Salamis, Aegina, Fleves, Angistri et Metopi, ainsi que la presqu'île de Methana ne sont pas facilement accessibles et elles ont été étudiées par bateau. Nous avons aussi étudié par bateau quelques secteurs profonds à l'aide d'instruments d'échantillonnage indirect (drague, benne).

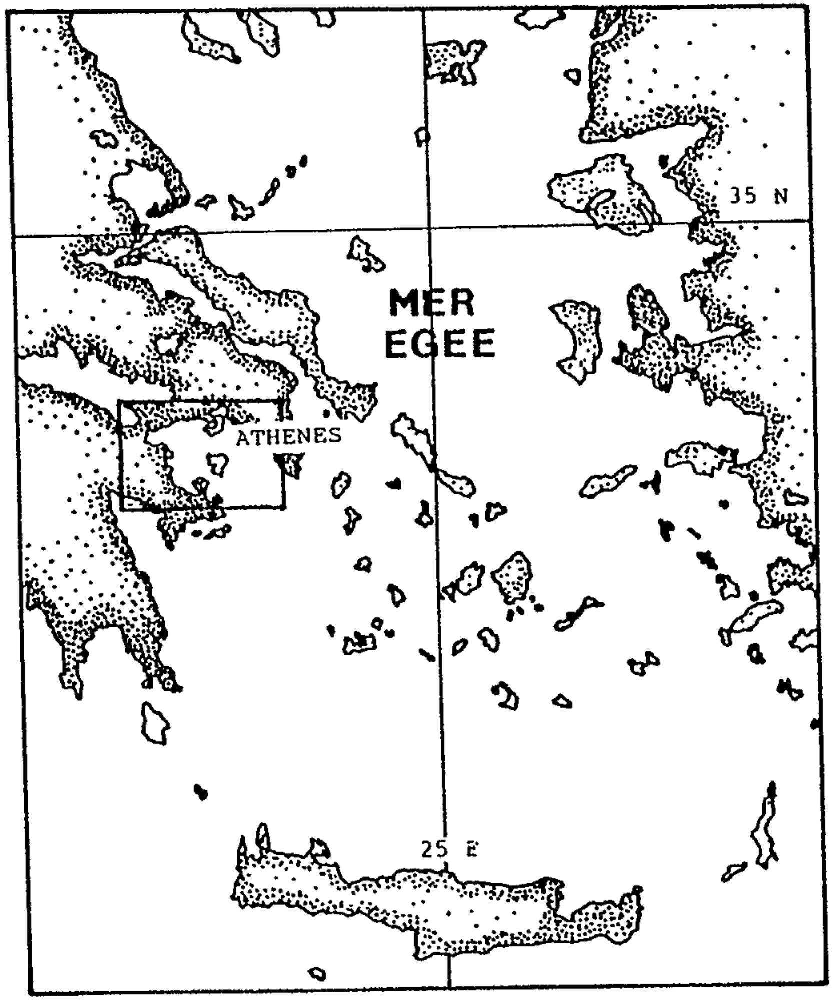
L'estimation de la densité de l'herbier a reposé sur des comptages effectués par plongée autonome, l'unité de comptage étant le faisceau des feuilles de P. oceanica (Fig. 3). Les comptages se réalisent sur une surface de 400 cm^2 d'herbier, définie par un cadre de 20x20 cm posé de place en place. Parallèlement aux comptages, nous avons noté in situ la position des faisceaux (verticale ou horizontale) et la présence ou absence de "matte" (échevauchement de racines et tiges de P. oceanica, issus de la croissance verticale de la plante). La microstructure de l'herbier a été prise en considération. Plusieurs lots de faisceaux espacés de quelques mètres ont été prélevés dans chaque station pour l'estimation de la variabilité de la densité au mètre carré.

2.1.2 Stations étudiées. Dans l'ensemble du golfe Saronikos, nous avons choisi 10 stations pour y effectuer des observations et des mesures (Fig. 2). Parmi les stations choisies, six sont situées à une profondeur de 5 à 6 mètres dans des baies abritées, tapissées d'herbier. Ces stations, qui sont à notre avis comparables au point de vue de l'impact de la pollution et convenables pour une suivi saisonnière, sont désignées par les symboles suivants:

Station 1: Agios Kosmas, située dans les parages nord du golf.

Station 2: Vagia, située dans les parages nord de l'île d'Aegina.

Station 3: Agia marina, située dans les parages est de l'île d'Aegina.



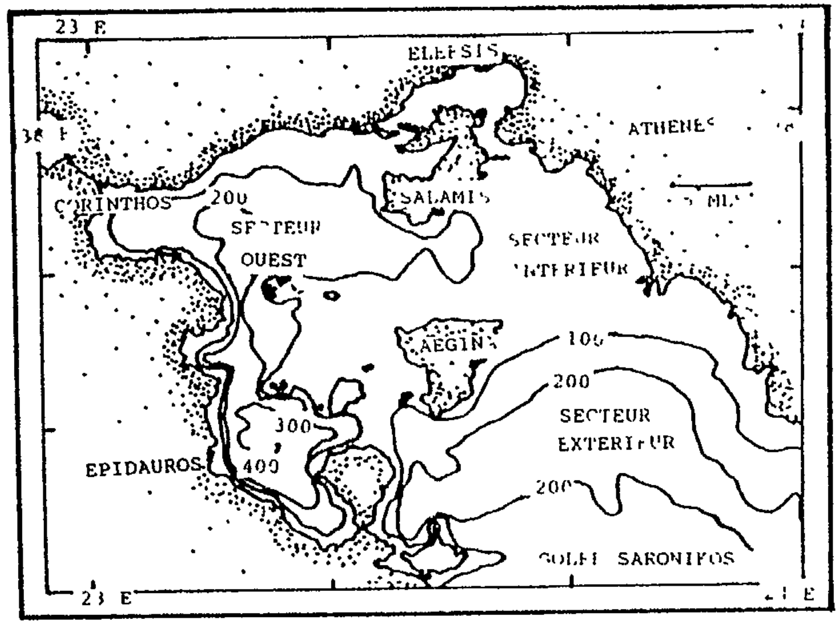


Fig. 1 Le golfe Saronikos dans la mer Egée

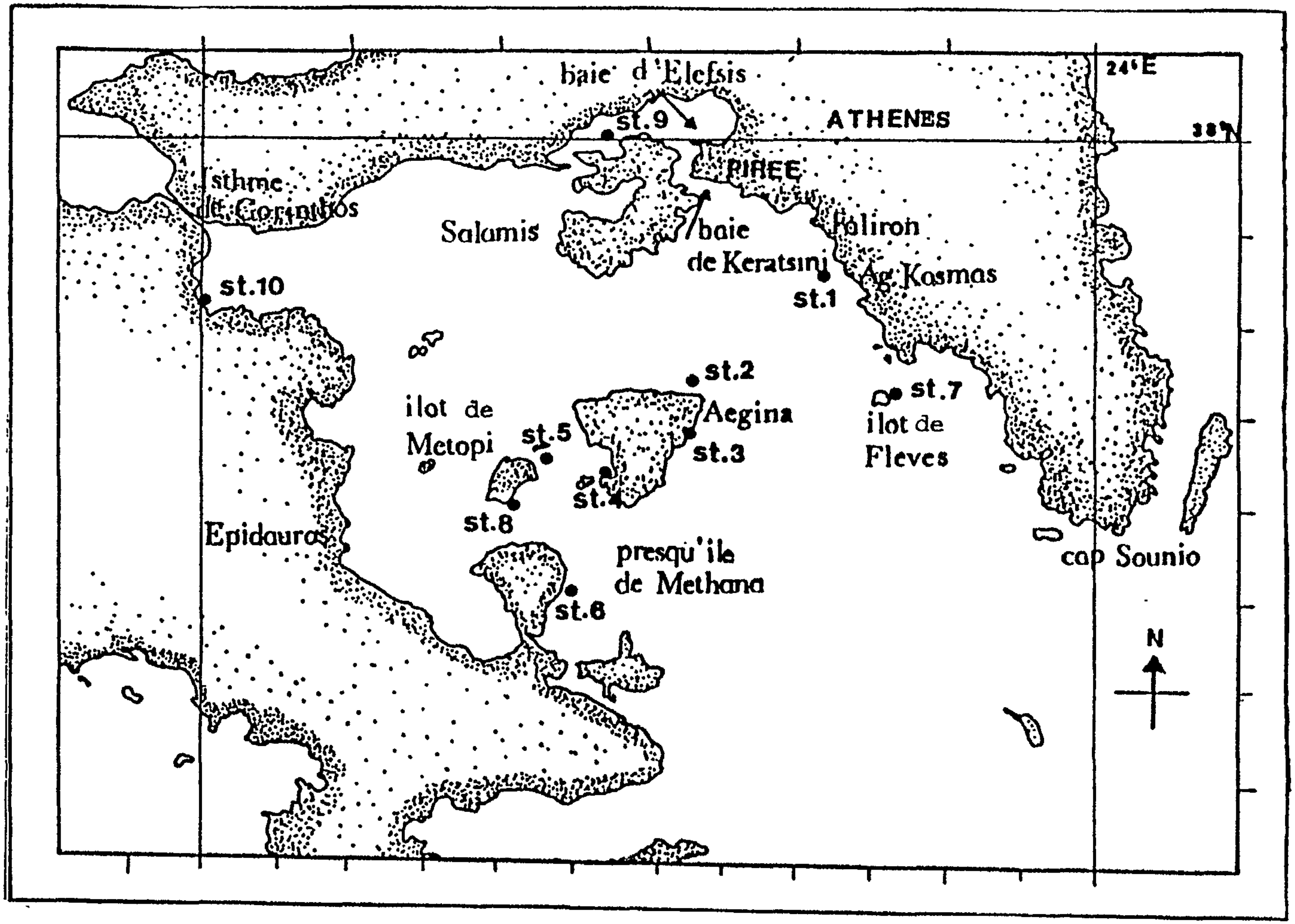


Fig. 2 Localités et stations du golfe Saronikos

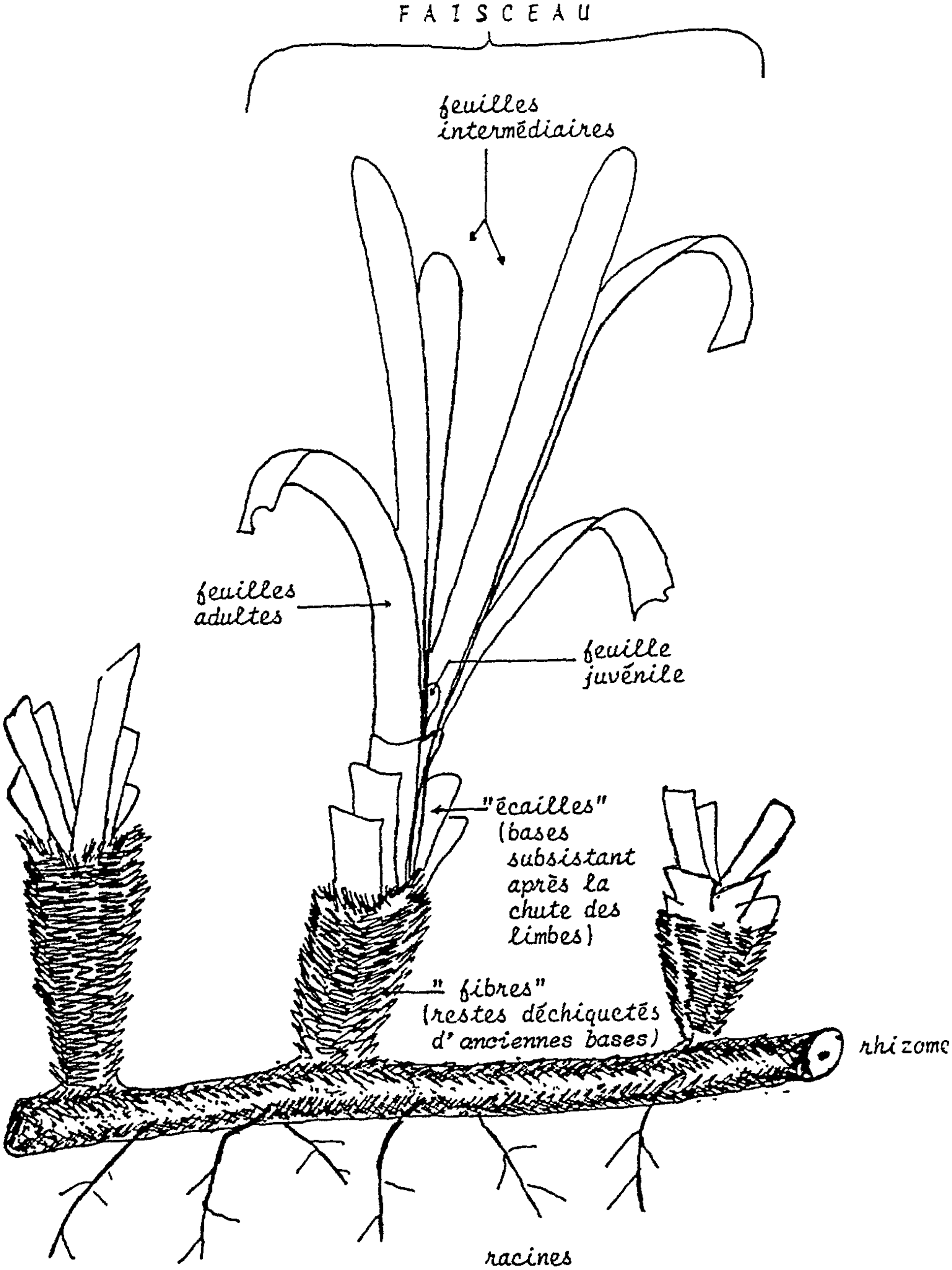


Fig. 3 Représentation schématique d'un faisceau de Posidonia oceanica X 3/4 (d'après Panayotidis, 1980)

Station 4: Perdica, située dans les parages sud-ouest de l'île d'Aegina.

Station 5: Metopi, située dans les parages sud-ouest de l'îlot de Metopi.

Station 6: Methana, située dans les parages est de la presqu'île de Methana.

Les Stations 1 et 2 sont situées dans la partie du golfe qui est directement influencée par la nappe de pollution de l'émissaire central d'Athènes (inner gulf, Dugdale et Hopkins, 1975). Les Stations 3 et 4 sont exposées à une pollution modérée, provenant des villages avoisinants, tandis que les Stations 5 et 6 se trouvent loin de tout rejet urbain.

Les quatre autres stations ont été choisies parce qu'elles présentent des conditions hydrologiques et hydrodynamiques intéressantes bien qu'elles ne soient pas directement comparables aux six stations précitées.

La Station 7: Fleves, est située dans les parages est de l'îlot de Fleve. Il s'agit d'une station exposée à un régime de pollution variable. L'herbier se trouve à 10 m de profondeur.

La Station 8: Angistri, est située dans les parages est de l'île d'Angistri. Il s'agit d'une station non polluée.

La Station 9: Phaneromeni, est située dans les parages nord de l'île de Salamis dans une région polluée où il n'existe actuellement qu'une prairie à Cymodocea et Caulerpa vers 4 m de profondeur.

La Station 10: Loutra Hellenis, est située dans les parages ouest du golfe (western gulf, Dugdale et Hopkins, 1975), dans un secteur non pollué où il n'existe actuellement qu'une prairie à Cymodocea, Caulerpa et Halophila, vers 4 m de profondeur.

2.2 Etude en laboratoire

A partir de chaque prélèvement de feuilles de P. oceanica, nous avons étudié les épibiontes selon la méthode proposée par Panayotidis (1980). Ensuite nous avons mesuré la surface foliaire. Pour étudier le cycle de vie de la plante nous avons soigneusement relevé les caractéristiques des structures foliaires (Fig. 4), selon le protocole proposé par Giraud, (1979). Au total, nous avons mesuré environ 10.000 feuilles. Les mesures de la longueur des feuilles ont été présentées sous forme d'histogrammes et polygones de fréquence. Cette technique permet une visualisation du cycle de renouvellement des feuilles.

Une étude du poids des feuilles en fonction de leur surface nous a permis d'établir une relation entre ces paramètres et d'émettre des hypothèses sur la biomasse et la productivité des herbiers.

Les différentes catégories de feuilles de P. oceanica expriment un niveau différent d'activité métabolique. Ce fait nous a conduit à étudier, parallèlement aux phénomènes de croissance, le phenomène de bioaccumulation de certains métaux lourds. La bioaccumulation des métaux Cd, Ni, Cr a été étudiée dans les différents tissus de P. oceanica: rhizomes, racines, feuilles adultes et feuilles intermédiaires.

Un point très important dans la méthodologie de l'analyse de métaux est le nettoyage des échantillons afin d'éliminer toute trace de sédiment et autre matière étrangère qui pourrait fausser les dosages. Les écailles des feuilles mortes sont ôtées des tiges; toutes les parties de la plante et spécialement les feuilles sont débarrassées des épiphytes à l'aide d'une spatule de PVC.

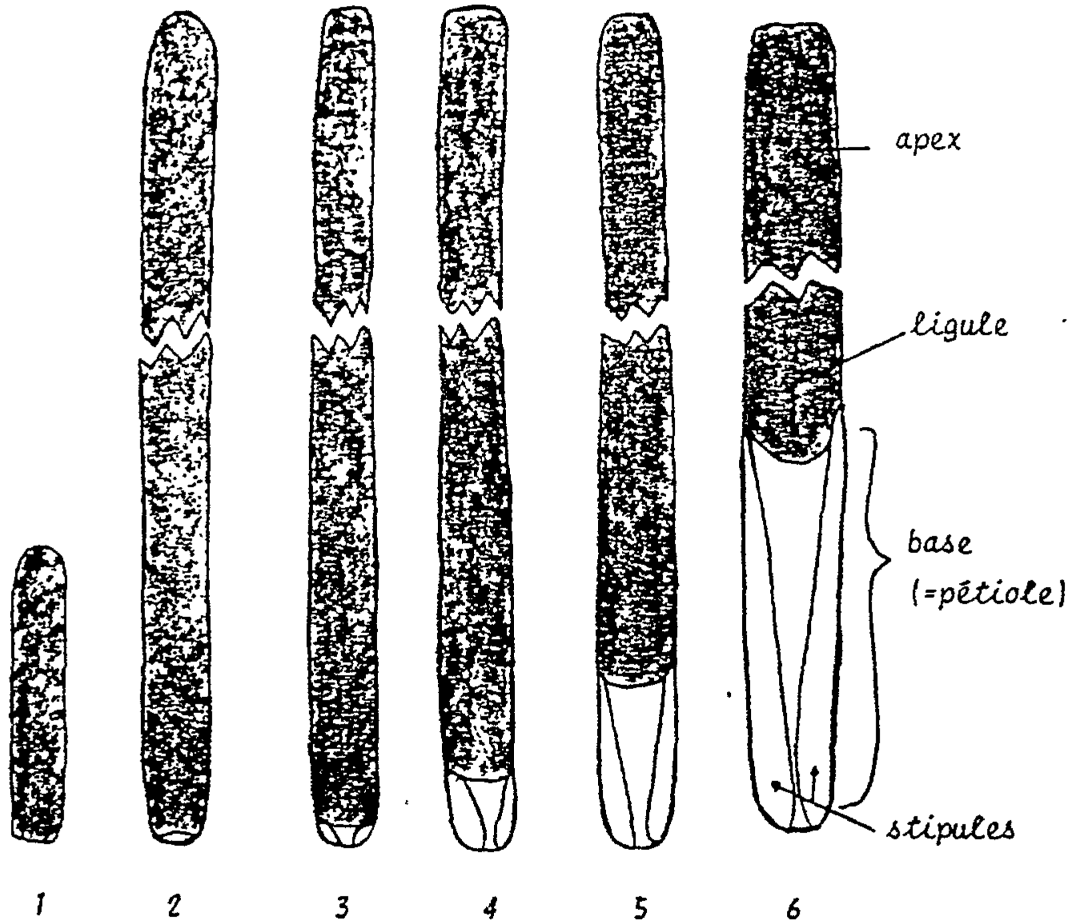


Fig. 4 Structures foliaires de P. oceanica. Passage d'une feuille du stade juvénile (1) au stade intermédiaire (2, 3) et adulte (4, 5, 6). Dimensions naturelles. (D'après Panayotidis, 1980)

Les tissus de P. oceanica ont été lyophilisés et homogénéisés selon le protocole proposé par Bernhard, (1976). Par la suite, nous avons appliqué le protocole proposé par UNEP/FAO/IAEA/IOC (1984), qui prévoit la digestion de 0.5 gr environ de tissus par 5 ml d'acide nitrique dans des bombes teflon pendant six heures à 150 °C. Ensuite, on realise le dosage des métaux par spectrophotométrie d'absorption atomique avec flamme pour les métaux Ni, Cr et Cd.

3. RESULTATS ET DISCUSSION

3.1 Cartographie et limites inférieures

Nos observations ont montré que les herbiers de P. oceanica couvrent de grandes surfaces de la partie extérieure du golfe (Fig. 5, 6, 7) limitée par la presqu'île de Methana, l'île d'Aegina et les côtes de l'Attique, de l'îlot de Fleves au cap Sounion. Plus à l'ouest entre l'île d'Aegina, l'île D'Angistri et l'îlot de Metopi, sur un vaste plateau (Fig. 8) limité par l'isobathe de 50 m, se trouvent les herbiers les plus étendus et les plus denses du golfe. Neanmoins, une grande partie du fond présente de larges entremattes provoquées par la pêche et le mouillage.

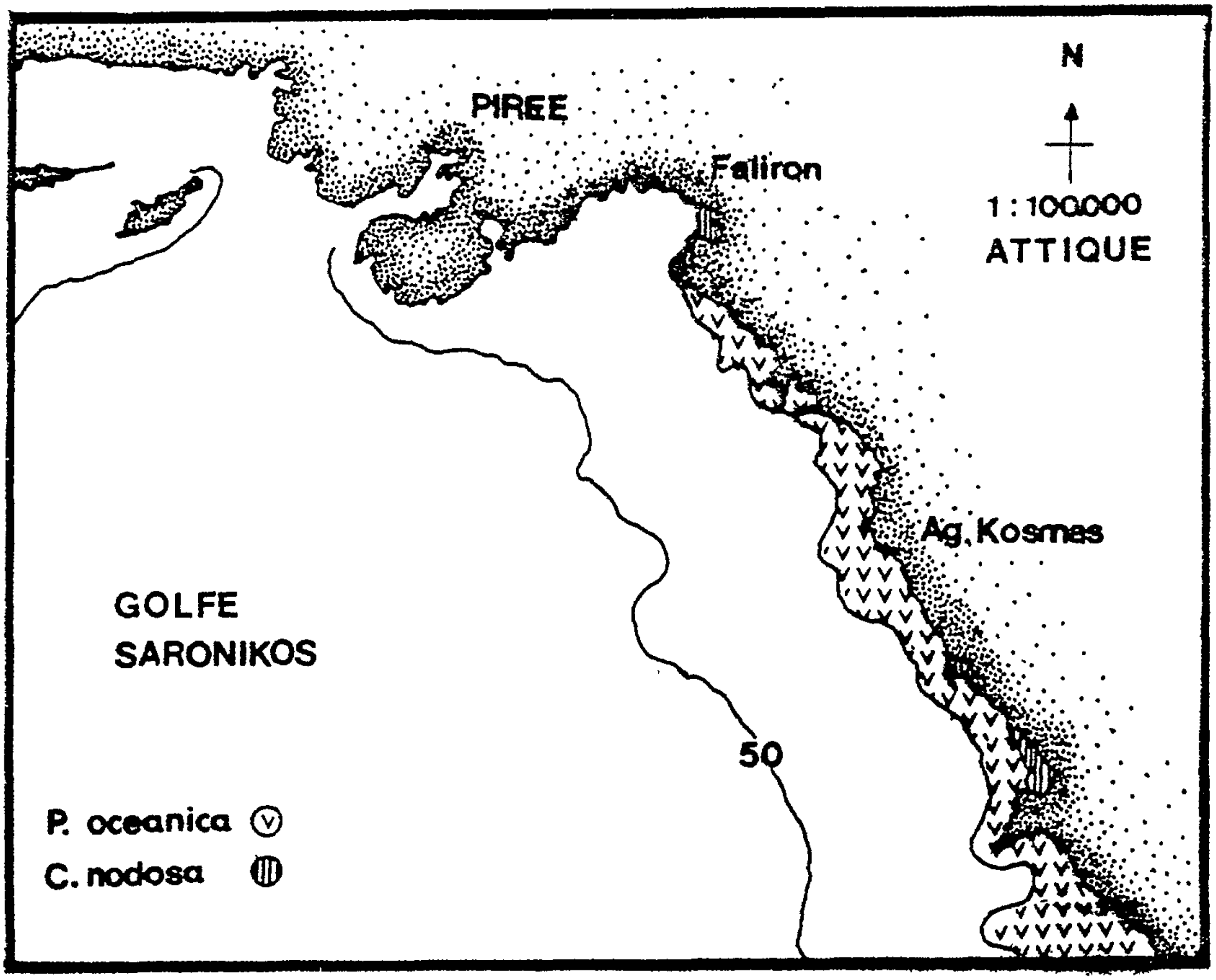


Fig. 5 Les parages du Pirée

La limite inférieure de l'herbier dans le secteur extérieur du golfe se situe à 35 m de profondeur environ.

Dans la partie intérieure du golfe, limitée par la côte de l'Attique (du Pirée à l'îlot de Fleves), la côte nord de l'île d'Aegina et la côte est de l'île de Salamis, les herbiers sont très discontinus. La bordure naturelle de cette partie de la côte de l'Attique a été modifiée par une série de constructions (surtout des ports de plaisance et des plages artificielles) qui ont affecté la granulométrie des sédiments, le parcours des courants et la transparence des eaux.

La limite inférieure de l'herbier dans ce secteur intérieur du golfe se situe à 25 m de profondeur environ.

Dans les parages du Pirée et de la côte est de l'île de Salamis, l'impact de la pollution associe des constructions sur le rivage (surtout la plage artificielle et le port de Faliron) d'une part et d'autre part le rejet en mer de l'émissaire central de la ville d'Athènes (dans la baie de Keratsini) qui a fait disparaître l'herbier sous la vase. Nos observations ont démontré l'existence de matte morte dans la baie de Keratsini, sous une couche de vase épaisse de 10 cm.

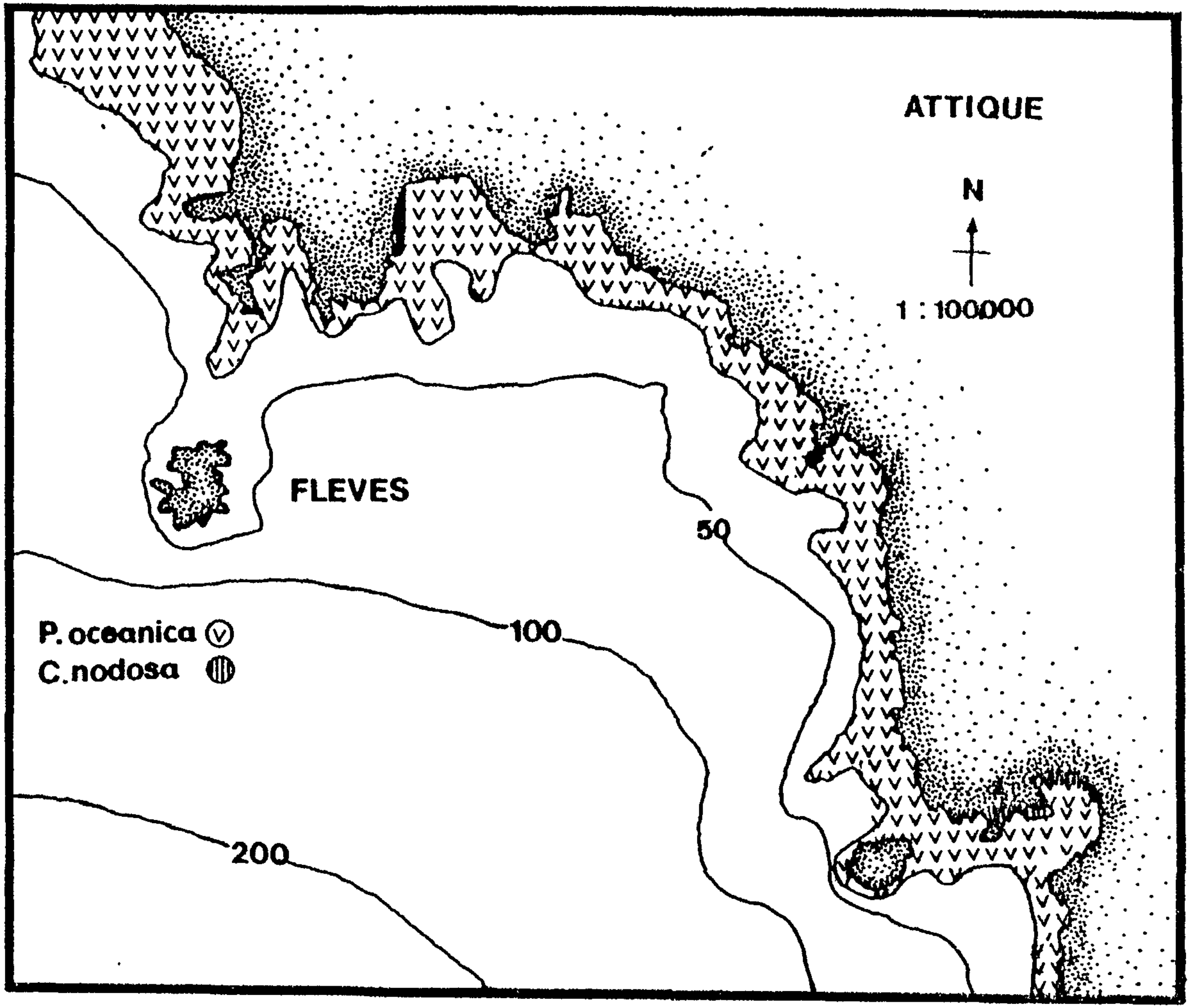


Fig. 6 Les parages de l'îlot de Fleves

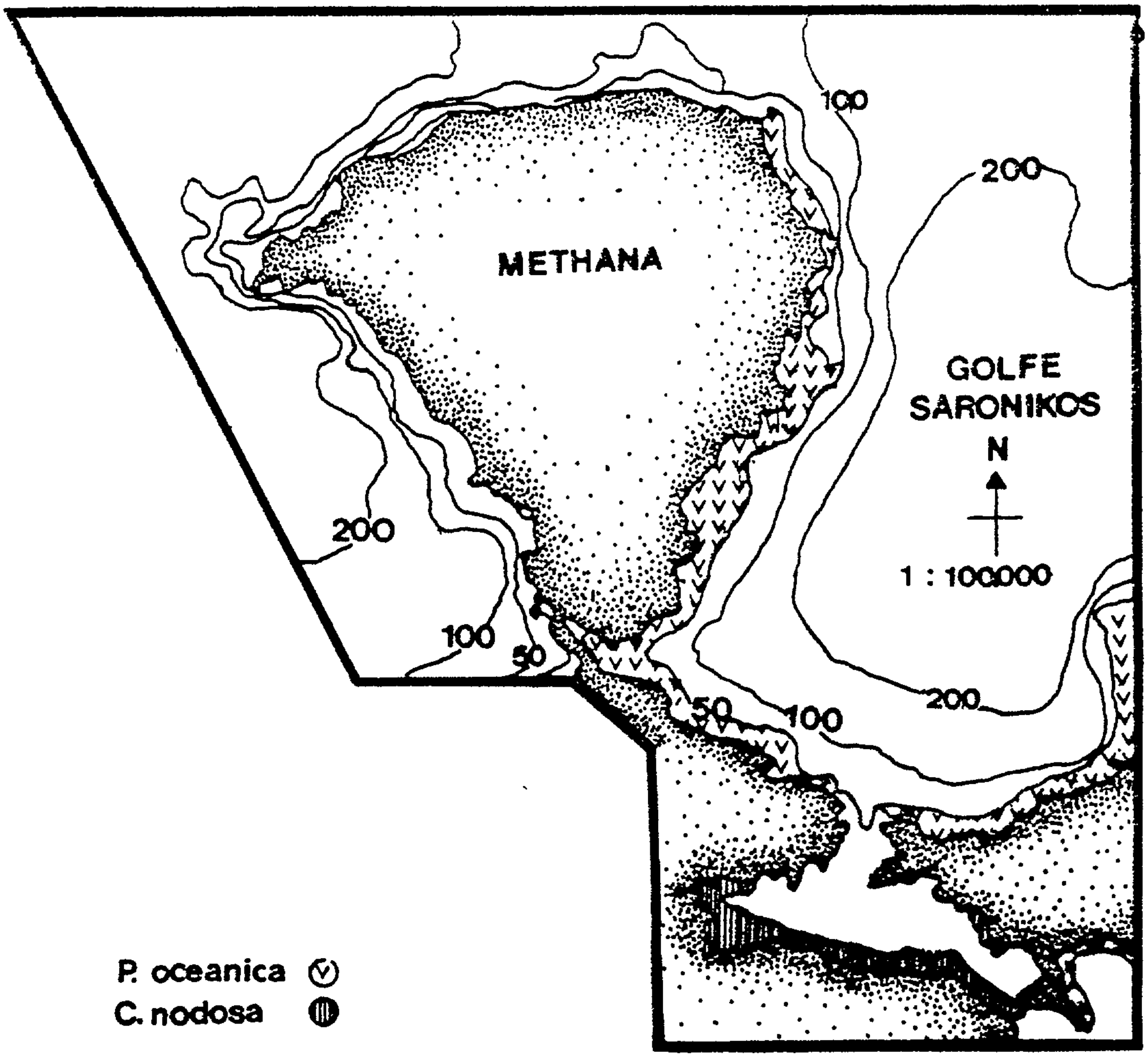


Fig. 7 Les parages de la presqu'île de Methana

Enfin, tout le long de la côte ouest du golfe, de l'île de Salamis à l'isthme de Korinthos et de là jusqu'au port d'Epidaure, P. oceanica est rare. Sur cette partie du golfe la végétation dominante est un ensemble de prairies mixtes de C. nodosa et H. stipulacea, cette dernière étant beaucoup plus commune qu'on ne le pensait récemment.

3.2 Analyse faunistique et floristique

Le Tableau I présente les résultats de l'analyse faunistique et floristique des épiphontes des feuilles de P. oceanica. En ce qui concerne la faune, nous avons mesuré séparément le recouvrement des feuilles par les bryozoaires et les hydraires qui sont les deux principaux groupes d'animaux épibiotiques. Dans une troisième catégorie (autres animaux), nous avons

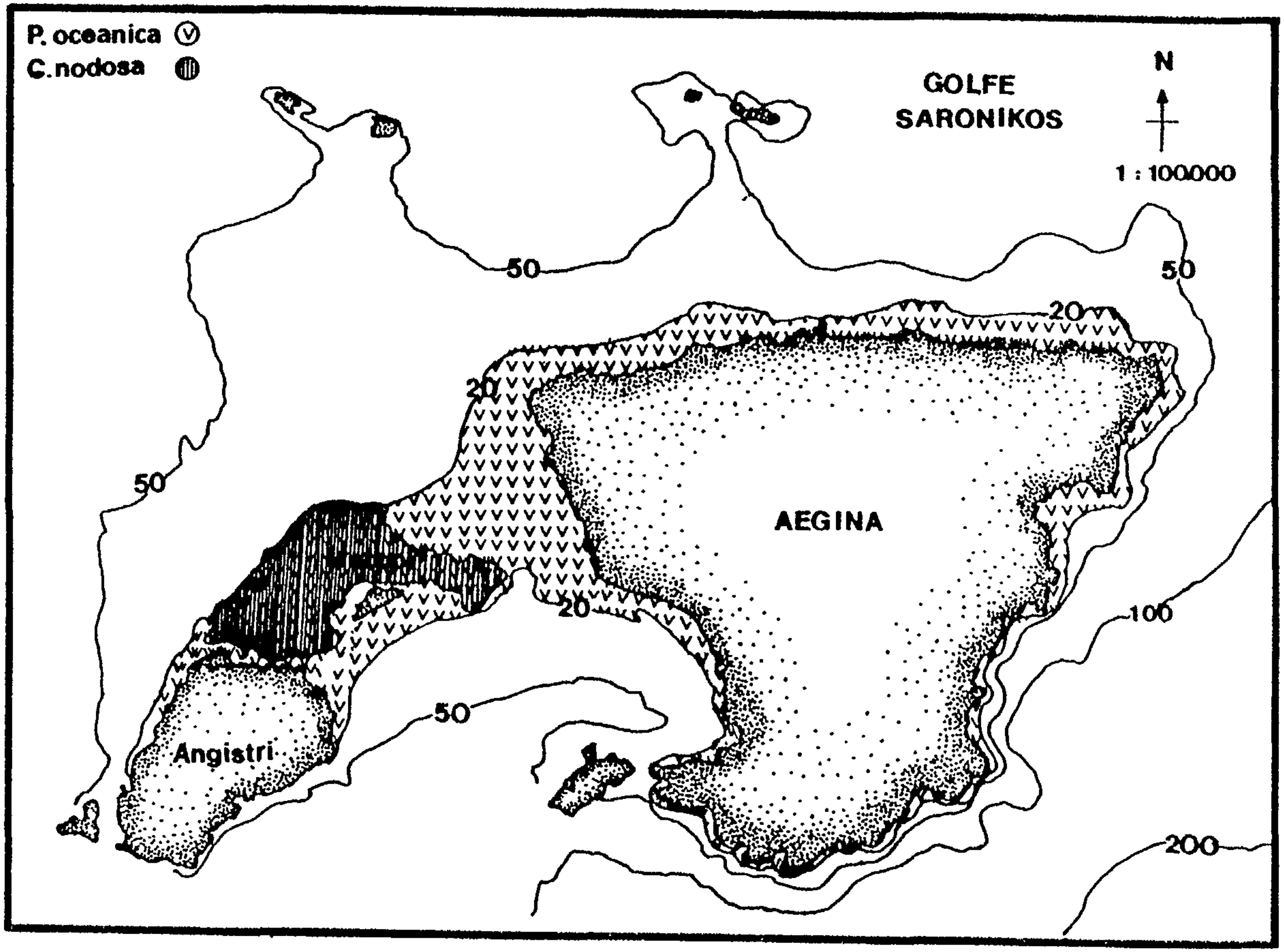


Fig. 8 Les parages d'Aegina

regroupé les ascidies, les mollusques, les polychaetes et autres animaux épibiotiques à faible recouvrement. En ce qui concerne la flore, nous avons mesuré séparément le recouvrement des feuilles par les rhodophycées, les phaeophycées et les chlorophycées, y compris les bryopsidophycées.

Nos résultats montrent une augmentation du recouvrement global en été (9/1985) aussi bien qu'une augmentation du recouvrement animal dans le secteur intérieur du golfe (St. 1 et St. 2). Cette dernière pourrait être attribuée à l'augmentation de la nourriture des hydraires et bryozoaires dans ce secteur qui se trouve au voisinage de l'émissaire central de la ville d'Athènes.

3.3 Densité des faisceaux et indices foliaires

Sur les côtes du golfe Saronikos, nous avons observé des herbiers du stade I selon Meinesz et al., 1981 (St. Ag. Kosmas et St. Vagia), du stade II (St. Perdica et St. Ag. Marina), et du stade III (St. Methana et St. Metopi).

La présence dans les herbiers des Stations Perdica, Ag. Marina, Metopi et Methana (herbiers du stade II et III) d'un grand nombre de faisceaux à croissance horizontale, coéxistant avec une matte d'épaisseur supérieure à 20 cm montre que ces herbiers, bien qu'ils subissent les conséquences des activités humaines (surtout la pêche et le mouillage) conservent encore leur capacité de régénération.

Les paramètres caractéristiques des herbiers des différents secteurs du golfe sont présentés sur le Tableau II.

3.4 Longueur des feuilles et cycle de vie

Nos mesures de la longueur des feuilles de *P. oceanica* dans les stations et saisons étudiées sont présentées sur le Tableau III.

L'étude des histogrammes de fréquence relative de la longueur des feuilles de *P. oceanica* dans le golfe (Fig. 9) a confirmé le modèle du cycle de renouvellement des feuilles proposé par Panayotidis et Giraud (1981), pour le golfe de Marseille. La reproductibilité des observations saisonnières nous a permis de faire l'analyse suivante:

- En été, le polygone des fréquences relatives de la longueur des feuilles intermédiaires (jeunes) se trouve toujours à gauche du polygone des feuilles adultes; par conséquent les jeunes feuilles occupent les classes de faible taille.

- En automne, la disposition des deux polygones est la même, mais l'écart entre eux est plus faible.

- Au début du printemps (avril), la superposition des deux polygones, amorcée en hiver, devient complètè.

- Vers la fin du printemps (juin), la position des deux polygones est l'inverse de la position estivale.

Le cycle annuel de renouvellement des feuilles comprend 10 à 11 feuilles par an. On peut donc estimer la production annuelle des feuilles de *P. oceanica* à partir du cycle de renouvellement et de la biomasse des feuilles (Tableau IV).

Les stations étudiées n'ont pas présenté de différences au niveau du cycle de renouvellement des feuilles. Cette observation nous permet de penser que dans le golfe Saronikos *P. oceanica* ne présente pas de problèmes physiologiques.

Tableau I

Epibiontes des feuilles de *P. oceanica* dans les stations selon les saisons étudiées (recouvrement en pourcentage de la surface des feuilles).

	STATION 1				STATION 2			
	2/85	5/85	9/85	11/85	2/85	5/85	9/85	11/85
EPIBIONTES DES FEUILLES								
Peuplement animal								
Bryozoaires	12	24	29	4	10	21	24	7
Hydraires	7	9	26	5	7	9	20	5
Autres animaux	1	4	10	2	1	5	7	2
Peuplement végétal								
Rhodophyceae	25	15	45	20	23	20	45	22
Phaeophyceae	10	5	25	6	10	11	24	7
Chlorophyceae (s.l.)	1	1	1	1	1	1	1	1
Recouvrement animal	20	37	65	11	18	35	51	16
Recouvrement végétal	36	21	71	27	34	32	70	30
Recouvrement total	56	58	136	38	42	67	121	46

	STATION 3				STATION 4			
	2/85	5/85	9/85	11/85	2/85	5/85	9/85	11/85
EPIBIONTES DES FEUILLES								
Peuplement animal								
Bryozoaires	8	17	20	9	6	15	21	5
Hydraires	7	8	15	6	4	10	13	5
Autres animaux	2	5	5	2	1	3	4	2
Peuplement végétal								
Rhodophyceae	21	24	45	24	16	24	45	19
Phaeophyceae	9	15	21	7	8	16	21	6
Chlorophyceae (s.l.)	1	1	1	1	1	1	1	1
Recouvrement animal	17	20	40	17	11	28	38	12
Recouvrement végétal	31	40	67	32	25	41	67	26
Recouvrement total	48	60	107	49	36	69	105	36

	STATION 5				STATION 6			
	2/85	5/85	9/85	11/85	2/85	5/85	9/85	11/85
EPIBIONTES DES FEUILLES								
Peuplement animal								
Bryozoaires	5	12	22	4	5	12	17	2
Hydraires	1	12	10	9	13	11	8	4
Autres animaux	1	1	3	1	1	2	3	1
Peuplement végétal								
Rhodophyceae	11	25	45	15	13	25	35	12
Phaeophyceae	7	18	20	5	8	14	17	11
Chlorophyceae (s.l.)	1	1	1	1	1	1	1	1
Recouvrement animal	7	25	35	14	19	25	28	7
Recouvrement végétal	19	44	46	21	22	40	53	24
Recouvrement total	26	69	81	35	41	65	31	31

Tableau I (suite)

	STATION 7				STATION 8			
	2/85	5/85	9/85	11/85	2/85	5/85	9/85	11/85
EPIBIONTES DES FEUILLES								
Peuplement animal								
Bryozoaires	5	12	15	1	5	12	19	3
Hydraires	16	10	8	2	9	11	9	6
Autres animaux	1	3	3	1	1	2	3	1
Peuplement végétal								
Rhodophyceae	14	25	31	11	13	25	38	13
Phaeophyceae	8	13	16	10	8	16	18	12
Chlorophyceae (s.l.)	1	1	1	1	1	1	1	1
Recouvrement animal	22	25	26	22	15	25	31	10
Recouvrement végétal	23	39	48	26	22	32	57	26
Recouvrement total	45	64	74	26	37	57	88	36

Tableau II

Paramètres caractéristiques de l'herbier.

	AEGINA	METOPI SECTEUR	SECTEUR INTERIEUR	EXTERIEUR
INDICE				
DENSITE DES FAISCEAUX AU M2	600-700	300-1000	500-700	750
FEUILLES PAR FAISCEAU	4-5	4	5	4-5
SURFACE FOLIAIRE PAR FAISCEAU (cm^2)	200	250	150	150
INDICE FOLIAIRE	15	25	15	20
BIOMASSE DES FEUILLES (grdw m^{-2})	500-700	1000	500	1000
BIOMASSE DES RHIZOMES (grdw m^{-2})	2000	2000	1000	2000

Tableau III

Fréquence rélative des classes de longueur de feuille de *P. oceanica*.

Classes de longueur de feuille en centimètres	STATION 1		STATION 2		STATION 3	
	27/3/85 %	27/7/85 %	3/4/85 %	2/7/85 %	3/4/85 %	2/7/85 %
5-100	5,3	2,1	4,1	1,3	0,8	2,6
101-200	25	14,7	9	1,3	11,5	4
201-300	60,6	16,8	6,6	1,3	9,7	2,6
301-400	8,3	15,7	26,4	7,8	9,7	5,3
401-500	0,7	9,4	13,2	3,9	20,3	8
501-600	-	15,7	22,3	23,6	15,9	8
601-700	-	17,8	13,2	17,1	21,2	25,3
701-800	-	2,1	4,9	25	9,7	17,3
801-900	-	4,2		17,1	0,8	20
901-1000	-	1		1,3		6,6

Classes de longueur de feuille en centimètres	STATION 5			
	2/4/85 %	24/6/85 %	1/11/85 %	19/12/85 %
5-100	1,3	-	11,1	2,6
101-200	10	1,8	21,2	18,5
201-300	34,2	1,8	33,3	23
301-400	18,7	6,6	24,2	24,7
401-500	28	10,3	9	22
501-600	6,7	10,3	1	7,9
601-700	7,1	13,2	-	0,8
701-800	-	35,8	-	-
801-900	-	19,8	-	-

Classes de longueur de feuille en centimètres	STATION 4			STATION 6	
	2/4/85 %	2/7/85 %	3/5/85 %	30/7/85 %	31/10/85 %
5-100	2,7	2,3	0,7	11,1	7
101-200	7,5	7	6	12,1	23,2
201-300	20,6	11,7	16,5	25,2	32,3
301-400	17,2	15,2	17,2	16,1	23,2
401-300	20	17,6	18	21,2	13,1
301-400	16,5	16,4	13,5	11,1	1
401-500	13,7	22,3	13,2	3	-
501-600	1,3	7	12	-	-
601-700	-	-	2,2	-	-

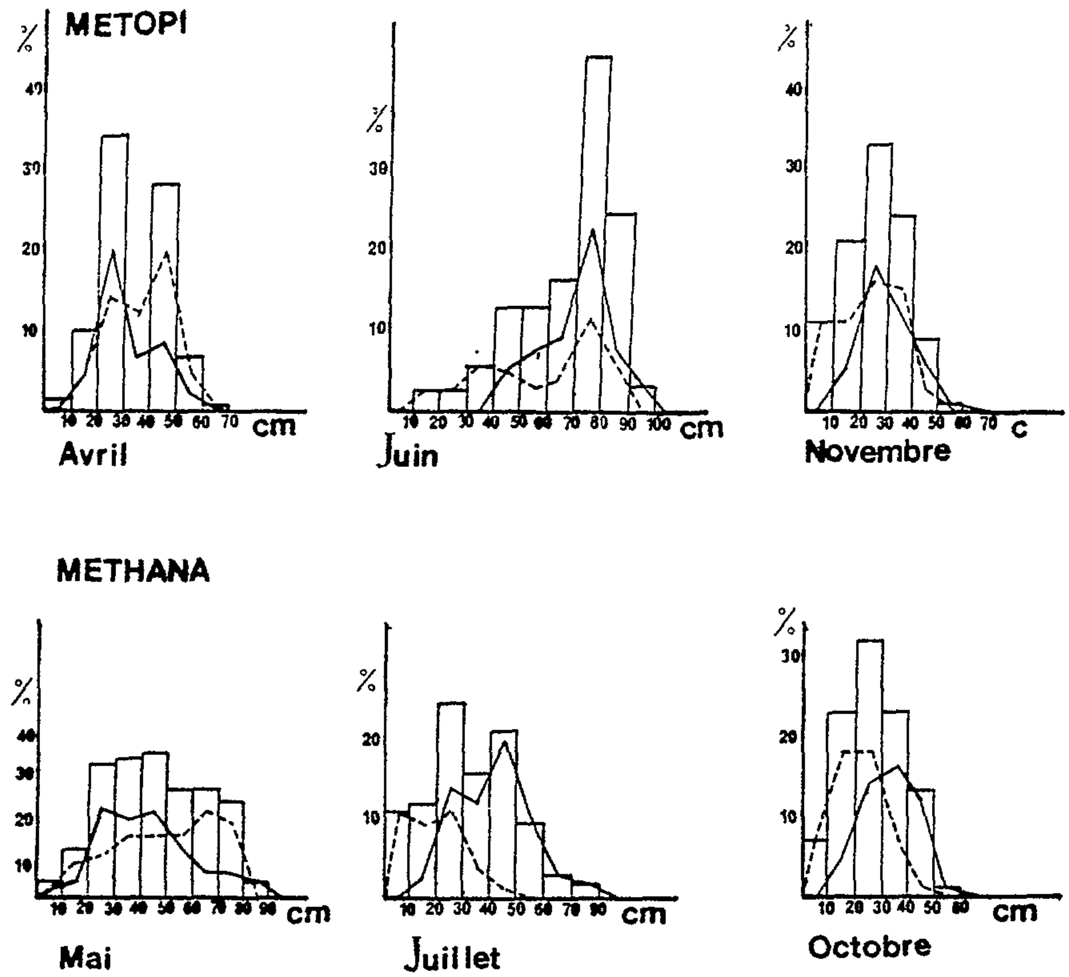


Fig. 9 Cycle de renouvellement des feuilles de P. oceanica

L'étude du cycle de vie de P. oceanica dans le golfe Saronikos nous a permis de décrire une floraison pendant l'hiver 1984-1985 (Panayotidis, et al., sous presse). La floraison a été massive, (200 inflorescences m^{-2}) dans les herbiers de la presqu'île de Methana et de l'îlot de Metopi.

3.5 Bioaccumulation

La bioaccumulation des ions métalliques dans les différentes parties de P. oceanica est présentée sur le Tableau V. D'après ces données, la concentration des métaux est plus élevée dans la partie de la plante qui se trouve hors du sédiment (feuilles) que dans les parties souterraines (racines et rhizomes). En outre, la concentration est en général plus élevée dans les feuilles jeunes dont l'activité biologique est plus intense.

Les valeurs obtenues dans les différentes stations et saisons d'échantillonnage présentent de faibles variations, ce qui nous permet de penser que la source des ions métalliques dans le golfe ne serait pas forcément liée à l'émissaire central de la ville d'Athènes.

Tableau IV

Estimation de la production annuelle des feuilles de P. oceanica.

mois	feuilles nouvelles	longueur maximum des feuilles intermédiaires par faisceau	* biomasse grps
janvier	1	20	0,09
février	1	40	0,18
mars			
avril	1	60	0,27
mai	1	80	0,36
juin	1	100	0,45
juillet	1	80	0,36
août			
septembre			
octobre	1	30	0,14
novembre	1	30	0,14
décembre	1	20	0,09
total	10	total 510	production annuelle par faisceau=2,31

* longueur moyenne des feuilles = 1 cm, surface des feuilles = longueur x largeur. La relation entre Y=biomasse (grps) et X=surface (cm) est Y=0,0045X.

Des phénomènes géochimiques et les conditions hydrologiques jouent probablement un rôle important dans la présence des ions et leur taux de concentration. C'est pourquoi dans certaines stations P. oceanica présente une bioaccumulation importante. La présence de valeurs élevées pour le Cr à la St. Fleves en est un exemple.

Tableau V

Bioaccumulation des ions métalliques par les racines, rhizomes, feuilles intermédiaires et feuilles adultes.

				CADMIUM			
	Angistri	Fleves	Ag.Kosmas	Angistri	Peraica	Methana	Peraica
	6/84	6/84	8/84	9/84	4/85	5/85	7/85
Racines	1.4	1.5	1.2	1.3	1.5	2.3	1.6
Rhizomes	1.1	0.9	0.9	0.8	1.0	1.5	0.8
Feuilles interméd.	2.3	1.7	1.9	2.9	3.0	3.2	2.3
Feuilles adultes	2.7	2.0	2.3	2.5	2.8	4.1	1.1
				CHROME			
Racines	.	44.2	7.0	.	.	.	.
Rhizomes	.	68.9	.	.	.	.	.
Feuilles interméd.	.	28.6	.	.	.	.	.
Feuilles adultes	.	107.6	7.7	.	.	.	.
				NICKEL			
Racines	9.0	6.6	9.4	10.7	7.6	8.7	2.3
Rhizomes	10.6	4.4	12.4	16.5	21.2	9.4	6.5
Feuilles interméd.	19.7	16.0	26.0	20.0	38.5	28.1	17.9
Feuilles adultes	14.4	10.6	27.6	17.4	27.0	20.2	13.4

4. CONCLUSION

Les herbiers de P. oceanica sont bien developpés dans le secteur extérieur du Golfe Saronikos, tandis que dans le secteur ouest ils sont pratiquement absents. Le secteur intérieur peut être considéré comme une zone de transition.

La rareté des herbiers dans le secteur ouest du Golfe Saronikos ne semble pas être liée à la topographie mais plutôt aux conditions hydrologiques étant donné que dans des golfes beaucoup plus fermés sur le plan topographique du point de vue topographie (ex. golfe Thermaikos, golfe de Geras) les herbiers se dévéloppent là où les courants assurent le renouvellement de l'eau. Sous des conditions hydrologiques défavorables pour le développement des herbiers dans le secteur ouest du golfe, on pourrait incriminer en plus un impact indirect de pollution tel que la diminution de la transparence résultant de l'augmentation de la concentration des sels nutritifs et de la biomasse du plancton.

Le secteur intérieur du golfe est touché directement par la pollution urbaine et industrielle. De plus, sur les côtes de l'Attique qui appartiennent à ce secteur (du port du Pirée à l'îlot de Fleves), une série de constructions a modifié la quasi-totalité du rivage naturel. L'impact de ces interventions humaines a été nefaste pour le développement des herbiers: la côte est de l'île de Salamis et les parages du Pirée sont pratiquement sans herbiers. Le long des côtes où il y a encore un herbier (ex. Ag. Kosmas sur les côtes de l'Attique et Vagia sur les côtes d'Aegina), nous avons observé quelques modifications des caractéristiques de P. oceanica qui traduisent l'impact de la pollution: 1) la densité des faisceaux au m^2 et l'indice foliaire diminuent; 2) le recouvrement des feuilles par les épibiontes augmente surtout à cause de l'augmentation des Hydrozoaires et Bryozoaires qui sont probablement favorisés par l'augmentation de la matière organique en suspension provenant de l'émissaire central. Par contre, nous n'avons pas observé de modifications du cycle de renouvellement des feuilles de P. oceanica, ce qui nous permet de considérer que sous le régime actuel de la pollution les herbiers du secteur intérieur ne risquent pas de disparaître brutalement.

Dans le secteur extérieur du golfe, les herbiers sont bien développés. La seule trace d'activité humaine sur les herbiers de ce secteur est la présence de "matte" morte liée à la pêche et au mouillage. Parmi les herbiers du secteur extérieur, ceux de Metopi (st.6) et de Methana (st.7) semblent être les mieux développés et la floraison massive qu'ils ont présentée en 1984-1985 traduit probablement leur grande vitalité.

Enfin, dans l'ensemble du golfe, la concentration des métaux lourds dans les différentes parties végétatives de P. oceanica est faible et ne présente de variations importantes ni dans le temps ni dans l'espace.

Par conséquent, si l'on voulait hiérarchiser les différentes sources de nuisances sur les herbiers de P. oceanica dans le golfe Saronikos, on aurait en premier lieu l'impact des constructions sur le rivage associé à la décharge de l'émissaire central de la ville d'Athènes, en second lieu l'impact de la pêche et du mouillage, tandis que l'impact de la pollution par les métaux lourds pourrait être considéré comme négligeable.

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POLLUTION-INDUCED ECOSYSTEM MODIFICATION IN THE COASTAL AREA OF THE CENTRAL ADRIATIC

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A B S T R A C T

Kastela Bay is one of the largest bays in the middle Adriatic (61 km^2) situated in a markedly shallow and enclosed area under direct influence from land. The investigations of abiotic factors have shown that basic hydrographic parameters such as temperature, salinity, density, transparency, etc., were under the direct and very strong impact of pollution caused by freshwater and wastewater discharges. The concentrations of heavy metals have also indicated increasing pollution with the highest values recorded in the vicinity of outfalls. All these changes are reflected in the biotic components of the bay, disturbing the composition and relationships within the phytoplanktonic, zooplanktonic and zoobenthic communities. The dominance of a small number of species, or even one species making up to 80 to 90% was found as well as a changed rhythm of seasonal oscillations of the total number of phyto - and zooplanktonic organisms, with three, instead of two maxima. So it is clear that the marine ecosystem has changed in the Bay of Kastela under the strong influence of pollution. It is therefore recommended that long-term investigations be carried out in the area with special attention to possible indicator species.

1. INTRODUCTION

Some parts of the eastern Adriatic coast provide very good examples of pollution-induced eutrophication of the coastal area. Thus, Kastela Bay is one of the most productive regions of the Central Adriatic, strongly affected by the land. Recent studies of basic hydrographic parameters of the bay such as temperature, salinity, density, transparency, oxygen content (O_2), oxygen saturation (O_2%), pH, as well as studies of qualitative and quantitative composition of planktonic and benthic populations (Zore-Armanda M. et al., 1974) have shown that the bay is very strongly affected by land factors (freshwater and wastewater discharges) reflected in the chemical and biological properties of the bay, particularly in the eastern part.

In the framework of this project it was possible to explore the most threatened shallow marginal parts of the bay, the intensity of changes in the above-mentioned biocenoses and the relationship of the various parts of the ecosystem. Material for these investigations was collected from five stations in Kastela Bay (Fig. 1).

Station 1 (10 m depth) is under the strongest impact from agricultural wastes, station 2 (10 m depth) is directly affected by industrial wastes (chemical industry), station 3 (20 m depth) is under the combined influence of different industrial plants (food processing shipyard, breaker's yard, etc.), station 4 (40 m depth) is at the entrance to the bay and station 5 (35 m depth) being in the middle of the bay is less likely to come under these influnces.

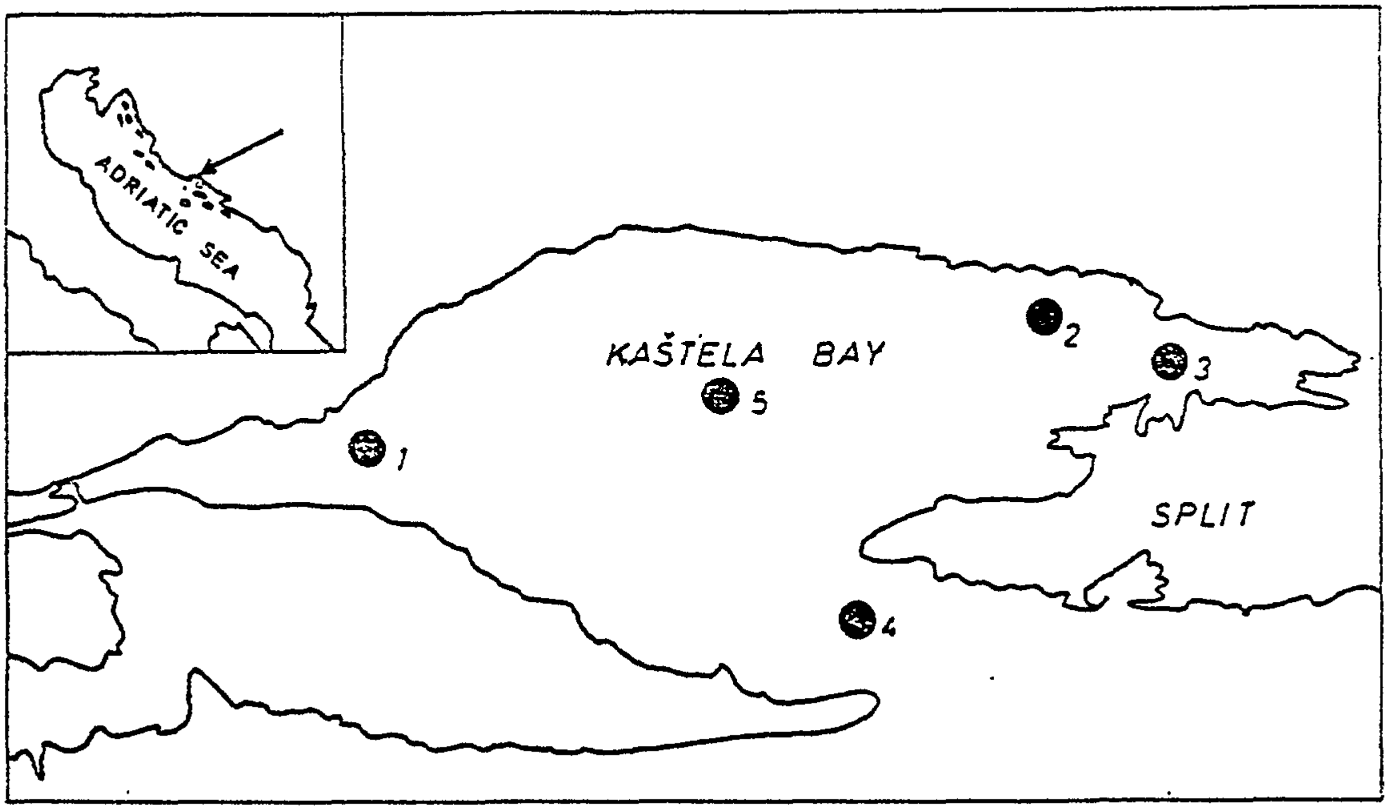

Fig. 1 The study area

2. MATERIALS AND METHODS

Material for this investigation was collected seasonally, using the following methods:

(a) Environmental parameters: temperature, salinity, density, transparency, oxygen content (O_2), oxygen saturation (O_2%), pH, nutrients (phosphates, silicates, nitrates, ammonia) etc. as dynamics of water masses, were determined by standard physical and chemical methods.

(b) Phytoplankton: qualitative-quantitative composition, settling techniques using the Utermöhl inverted microscope method.

(c) Zooplankton: Qualitative-quantitative composition of copepods collected with HENSEN plankton net, by means of a binocular microscope MAK-KS.

(d) Phytobenthos: Direct sampling from defined surfaces (20 cm x 20 cm - 400 cm^2) by Scuba.

3. RESULTS AND DISCUSSION

Kastela Bay is one of the largest bays in the middle Adriatic (61 km^2), located in a markedly shallow and enclosed area under direct influence from the land. It is connected with the adjacent sea through a small strait near the town of Trogir and a larger opening to the Brac Channel. The sea bed is muddy, rocky in places and of about 23 m mean depth. Maximum depth of 47 m was recorded from the deepest middle part of the bay. The freshwater runoffs come from the Jadro River, the Pantan stream, and the springs along the coast, some of which are submarine. The mean current speed in the bay is up to 13 cm sec^{-1} in the surface layer, and up to 6 cm sec^{-1} at depths of 15 and 30 m. From the viewpoint of dynamics, the eastern part of the bay is somewhat isolated (Zore-Armanda et al., 1976). Water enters the bay predominantly at the surface layer and leaves it in the intermediate and bottom layers (Zore-Armanda, 1980).

The current direction is westerly in winter, north westerly in spring and early summer, easterly in summer and southerly in autumn (Zore-Armanda et al., 1976). From current roses drawn seasonally, Zore-Armanda (1974) calculated that a complete exchange of water with the Brac Channel takes place twice a month. Surface temperature ranged from 9.5 °C (February, 1984) to 26 °C (July, 1984). Salinity ranged from 34.74 °/oo (March, 1984) to 38.27 °/oo (August, 1982) (Table I).

Table I

Long term (1982-85) seasonal means of temperature (°C) and salinity °/oo at the investigated stations.

Station	T°C	Sal °/oo
1	17.90	36.68
2	17.97	36.21
3	17.48	36.93
4	16.66	37.42
5	16.64	37.10

There were no marked differences between stations; this is probably due to a very quick nutrient turnover by phytoplankton organisms. Phosphate levels showed small non-significant differences among the investigated stations (Vukadin and Huljic, 1981; Vukadin and Stojanoski, 1984). Given the fact that the total surface of the bay is relatively small, only 61 km^2, and the distance between investigated stations only a few miles, such differences in phosphate quantity were to be expected.

However, since the bay is under the strong influence of the land, such a small difference between this area and the open sea (Table II) was unexpected.

We believe that the only explanation for such small differences in the quantity of nutrients between closed coastal areas and the open sea station is in the very quick turnover of nutrients by phytoplankton organisms (as will be seen later).

Table II

Long term (1982-1985, seasonal) means of nutrients at the investigated area (umol dm^{-3})

Station	PO_4-P	NO_3-N
1	0.065	0.71
2	0.084	0.80
3	0.088	0.70
4	0.064	0.71
5	0.061	0.71
Stoncica (open sea)	0.041	0.61

During our recent investigations, marine sediments were also sampled at the permanent Kastela Bay station (Fig. 2) on two occasions in 1983 (winter and summer). Sediments were collected from the 0-5 cm layer (SL) and the 20-25 cm layer (SSL) for the analysis of the following heavy metals: Hg, Cd, Zn, Cu, Cr and As.

The discharge of municipal (domestic and industrial) wastewater is the dominant source of pollution in the study area of Kastela Bay. The discharge entering the sea still contains unpurified water with considerable quantities of suspended and particulate matter, with which heavy metals are associated. Suspended and particulate matter are quickly deposited on the sea bottom which is thus in fact a permanent reservoir of heavy metals for the water layer above it and the marine biota (Vukadin et al., 1985). Our studies have shown that the concentrations of some heavy metals (Hg, Zn, Cu) in the surface sediment layer exceed by almost an order of magnitude the concentrations in the subsurface sediment layer (20-25 cm) (Table III).

Spatial distribution of heavy metals is also very significant. The highest values were recorded in the vicinity of the outfalls which are the principal source of pollutants (Station 3 - Vranjic basin). The results obtained are indicative of the increasing pollution by heavy metals which threatens the coastal area. These problems should be given particular attention and treatment.

The investigation of phytoplankton organisms at Kastela Bay shows that Area A (eastern part of the Bay) differs in the phytoplankton structure from Areas B and C (Fig. 2). Due to the poorer circulation of water masses in the summer these differences are more pronounced then. Thus in August 1984, the quotient of similarity by Sorensen (1948) for diatom and dinoflagellate populations was 38.9 between areas A and B, while between B and C it was much higher - 69.9 (Marasovic and Pucher-Petkovic, 1985).

Table III

Heavy metals in marine sediments in Kaštela Bay. Mean levels ($\bar{x}$) of studied heavy metals in the surface (SL 0-5 cm) and subsurface (SSL 20-26 cm) sediment layers (mg Kg^{-1} DW).

Station	Layer	Hg	Cd	Zn	Cu	Cr	As
1	SL	1.89	0.25	70	20.0	51	10.5
	SSL	0.03	0.18	32	11.5	58	14.5
	SL	3.83	0.25	52	12.9	96	12.7
2	SSL	0.06	0.11	27	4.09	138	11.0
	SL	4.46	0.39	204	23.8	111	13.0
3	SSL	1.55	2.28	155	13.1	97	9.8
	SL	1.75	0.23	113	21.5	114	11.5
4	SSL	0.26	0.22	57	19.0	106	14.5
	SL	0.63	0.18	93	19.2	131	7.5
5	SSL	0.04	0.15	55	12.6	130	7.1

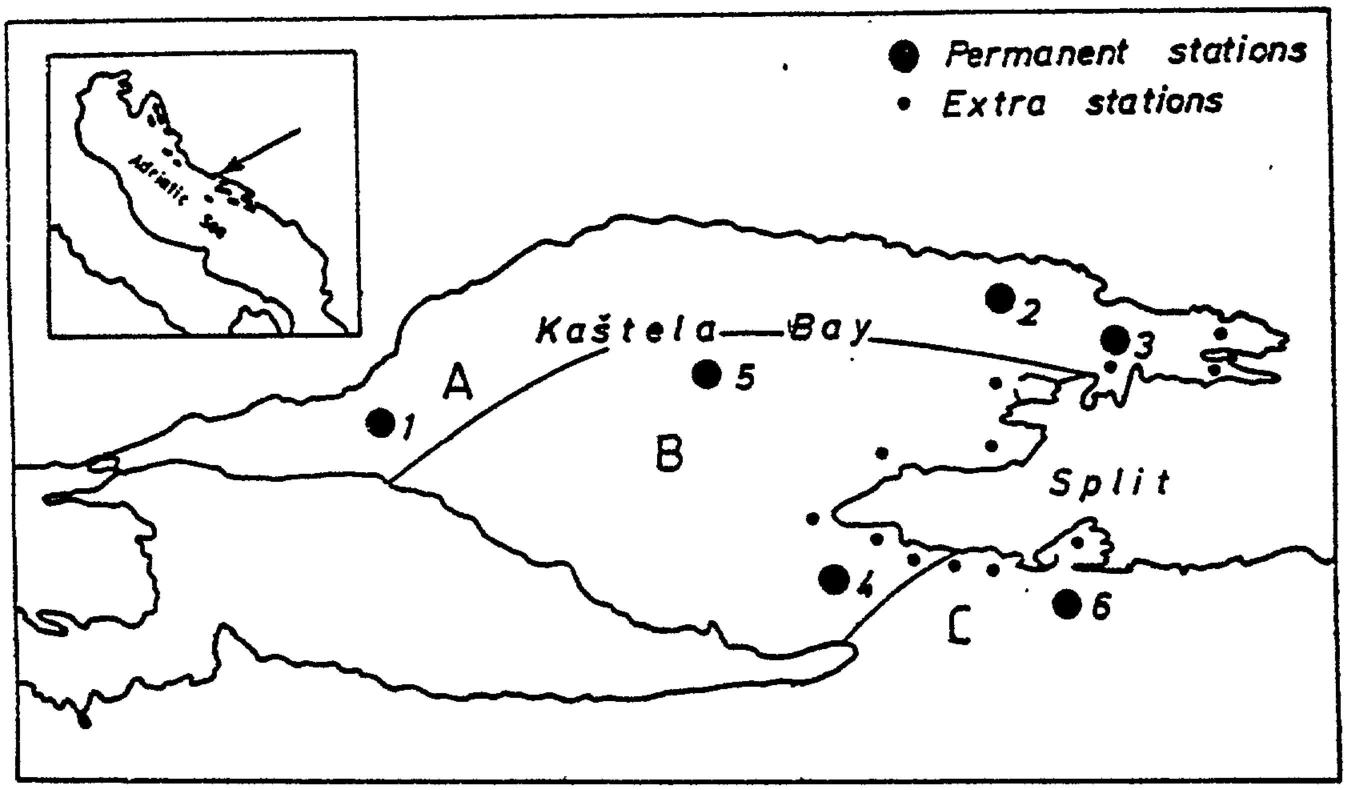

Fig. 2 Investigations of phytoplankton

At that point dinoflagellates were predominant in Area A with more than 90% of the phytoplankton density whereas in areas B and C diatoms prevailed with 65-81% of the whole phytoplankton. In the first six months of 1984, there was an unusual amount of rain, which intensified the influence of coastal zones and caused a very pronounced diatom bloom at the beginning of June. In area A a monospecific bloom of Gonyaulax polyedra provoked a change in the colour of the sea, while at the same time in areas B and C a monospecific bloom of Olisthodiscus luteus was found (Marasovic and Vukadin, 1982). We can conclude that ecological differences between area A (industrial and municipal wastewaters, poor circulation) and areas B and C (vicinity of the port, more intensive water exchange with the Brac channel) caused the difference between these two blooms.

The effects of land pollution on the qualitative and quantitative composition of copepods (dominant net zooplankton group) were even more significant. Therefore these results will be presented here separately for each examined station.

3.1.1 Station 1. Located in front of Trogir, it is under the strongest influence of agricultural wastes from the agricultural farms stretching along the coast (Table IV).

A total of 20 species and 2 genera, the determination of which was not possible, was recorded from this station (Table IV). Considering the fact that the depth at this station does not exceed 10m, the number of recorded species is quite usual for coastal areas. The occurrence of species such as Calanus helgolandicus, C. tenuicornis, Microsetella norvegica and Euterpina acutifrons is indicative of some open sea effects since all these are pelagic species. The highest number of species was recorded in autumn. Acartia clausi was extensively represented and constituted 50% of the total copepod counts. It accounted for between 15-50%. The number of individuals was highest in summer and lowest in winter. However, the number of copepods was considerably high all the year round (particularly if the shallowness of the station is taken into account), because they probably had enough food available due to favourable environmental conditions. All these data on copepod density and composition show a strong influence of land runoffs at this station. This is evident from disturbed relations between individual species, that is, marked dominance of Acartia clausi, as well as from the changes in the rhythm of seasonal density oscillations (Regner, 1982, 1984; Moraitou-Apostolopoulou, 1978) which showed lower copepod numbers only in winter. In addition, two annual maxima did not occur since the number of copepods was high throughout the year.

3.1.2 Station 2. Located in front of the small town of Kastel Sucurac, it is directly and strongly affected by industrial wastes (chemical industry) (Table V).

As with the previous station, depth does not exceed ten metres and the number of determined copepod species was almost the same (Table V). A total of 21 copepod species and two genera was recorded. Neritic species, which usually occur in greater numbers, dominated. However, those copepods characteristic for the open sea were also recorded: Calanus helgolandicus, Clausocalanus parapergens, Euterpina acutifrons and some others. The largest number of species was recorded in summer 1983 and the smallest in spring 1985. Acartia clausi was markedly dominant. It contributed from 17 to 93%, which had not previously been recorded earlier in Kastela Bay. These high percentages of Acartia clausi occurred in spring 1982.

Table IV

The qualitative and quantitative composition of copepods at Station 1 (ind. m^{-3}).

	Feb 82	May 82	Aug. 82	Oct 82	Jun 83	Mar 84	Aug 84	Dec 84	May 85
Calanus helgolandicus	0	20	0	0	5	0	20	0	0
Calanus tenuicornis						20	20	0	20
Calocalanus contractus	0	20	0	0	20	0	0	0	0
Paracalanus parvus	260	140	260	240	280	40	240	40	560
Ctenocalanus vanus	200	20	0	40	20	0	40	0	40
Clausocalanus jobei	0	0	0	20	0	0	0	0	0
Clausocalanus arcuicornis	20	0	0	0	0	0	0	0	0
Clausocalanus pergens	20	60	0	60	20	0	160	0	0
Clausocalanus furcatus	0	0	60	20	20	0	40	0	0
Centropages typicus	80	260	0	180	40	180	80	0	180
Centropages kröyeri	0	0	240	0	60	0	20	20	0
Temora stylifera	0	0	460	440	320	0	780	20	0
Temora longicornis	0	680	40	0	80	60	20	40	0
Acartia clausi	560	1280	1800	480	1040	100	440	60	460
Diaixis pygmaea	20	0	0	20	5	0	0	0	0
Oithona sp.	60	160	60	160	80	280	240	120	160
Microsetella norvegica	0	20	0	0	0	0	0	0	0
Euterpina acutifrons	0	0	0	20	0	0	20	0	0
Oncaea sp.	0	0	0	0	0	5	0	0	0
Corycaeus typicus	0	0	0	20	0	0	20	20	0
Corycaeus brehmi	0	0	0	0	20	0	0	0	0
Corycella rostrata	0	0	40	20	5	0	0	0	0
Copepodites and other copepods	240	1180	600	1200	1040	300	600	160	400
Total	1460	3220	3560	2920	3060	985	2740	480	1820
Total m^{-3}	487	1073	1188	973	1020	328	913	160	606

Table V

The qualitative and quantitative composition of copepods at Station 2 (ind. m^{-3}).

	Feb 82	May 82	Aug 82	Oct 82	Jun 83	Mar 84	Aug 84	Dec 84	May 85
Calanus helgolandicus	0	0	0	0	20	0	0	0	0
Calanus tenuicornis	80	0	0	0	40	20	5	0	0
Calocalanus contractus	0	0	0	0	0	0	0	0	0
Paracalanus parvus	0	20	0	20	220	40	60	160	0
Paracalanus nanus	0	0	0	40	0	0	0	0	0
Ctenocalanus vanus	140	0	0	0	80	0	0	120	0
Clausocalanus jobei	0	0	0	0	80	0	40	0	0
Clausocalanus pergens	40	0	0	20	40	0	20	0	0
Clausocalanus parapergens	0	0	0	0	160	0	0	0	0
Clausocalanus furcatus	0	0	20	0	0	0	20	20	0
Centropages typicus	60	0	60	20	40	40	0	0	0
Centropages kröyeri	80	40	380	40	320	0	160	0	0
Temora stylifera	40	0	680	200	260	0	360	40	0
Temora longicornis	0	20	0	0	20	0	0	0	60
Isias clavipes	0	0	0	0	40	0	0	0	0
Diaixis pygmaea	20	0	0	0	0	0	0	0	0
Acartia clausi	1880	4060	3360	180	1600	60	860	60	1260
Oithona sp.	260	40	80	180	80	0	40	20	0
Oncaea sp.	0	0	0	0	0	0	40	20	0
Euterpina acutifrons	20	0	0	0	0	0	20	0	20
Corycaeus typicus	20	0	0	20	0	0	20	40	20
Corycaeus brehmi	0	0	0	20	40	20	0	40	0
Corycella rostrata	0	0	0	20	0	0	5	0	0
Copepodites and other copepods	300	180	180	260	380	280	400	140	60
Total	2140	4360	4760	1020	3440	460	1990	680	1420
Total m^{-3}	713	1453	1588	340	1146	153	663	113	473

The number of copepods per m^3 showed greater variations than at the previous station. Maximum values were ten times the minimum ones, which was evidently due to the land influence. The values recorded in spring-summer were much higher. The autumn maximum, normally recorded, was not recorded at all. The number of copepods was very low in autumn and winter, particularly in 1984. Therefore, the situation at Station 2 is very similar to that at Station 1. Because of the high values of Acartia clausi it may even be regarded as a monoculture. The rhythm of seasonal density oscillations was also changed, since no marked maxima in spring and at the beginning of autumn were recorded, which in fact it not unusual due to the position of the Adriatic Sea in the temperature climatic zone. All these phenomena give additional evidence of disturbed relations in the copepod community at this station.

3.1.3 Station 3. At a depth of 30m, it is in the eastern part of the bay. It is affected by a variety of land pollution sources: food industry, breaker's yard, shipyard, etc. A total of 22 copepod species and 2 genera with almost identical species as those from the two preceding stations was found (Table VI). Acartia clausi was again markedly dominant, contributing some 60% (recorded in summer 1983). The number of individuals was considerably lower than at the two preceding stations. However, seasonal density oscillations showed almost the same trend as those at Stations 1 and 2, with increased values in spring-summer.

With respect to the fact that the depth is almost twice that at Stations 1 and 2, the above-mentioned changes in the plankton community are even more pronounced here.

3.1.4 Station 4. At a depth of 40m, it is at the entrance of the bay, and is therefore not a typical bay station.

All the studies concerning water mass dynamics carried out in this area so far (Table VII) show that under certain conditions (south wind "jugo") water enters the bay from the Split town port, while under other conditions (north wind "bura") it enters from the Brac Channel as a compensatory current to the outgoing component into the Brac Channel.

The Station's depth as well as its peculiar position are reflected in the species composition. Thus 28 species and 2 genera were recorded (Table VII). Many of the species recorded belong to the species more frequent in the open sea: Calanus helgolandicus, C. tenuicornis, Calocalanus contractus, Calocalanus plumulosus, Clausocalanus parapergens, Corycaeus furcifer and some others which is evidence of a good water exchange with the open sea. The highest number of species encountered in the colder part of the year confirms the results of our earlier studies of seasonal changes of qualitative composition of the copepod group (Regner, 1970, 1973, 1979). The species Temora stylifera, Acartia clausi, Centropages typicus, Paracalanus parvus and Ctenocalanus vanus were the best represented from the quantitative point of view. Other species however occurred in considerably smaller numbers. The total number of individuals varied during the year with a peak in spring and rather low values in summer. Minimum numbers were recorded in autumn 1982.

Species composition and number and dominant species, characteristic for the whole east Adriatic coast, and the annual variation rhythm usual in the coastal sea, were quite different at this station from those at the previous stations located in the shallowest and most threatened part of the bay.

Table VI

The qualitative and quantitative composition of copepods at Station 3 (ind. m^{-3}).

	Feb 82	May 82	Aug 82	Oct 82	Jun 83	Mar 84	Aug 84	Dec 84	May 85
Calanus helgolandicus	0	0	0	0	0	0	0	0	0
Calanus tenuicornis	160	0	0	0	0	0	0	0	160
Calanus contractus	0	0	0	0	20	0	0	0	0
Paracalanus parvus	320	0	60	80	60	80	80	280	260
Paracalanus pygmaeus	60	0	0	0	0	0	0	0	0
Ctenocalanus vanus	200	0	0	20	0	20	320	200	420
Clausocalanus jobei	0	0	0	40	0	0	0	20	40
Clausocalanus arcuicornis	0	0	0	20	0	0	0	0	60
Clausocalanus pergens	20	20	20	40	0	0	60	0	60
Clausocalanus parapergens	0	0	0	0	0	20	0	0	20
Clausocalanus furcatus	0	0	0	40	0	0	0	20	0
Centropages typicus	400	60	40	0	80	300	280	0	420
Centropages kröyeri	120	40	400	40	240	80	80	40	0
Candacia armata	0	0	0	0	0	0	0	0	60
Temora stylifera	0	0	580	560	40	0	360	0	0
Temora longicornis	0	100	0	0	0	40	0	0	500
Acartia clausi	2500	240	1600	480	1100	120	1600	20	1200
Diaixis pygmaea	20	0	0	0	0	20	0	20	40
Oithona sp.	100	20	80	140	60	20	80	80	180
Oncaea sp.	0	0	0	0	0	0	0	0	20
Euterpina acutifrons	60	0	0	5	40	0	0	0	20
Corycaeus typicus	0	0	0	0	0	20	80	20	0
Corycaeus brehmi	20	0	5	0	0	20	20	0	20
Corycella rostrata	0	0	0	20	0	0	20	0	20
Copepodites and other copepods	1600	380	500	760	180	760	500	280	560
Total	5580	860	3285	2245	1820	1500	3480	980	4080
Total m^{-3}	930	143	547	374	303	250	580	163	680

Table VII

The qualitative and quantitative composition of copepods at Station 4 (ind. m^{-3}).

	Feb 82	May 82	Aug 82	Oct 82	Jun 83	Mar 84	Aug 84	Dec 84	May 85
Calanus helgolandicus	0	60	0	5	0	0	0	0	0
Calanus tenuicornis	380	40	20	5	0	0	0	20	40
Calocalanus pavo	0	0	0	0	0	0	0	20	0
Calocalanus contractus	60	0	0	0	0	0	0	0	0
Calocalanus plumulosus	20	0	0	0	0	0	20	0	0
Paracalanus parvus	380	980	140	100	20	320	300	360	580
Macrosetella gracilis	0	0	0	0	0	0	0	0	60
Ctenocalanus vanus	480	360	240	0	0	140	360	220	300
Clausocalanus arcuicornis	0	0	0	0	0	0	40	0	80
Clausocalanus jobei	0	60	140	40	20	160	160	40	0
Clausocalanus pergens	160	140	0	60	0	0	0	0	120
Clausocalanus parapergens	0	60	0	0	0	0	0	0	180
Clausocalanus furcatus	80	60	0	120	0	0	0	0	0
Centropages typicus	560	1360	580	0	140	460	140	40	600
Centropages kröyeri	0	80	280	0	50	120	0	0	0
Temora stylifera	60	140	1210	420	600	2420	0	140	0
Temora longicornis	0	80	80	0	0	0	460	0	420
Acartia clausi	360	1200	1040	60	560	1360	340	1860	900
Diaixis pygmaea	20	60	20	0	20	0	0	0	300
Candacia armata	0	0	0	5	0	0	0	0	0
Lucicutia flavicornis	0	0	0	0	0	0	5	0	0
Oithona sp.	720	580	380	140	160	320	40	460	120
Euterpina acutifrons	0	20	0	5	0	0	0	0	100
Labidocera wollastoni	0	0	0	55	0	0	0	20	0
Oncaea sp.	0	0	0	60	0	40	0	0	0
Corycaeus typicus	60	0	0	0	0	40	60	80	180
Corycaeus brehmi	60	0	0	20	40	0	0	140	0
Corycella rostrata	20	0	0	40	0	0	0	0	0
Corycaeus latus	40	0	0	0	0	0	0	0	0
Corycaeus furcifer	0	0	0	0	0	0	0	40	0
Copepodites and other copepods	1080	1280	240	80	440	1120	1060	380	1300
Total	4540	6560	4370	1165	2060	6500	2985	3880	5280
Total m^{-3}	378	547	354	97	171	542	249	323	440

3.1.5 Station 5. This was located in the middle of Kastela Bay. Of 24 species and 2 genera recorded, the best represented species were: Acartia clausi, Temora stylifera, Centropages typicus, Paracalanus parvus and Ctenocalanus vanus (Table VIII). Most species were recorded in the colder part of the year as at Station 4. In addition to neritic species, the species more frequent in the open sea were also recorded at this station. The seasonal variation rhythm is similar to that recorded at the previous station, with the highest number of individuals in winter-spring. The composition and character of species, higher number of dominant species, as well as the rhythm of seasonal variations have not undergone any significant changes recently. Therefore it may be concluded that this station has not yet become strongly influenced by the land. This station had somewhat different properties from those at other stations; this may be partly due to some topographic and hydrographic features. Thus it has the greatest depth, it is farthest from the land and direct pollution sources and the dynamics are more intensive than in the marginal parts of the bay.

The investigation of the phytobenthos was also a very important part of this project. Since typical stratified phytobenthic communities were studied, each of the following strata was separately observed: the upper stratum I with the species of the Cystoseira genus, stratum II of epiphytic flora growing on Cystoseira and some bigger algae of stratum III and flora of the firm substratum II in the shade of branched Cystoseira.

A total of 74 species was identified from three samplings (January, July, October 1983) of Cystoseira compressa beds. Rhodophyceae were dominant with 46 species which constituted 62.2% of the total flora. Phaeophyceae and Chlorophyceae with 14 species did not exceed 18.9%.

The dominant species which determined the appearance of the beds were Cystoseira compressa (on the average 24 specimens per sample) that is the species of the stratum I and much poorer second, C. arinitophyila (on the average 3 specimens per sample) not found in all the samples. The species Dictyopteris membranacea, Ulva rigida, Gigartina acicularis, Hypnea musciformis and Dictyota dichotoma predominant in substratum III were ordinarily accompanied by large quantities of the smaller algal species Pseudochlorodesmis furcellata and Dermatolithon hepaliaioides which were present in all the samples. A large number of other species was also recorded from either one or more samples.

A total of 38 taxa (24 Rhodophyceae, 9 Phaeophyceae and 5 Chlorophyceae) was recorded from stratum II (epiphytes) and 56 taxa (35 Rhodophyceae, 10 Phaecophyceae and 11 Chlorophyceae) from substratum III. The records showed a total of 13 obligatory epiphytes, 28 facultative epiphytes and 33 epilithic sciaphilous forms.

The number of species in the samples was almost constant, varying from 32 in July to 34 in October (on the average 33 per sample). The relationship between the numbers of species in samples taken from strata II and III varied with the time of year during which samples were taken. Thus, while from January to October the number of epilithic species of substratum III decreased, the number of facultative epiphytes in the strata II and III increased. The number of obligatory epiphytes remained almost unchanged (Table IX).

Table VIII

The qualitative and quantitative composition of copepods at Station 5 (ind. m^{-3}).

	Feb 82	May 82	Aug 82	Oct 82	Jun 83	Mar 84	Aug 84	Dec 84	May 85
Calanus helgolandicus	20	20	0	0	0	20	0	0	0
Calanus tenuicornis	100	20	5	20	0	40	0	0	280
Calocalanus plumulosus	0	40	0	0	0	20	20	0	0
Paracalanus parvus	1340	640	20	240	120	220	200	180	460
Ctenocalanus vanus	780	500	80	420	160	120	380	180	160
Clausocalanus arcuicornis	0	0	40	80	120	200	0	0	140
Clausocalanus jobei	0	160	20	130	80	180	260	0	140
Clausocalanus pergens	60	80	60	0	20	80	0	80	40
Clausocalanus parapergens	20	80	0	60	0	0	0	20	40
Clausocalanus lividus	0	20	0	0	0	0	0	0	0
Centropages typicus	180	805	100	420	300	220	600	280	280
Centropages kröyeri	140	0	40	0	60	80	200	20	0
Temora stylifera	60	0	740	540	420	60	200	360	0
Temora longicornis	0	20	20	40	0	0	0	80	780
Acartia clausi	2280	780	700	395	1245	700	1020	520	2300
Diaixis pygmaea	60	60	0	0	0	0	0	80	5
Candacia armata	20	0	0	5	0	0	0	0	0
Mecynocea clausi	20	0	0	40	0	0	0	0	0
Euterpina acutifrons	0	0	5	0	0	0	0	0	0
Corycaeus typicus	0	0	0	0	0	20	0	80	0
Corycaeus brehmi	20	0	0	0	20	0	0	40	0
Corycella rostrata	0	0	0	0	0	10	0	0	40
Oithona sp.	140	220	440	160	280	200	340	380	260
Copepodites and other copepods	1300	1280	400	820	850	600	400	760	1500
Total	6540	4725	2670	3360	3675	3670	3620	3496	7560
Total m^{-3}	623	450	254	320	350	350	345	333	720

Table IX

Presence of facultative and obligatory epiphytes and epilithes in the samples.

	January	July	October
Facultative epiphytes	6	16	18
Obligatory epiphytes	7	4	6
Epilithes	29	12	10
Total:	33	32	34

Quantitative studies (even though the number of samples was rather small) showed that the biomass (wt weight) of beds varied from a maximum of 367.5 g 400 cm^{-2} (= 9186 g m^{-2}) in May to the minimum of 96 g 400 cm^{-2} (= 2400 g m^{-2}) in July. The obtained biomass values were as a rule lower than those recorded from other areas along the eastern Adriatic coast and in the vicinity of Split, where in July maximum values were 545 g 400 cm^{-2} (= 14175 g m^{-2}).

Cystoseira compressa made up the highest proportion in the total biomass of each of stratum I samples, whereas Dictyopteris membranacea and Ulva rigida were predominant in substratum III. Their values however showed different variations in different samples. Thus, whereas the minimum of Dictyopteris membranacea was recorded in May and maximum in October, the opposite was true for Ulva rigida (maximum in May and minimum in October): Gigartina acicularis and Halopteris scoparia were to a certain extent significant in quantity, their biomass being somewhat higher in substratum III in some seasons (Table X).

So we can conclude that Cystoseira compressa is one of the rare species of Cystoseira genus that is relatively resistant to the present pollution level of the Kastela Bay waters (Span et al., 1981). Nevertheless, the floristic composition of its beds has been gradually changed and replaced by other more resistant algal species. These changes are manifested through the occurrence and increasing relative abundance and biomass of some nitrophilous species (Dictyopteris membranacea, Ulva rigida, Gigartina acicularis) which are either absent or present in small quantities in the Cystoseira compressa beds in clean waters. The coverage of the beds of this species has not been reduced by pollution effects, since, owing to stratification and abundant settlement of substratum III by the above mentioned species, it frequently exceeds 100%. The biomass values of the entire beds at sampling locations are lower than at other sites of the eastern Adriatic and even of the Split area; this may be due rather to the effects of some less favourable natural conditions (shallow depths, 0.3 - 0.5 m and unsheltered areas) which cause smaller talus lengths of Cystoseira compressa rather than to pollution effects.

Table X

Variations of biomass of individual dominant species, (g w.wt 400 cm^{-2} and g m^{-2}).

	May	July	October
Cystoseira compressa	303.00 (7575.00)	73.12 (1828.00)	53.49 (1337.25)
Cystoseira crinitophylla	-	11.85 (296.25)	4.46 (111.59)
Dictyopteris membranacea	8.38 (209.80)	26.06 (601.50)	33.05 (826.25)
Ulva rigida	42.07 (1052.00)	6.76 (169.00)	6.08 (152.00)
Halopteris scoparia	25.20 (630.00)	18.70 (467.50)	3.50 (87.50)
Gigartina acicularis	-	5.91 (147.75)	30.88 (772.00)

4. CONCLUSIONS

Summing up we can conclude that some very interesting changes have occurred in Kastela Bay.

Firstly, only some abiotic factors such as temperature, salinity, sea water density, transparency of the sea etc. have shown the considerable effect of the coastal factors. The studies of heavy metals show that pollution is growing, that there is a significant spatial distribution and that the highest values were recorded in the vicinity of the outfalls of pollutants (Vukadin et al., 1985). On the contrary, the quantities of nutrients (phosphates, nitrates) were not high enough to draw attention to the changes of ecosystems in the bay. Nevertheless, the biotic component was endangered to a much greater degree because the turnover of phytoplanktonic organisms was obviously very fast and the required quantities of nutrients could not be found. At the same time we found disturbed composition and relation between phytoplankton and zooplankton species (copepods) and changes in the floristic composition of phytobenthos with an increase in relative abundance and biomass of some dominant species. In addition, there was a different rhythm of seasonal oscillations of the total phytoplankton and zooplankton organisms (copepods). Instead of the two maxima usually found in the Adriatic, three of these were found in the Bay of Kastela as a consequence of pollution from land-based sources (Pucher-Petkovic, 1970; Regner, 1982).

It is therefore clear that the area of Kastela Bay which is exposed to the strong influence of the land, should be observed over a longer period, since no short-term investigations could establish the changes these effects produce. In addition, special attention must be paid to the dominant species as possible indicators of polluted areas at coastal regions of the Adriatic (and perhaps the Mediterranean as a whole).

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AN INVESTIGATION OF PLANKTON COMMUNITIES IN THE ZUPA DUBROVACKA BAY (1983-1984)

by

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ABSTRACT

The investigation of plankton in the Zupa Dubrovacka Bay was carried out at three stations during four cruises in 1983/84.

Phytoplankton samples were taken with Nansen bottles and analysed by the inverted microscope method. The phytoplankton biomass was expressed as total cell volume per litre. Microzooplankton and mesozooplankton were collected with vertical hauls from the bottom to the surface using a 53 um and a 250 um mesh net. Macrozooplankton was sampled only at night with horizontal tows from 5 m to the surface.

The total phytoplankton biomass ranged from 2.6×10^7 to 1.1×10^9 um^3 l^{-1} and most frequently ranged between 10^8 and 5×10^8 um^3 l^{-1}. The numerical abundance higher than 10^5 cells l^{-1} and 5×10^8 um^3 l^{-1} was recorded only between the surface and 5 m depth.

Microzooplankton population density ranged from 15,161 ind. m^{-3} to 2,126 ind. m^{-3}. The contribution of Foraminifera and Radiolaria to total microzooplankton was less than 9%. Fauna of tintinnines was recorded with a total of 35 species. The number of tintinnines ranged between 1,888 ind. m^{-3} and 93 ind. m^{-3}. Nauplii contributed in all cases over 50% of the total number of microzooplankton. The highest numerical abundance was recorded in April (13,753 ind. m^{-3}). The number of copepodites ranged from 151-1,690 ind. m^{-3} with the highest values recorded in July. The composition and quantity of plankton population was similar at all investigated stations.

Considered as a coastal pelagic ecosystem, the Zupa Dubrovacka Bay contains a plankton community typical of the unpolluted areas in the southern Adriatic zone. In view of the increasing investment in touristic facilities, as well as the planned construction of a common sewage system for the entire bay, it will be necessary to monitor the biological and chemical parameters at the location of sewage outflow and in the bay as a whole. The weak eutrophication noted in the bay suggests a need for permanent control of the environment.

1. INTRODUCTION

The Zupa Dubrovacka Bay is situated approximately 10 kilometres southeast of Dubrovnik and is surrounded by evergreen vegetation, due to the Mediterranean climate and karst foundation. The bay does not extend too far into the shore and is thus under the constant influence of the open sea waters. As there is an hydro-electric plant, this region is also under the influence of fresh water. In the Zupa Dubrovacka Bay area, tourism is quite important so that the population doubles during the summer period. In addition to the existing hotels, there is a plan to construct several new hotels, which will increase the quantity of sewage.

The aim of this report is to investigate the plankton population in the Zupa Dubrovacka Bay before installing drainpipes under the sea.

2. MATERIAL AND METHODS

Samples for the plankton study in the Zupa Dubrovacka Bay were collected at three stations during four cruises in 1983/84 (Fig. 1). Nansen bottle samples were taken for the quantitative analysis of phytoplankton. The phytoplankton counts were obtained by the inverted microscope method (Utermöhl, 1958). The limit between microphytoplankton and nanoplankton is 15 um. The phytoplankton biomass was expressed as total cell volume and calculated according to Eppley *et al.* (1970). More details on cell size measurements were provided by Vilicic (1985). Plankton net with 53 um mesh netting was used for qualitative analysis. Microzooplankton and mesozooplankton were sampled with vertical tows from the bottom to the surface. Microzooplankton was taken with a 53 um mesh Nansen net, while mesozooplankton was taken with a 250 um mesh Indian Ocean Standard net. The numbers of microzooplankton and mesozooplankton are expressed as numbers of individuals per m^3. Macrozooplankton was sampled with horizontal tows from 5 metres to the surface at Station 9. Only nocturnal samples were collected because mysids and cumaceans are at the sea bottom during the daytime and at night they swim towards the surface. The number of macrozooplankton is expressed as a number of individuals per 10 m^3. All samples were preserved with 2% neutralized formalin solution.

3. RESULTS AND THEIR INTERPRETATION

3.1 Phytoplankton

The phytoplankton population density in the Zupa Dubrovacka Bay ranged from 3,000 to 198,000 microphytoplankton cells l^{-1}, and from 374,000 to 3,517,000 nanoplankton cells l^{-1} (Fig. 2, Table I).

The range of phytoplankton biomass (expressed as total cell volume) equalled $5x10^6$ - $9.5x10^8$ um^3 l^{-1} for microphytoplankton, $2x10^7$ - $1.8x10^8$ um^3 l^{-1} for nanoplankton, and $2.6x10^7$ - $1.1x10^9$ um^3 l^{-1} for total phytoplankton (Fig. 3).

Most frequently the microphytoplankton population density recorded ranged from 10^4-$5x10^4$ cells l^{-1} and cell volume from 10^8-$5x10^8$ um^3 l^{-1}. Most frequently the nanoplankton quantity ranged between 10^6 and $5x10^6$ cells l^{-1}, and between $5x10^7$ and 10^8 um^3 l^{-1} respectively. Total phytoplankton cell volume most frequently ranged from 10^8 to $5x10^8$ um^3 l^{-1}. The microphytoplankton population density usually decreased with depth (Table II). The values higher than 10^5 cells l^{-1} and $5x10^8$ um^3 l^{-1} were recorded only in the layer between the surface and 5 metres.

Both neritic and oceanic species of phytoplankton were identified in this area (Table III). Phytoplankton quantity was similar at all investigated stations. The mean microphytoplankton population densities at Stations 1, 3 and 9 were equal to 40,460, 41,140 and 31,110 cells l^{-1} respectively. The mean phytoplankton quantity increased at Station 3 (central station of the bay) and decreased at the outer Station 9.

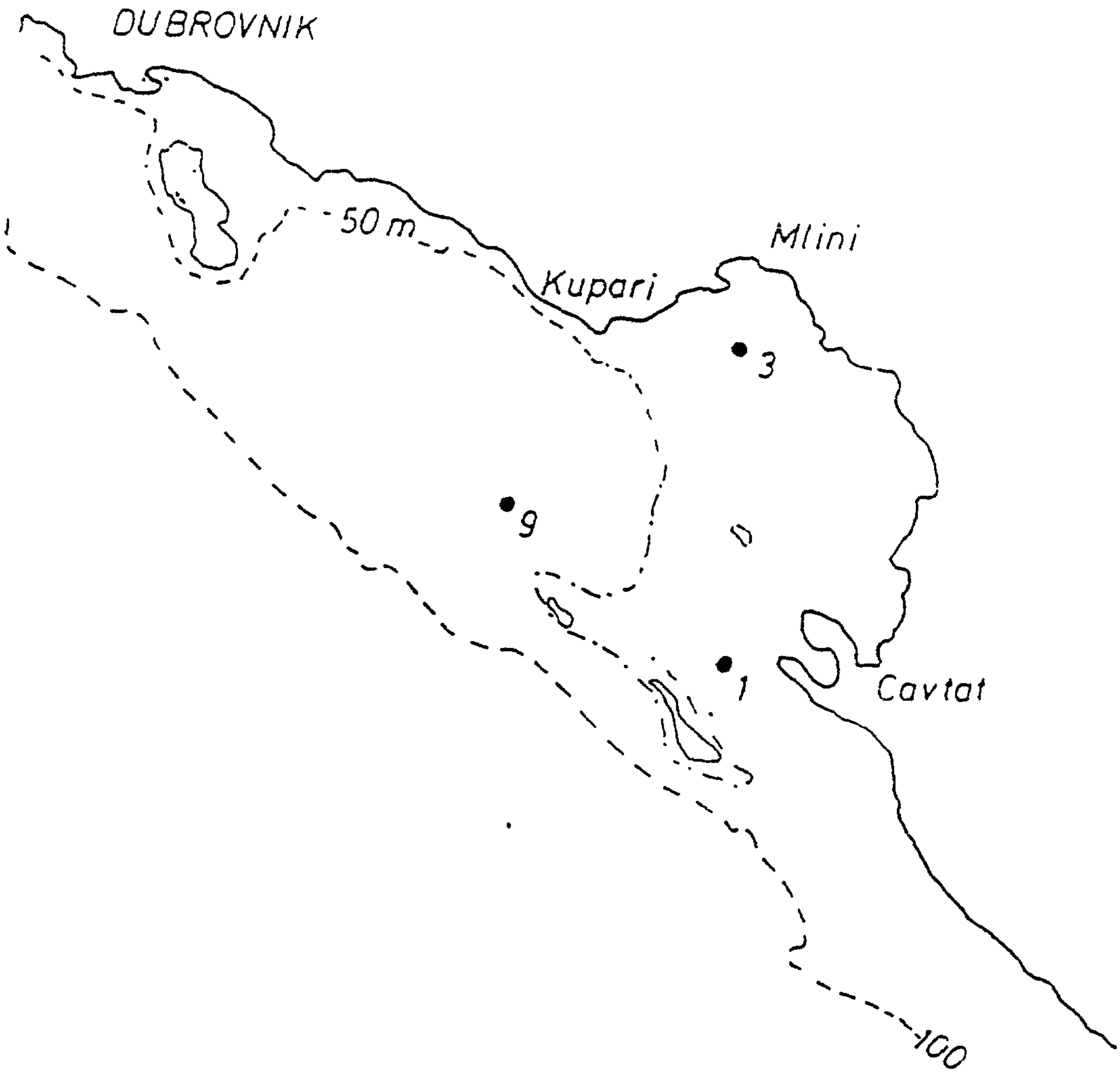

Fig. 1 Map of the area investigated with location of stations

3.2 Zooplankton

3.2.1 Microzooplankton

The total number of microzooplankton ranged from 15,161 ind. m^{-3} to 2,126 ind. m^{-3} (Table IV). Ciliates other than tintinnines were not recorded due to the inadequate method of sampling. Sampling by net provides one reason why the abundance of microzooplankton was low (Rudenjak-Lukenda, 1985).

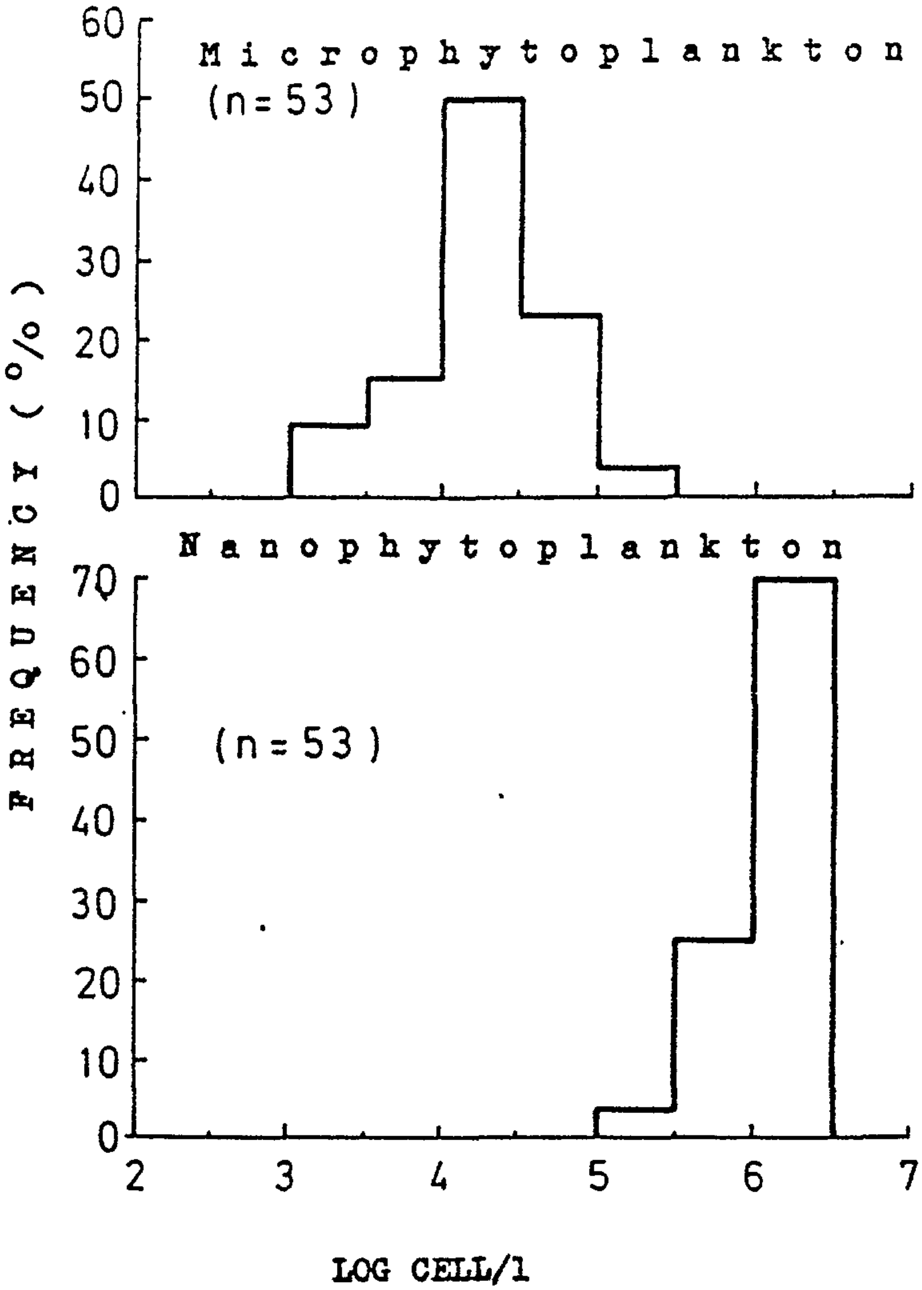

Fig. 2 Frequency distribution of microphytoplankton and nanophytoplankton population density

Table I

Microphytoplankton and nanophytoplankton population density in the Zupa Dubrovacka Bay.

Date	Station	Depth (m) Depth (m)	MICR. cell x 1000 l^{-1}	NANO cell x 1000 l^{-1}
10/11/83	1	0	4	981
		5	6	947
	3	0	199	734
		5	7	888
		10	4	636
		20	3	1338
		30	4	532
	9	0	9	794
		5	5	829
		10	10	508
		20	5	471
		50	5	375
05/04/84	1	0	49	1521
		5	139	1470
		10	54	1420
		25	18	1141
	3	0	43	1132
		5	57	1352
		10	52	1268
		20	42	1462
		30	19	1301
	9	0	92	1090
		5	73	1606
		10	48	1141
		20	32	1175
		50	19	1403
15/06/84	1	0	82	2163
		5	24	2147
		10	63	2265
		20	41	2299
		40	55	2130
	3	0	28	3617
		5	34	2282
		10	93	2265
		20	74	3228
	9	0	85	2535
		5	82	3363
		20	44	3178
		40	26	1876
28/07/84	1	0	11	1217
		5	15	1217
		10	10	1589
		25	35	1893
	3	0	16	1352
		5	14	1589
		10	40	1251
		20	33	2130
		30	20	2231
	9	0	9	845
		5	12	744
		10	11	980
		20	10	913
		50	15	1453

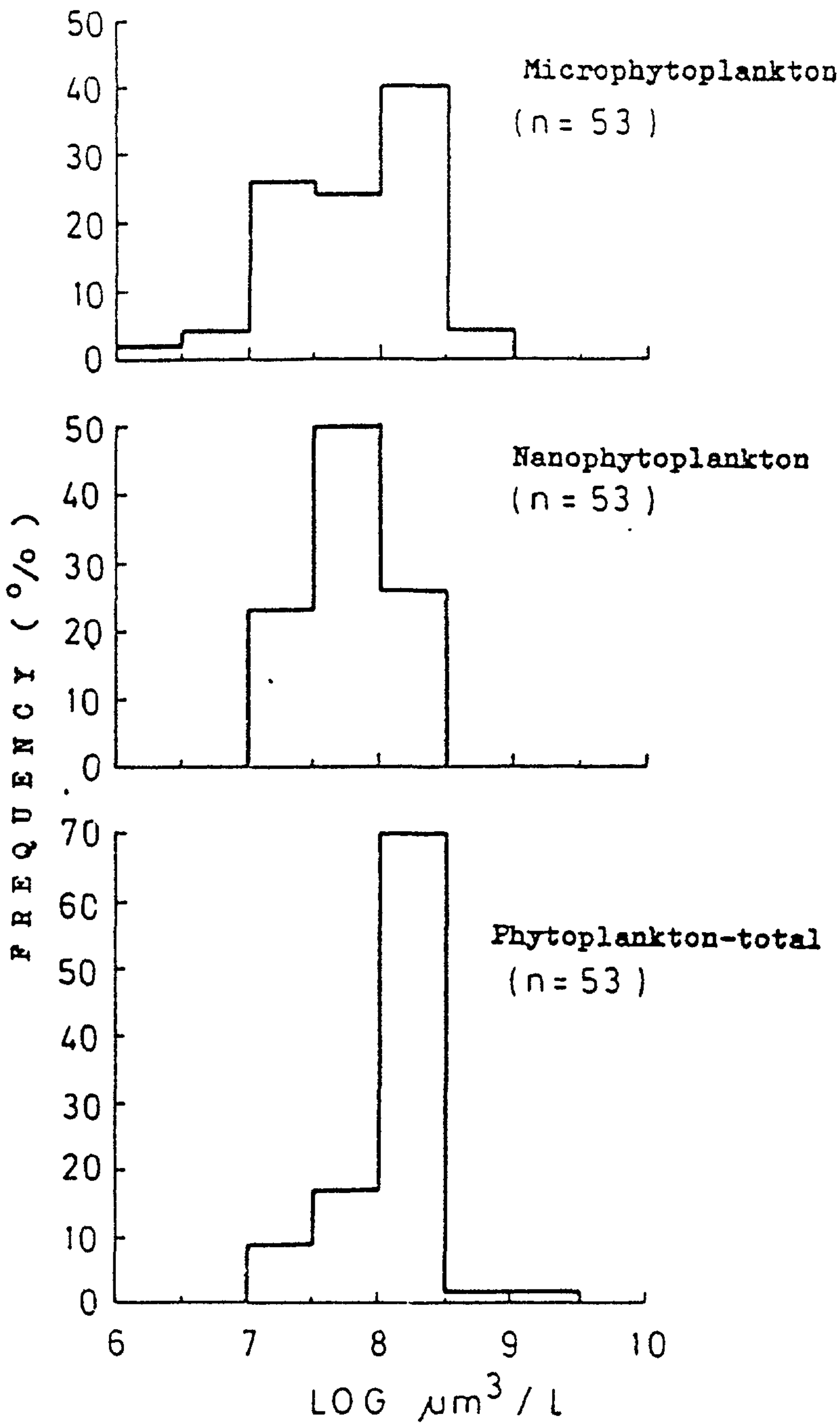

Fig. 3 Frequency distribution of microphytoplankton, nanophytoplankton and total phytoplankton cell volume

Table II

Vertical distribution of microphytoplankton population density in the Zupa Dubrovacka bay.

Date	Depth (m)	Station 1	Station 3	Station 9
		Microphytoplankton cell x 1000 l^{-1} (minimum-maximum)		
10/11/83	0-5	3-6	6-198	4-8
	10-20	-	3-4	5-9
	20	-	3	5
05/04/84	0-5	49-139	42-56	73-91
	10-20	53	41-52	32-48
	20	18	19	18
15/06/84	0-5	23-81	27-34	81-84
	10-20	41-63	74-92	44
	20	54	-	25
28/07/84	0-5	11-15	14-16	9-12
	10-20	10	32-39	9-10
	20	35	20	15
Annual range	0-5	3-139	6-198	4-91
	10-20	10-63	3-92	5-48
	20	18-54	3-20	5-25
Annual average		40	41	31

The contribution of Foraminifera and Radiolaria to the total number of microzooplankton was less than 9% and ranged between 1,105 ind. m^{-3} and 4 ind. m^{-3} (Table V). A total of 35 species of tintinnines was recorded (Table IV). The number of tintinnines ranged from 1,888 ind. m^{-3} in November to 93 ind. m^{-3} in June (Table V). The contribution of tintinnines to the total number of microzooplankton does not exceed 21%. Oceanic species of tintinnines prevail at Stations 1 and 9 (Table IV). At Station 3, in addition to neritic species, a great number of oceanic tintinnines was identified, which means that the influence of the open sea waters is high in the Zupa Dubrovacka Bay. The most numerous tintinnine species was Eutintinnus fraknoi, with 507 ind. m^{3} in April (61% of the total number of microzooplankton).

The contribution of nauplii in microzooplankton was always above 50%. The maximum abundance of nauplii with 13,753 ind. m^{-3} was recorded in April and the minimum with 1,489 ind. m^{-3} in June (Table V).

Table III

List of determinate microphytoplankton species in the Zupa Dubrovacka Bay.

Species	11/83	04/84	06/84	07/84
	Month-Year			
BACILLARIOPHYCEAE				
Amphiprora sulcata	+	-	-	-
Asterionella bleakeleyii	+	-	+	-
Asterionella japonica	+	+	+	+
Asterionella notata	+	+	+	+
Asteromphalus heptactis	+	+	+	+
Asterolampra marylandica	+	+	+	+
Auricula insecta	+	+	+	+
Bacteriastrum biconicum	+	+	+	+
Bacteriastrum delicatulum	+	+	+	+
Bacteriastrum elongatum	+	+	+	+
Bacteriastrum hyalinum	+	+	+	+
Bacteriastrum mediterraneum	+	+	+	+
Campylodiscus decorus	+	+	+	+
Cerataulina pelagica	+	+	+	+
Chaetoceros affinis	+	+	+	+
Chaetoceros anastomosans	+	+	+	+
Chaetoceros brevis	+	+	+	+
Chaetoceros coarctatus	+	+	+	+
Chaetoceros compressus	+	+	+	+
Chaetoceros convolutus	+	+	+	+
Chaetoceros curvisetus	+	+	+	+
Chaetoceros decipiens	+	+	+	+
Chaetoceros diversus	+	+	+	+
Chaetoceros dadayii	+	+	+	+
Chaetoceros danicus	+	+	+	+
Chaetoceros lorenzianus	+	+	+	+
Chaetoceros peruvianus	+	+	+	+
Chaetoceros rostratus	+	+	+	+
Chaetoceros simplex	+	+	+	+
Chaetoceros tortissimus	+	+	+	+
Chaetoceros vixvisibilis	+	+	+	+
Chaetoceros wighamii	+	+	+	+
Coscinodiscus excentricus	+	+	+	+
Coscinodiscus thorii	+	+	+	+
Dactyliosolen mediterraneus	+	+	+	+
Eucampia cornuta	+	+	+	+
Fragillaria sp.	+	+	+	+
Grammatophora oceanica	+	+	+	+
Gyrosigma balticum	+	+	+	+
Guinardia flaccida	+	+	+	+
Guinardia blavyana	+	+	+	+
Hemiaulus hauckii	+	+	+	+
Leptocylindrus danicus	+	+	+	+
Licmophora reichardtii	+	+	+	+
Licmophora falbellata	+	+	+	+
Licmophora paradoxa	+	+	+	+
Melosira sulcata	+	+	+	+
Navicula distans	+	+	+	+
Navicula sp.	+	+	+	+

Table III (continued)

Species	Month-Year 11/83	04/84	06/84	07/84
Nitzschia closterium	+	+	+	+
Nitzschia "delicatissima"	+	+	+	+
Nitzschia longissima	+	+	+	+
Nitzschia paradoxa	+	+	+	+
Nitzschia "seriata"	+	+	+	+
Pleurosigma angulatum	+	+	+	+
Rhizosolenia alata f. gracillima	+	+	+	+
Rhizosolenia alata f. indica	+	+	+	+
Rhizosolenia calcar-avis	+	+	+	+
Rhizosolenia castracanei	+	+	+	+
Rhizosolenia fragilissima	+	+	+	+
Rhizosolenia imbricata	+	+	+	+
Rhizosolenia robusta	+	+	+	+
Rhizosolenia stolterfothii	+	+	+	+
Skeletonema costatum	+	+	+	+
Striatella unipunctata	+	+	+	+
Synedra crystallina	+	+	+	+
Synedra undulata	+	+	+	+
Synedra sp.	+	+	+	+
Thalassiothrix frauenfeldii	+	+	+	+
Thalassionema nitzschioides	+	+	+	+
Thalassiosira decipiens	+	+	+	+
DINOPHYCEAE + DESMOPHYCEAE				
Amphisolenia bidentata	+	+	+	+
Ceratium candelabrum	+	+	+	+
Ceratium carriense	+	+	+	+
Ceratium concilians	+	+	+	+
Ceratium euarcuatum	+	+	+	+
Ceratium furca	+	+	+	+
Ceratium fusus	+	+	+	+
Ceratium gibberum	+	+	+	+
Ceratium hexacanthum	+	+	+	+
Ceratium karstenii	+	+	+	+
Ceratium longirostrum	+	+	+	+
Ceratium macroceros	+	+	+	+
Ceratium massiliense	+	+	+	+
Ceratium pentagonum	+	+	+	+
Ceratium pulchellum	+	+	+	+
Ceratium ranipes f. palmatum	+	+	+	+
Ceratium symetricum	+	+	+	+
Ceratium trichoceros	+	+	+	+
Ceratium teres	+	+	+	+
Ceratium tripos	+	+	+	+
Ceratocorys gourretii	+	+	+	+
Ceratocorys horrida	+	+	+	+
Centrodinium eminens	+	+	+	+
Dinophysis acuta	+	+	+	+
Dinophysis acuminata	+	+	+	+
Dinophysis caudata	+	+	+	+
Dinophysis hastata	+	+	+	+
Dinophysis mitra	+	+	+	+
Dinophysis parvula	+	+	+	+
Dinophysis schuettii	+	+	+	+

Table III (continued)

Species	Month-Year 11/83	04/84	06/84	07/84
Dinophysis tripos	-	+	-	+
Glenodinium lenticula	+	-	+	-
Gonyaulax hyalina	-	-	+	-
Gonyaulax kofoidii	-	-	+	-
Gonyaulax polygramma	+	-	-	-
Gonyaulax sp.	-	-	-	+
Goniodoma polyedricum	+	+	+	+
Kofoidinium velleloides	+	-	-	-
Noctiluca miliaris	+	-	-	-
Ornithocercus heteroporus	+	-	-	-
Ornithocercus magnificus	+	+	-	-
Ornithocercus quadratus	+	-	-	-
Oxytoxum scolopax	+	+	-	-
Peridinium brochii	+	-	-	-
Peridinium conicum	-	-	-	+
Peridinium depressum	-	+	+	+
Peridinium divergens	+	+	-	-
Peridinium globulus	+	+	-	-
Peridinium leonis	-	-	-	+
Peridinium oceanicum	-	-	+	+
Peridinium pyriforme	+	-	-	-
Peridinium steinii	+	-	-	-
Phalacroma rotundatum	+	-	-	-
Podolampas bipes	+	-	+	+
Podolampas palmipes	-	-	+	-
Prorocentrum compressum	+	-	-	+
Prorocentrum micans	-	-	+	+
Prorocentrum scutellum	+	-	-	-
Pyrocystis elegans	+	+	-	-
Pyrocystis pseudonoctiluca	+	-	+	-
Pyrophacus horologicum	+	+	+	-
HAPTOPHYCEAE + CHRYSOPHYCEAE				
Calciosolenia granii	+	-	-	-
Dictyocha fibula	+	-	-	-
Dinobryon sp.	+	-	-	-
Scyphosphaera apsteinii	+	-	-	-
Syracosphaera pulchra	+	-	+	-
PRASINOPHYCEAE				
Halosphaera viridis	+	+	+	+

The abundance of copepodites ranged between 1,690 ind. m^{-3} and 151 ind. m^{-3} (Table V). *Oncaea* copepodites prevailed in the total number of copepodites in November and *Oithona* copepodites in July, which were also present as adults.

Table IV

Qualitative and quantitative composition of microzooplankton in the Zupa Dubrovacka Bay in 1983/84 - net samples /no. ind. m^{-3}.

DATE	10/11			05/04			15/06			28/07		
STATION	1	3	9	1	3	9	1	3	9	1	3	9
FORAMINIFERA	345	56	211	-	-	51	-	11	6	-	-	-
RADIOLARIA	760	478	270	17	85	25	13	6	8	4	21	25
TINTINNINA												
Tintinnopsis beroidea	-	-	-	17	28	-	-	-	-	-	14	8
Tintinnopsis fennica	-	-	-	-	-	-	-	-	-	-	7	8
Tintinnopsis campanula	-	14	8	59	85	51	-	-	-	-	-	-
Tintinnopsis lindeni	-	-	-	-	-	-	-	-	-	18	21	25
Tintinnopsis radix	17	-	17	-	-	-	-	-	2	4	-	-
Tintinnopsis cylindrica	-	14	8	-	-	-	-	-	-	-	-	-
Codonella aspera	17	14	152	-	-	-	4	-	-	-	-	8
Codonella galea	101	28	34	-	-	-	-	-	-	-	-	-
Codonella apicata	-	-	8	-	-	-	-	-	-	-	-	-
Codonaria cistellula	84	28	17	-	-	-	-	-	-	-	-	-
Stenosemella ventricosa	-	112	42	8	14	25	-	-	-	-	-	-
Codonellopsis orthoceras	236	28	34	-	-	-	-	-	-	-	-	-
Codonellopsis orthoceras	236	323	278	-	14	-	-	-	-	-	-	-
Favella ehrenbergii	-	-	-	17	14	34	-	-	-	-	-	-
Epiplocylis acuminata	-	-	8	-	28	8	2	-	2	28	21	76
Rhabdonella spiralis	17	28	34	-	-	-	15	-	4	53	84	84
Xystonella longicauda	17	28	8	-	-	-	2	-	-	-	-	-
Xystonella lohmanni	-	-	-	-	-	-	-	-	-	11	21	25
Undella hyalina	287	295	287	-	-	-	2	2	-	4	35	203
Undella claparedei	17	-	-	-	14	51	-	-	-	-	14	8
Dictyocysta elegans	17	14	34	-	28	8	21	-	6	32	49	186
Dictyocysta lepida	67	-	8	8	-	-	-	-	-	-	-	-
Dictyocysta mitra	101	28	17	-	-	-	-	-	-	-	7	-
Steenstrupiella steenstrupii	186	112	219	-	42	17	6	4	6	25	28	59
Amphorides quadrilineata	-	14	-	-	-	-	-	-	2	-	-	-
Amphorides quadrilineata var. minor	118	28	8	-	-	-	4	-	2	-	-	-

Table IV (continued)

DATE	10/11			05/04			15/06			28/07		
STATION	1	3	9	1	3	9	1	3	9	1	3	9
Dadayiella ganymedes	67	-	42	-	14	-	-	-	-	-	-	-
Eutintinnus fraknoi	67	70	127	245	507	490	44	23	135	42	35	203
Eutintinnus lusus-undae	67	14	42	-	-	-	44	6	49	4	21	34
Eutintinnus elegans	-	-	-	-	-	-	13	7	4	28	14	51
Eutintinnus tubulosus	-	-	8	-	-	-	8	-	4	4	21	17
Eutintinnus apertua	169	56	76	-	-	-	8	-	-	46	70	34
Eutintinnus stramentus	-	-	8	-	-	-	-	-	-	-	-	-
Salpingella glockentoegeri	-	14	25	-	-	-	27	-	21	218	183	448
Salpingella rotundata	-	-	-	-	-	-	11	-	-	7	35	59
NAUPLII	6910	5204	4262	9343	10954	13753	1489	1820	1529	3914	6674	7679
COPEPODITES	607	196	151	177	423	414	319	356	543	704	1690	853
COPEPODA												
Oithona nana	-	-	8	-	-	-	2	7	4	28	113	42
Oncaea media	321	70	93	8	+	42	6	+	4	4	7	8
Oncaea subtilis	388	14	34	+	42	34	6	+	23	4	70	42
Oncaea mediterranea	67	14	17	-	-	-	-	-	-	-	-	-
Oncaea zernovi	84	28	8	-	-	-	6	-	17	-	14	-
Oncaea ivlevi	17	-	-	-	-	8	2	-	2	-	-	-
Euterpina acutifrons	34	14	+	-	-	-	+	4	2	-	-	-
Microsetella norvegica	+	60	34	+	14	8	2	11	2	11	14	25
PTEROPODA juv.	135	352	405	-	14	8	15	51	17	39	91	93
CHAETOGNATHA juv.	-	-	-	-	-	-	4	-	1	-	-	-
APPENDICULARIA juv.	101	56	34	17	28	8	19	28	40	92	106	118
LARVAE												
Bivalvia	51	+	135	42	42	42	30	61	21	42	113	34
Polychaeta	118	141	59	17	+	8	2	7	4	4	7	17
Echinodermata	+	56	+	+	+	17	+	2	4	-	-	-
TOTAL	11826	8015	7270	10127	12432	15161	2126	2406	2464	5370	9600	10532

During the investigation, eight species of copepods were recorded (Table IV). They were most abundant in November with 911 ind. m^{-3} when Oncaea subtilis and O. media contributed 71% of the total number (Table V).

The number of juvenile Pteropoda, Chaetognatha and Appendicularia, as well as Bivalvia, Polychaeta and Echinodermata larvae (other metazoa) in total microzooplankton was rather small (Table V).

When the quantity of microzooplankton is taken into consideration, the Zupa Dubrovacka Bay could be compared with the open waters of the central Adriatic.

3.2.2 Mesozooplankton

On the basis of the qualitative analysis of mesozooplankton in the Zupa Dubrovacka Bay, the region is neritic with the influence of the open sea waters (Benovic et al., 1979; Onofri, 1984). The greatest diversity was recorded for copepods with 40 species identified (Tables VI and VII). The highest values were due to only two neritic species, Acartia clausi and Paracalanus parvus. The other species of copepods, mostly oceanic, were less numerous. The qualitative composition of copepods was similar at all stations. *Increased numerical abundance of copepods was recorded in April* with 934 ind. m^{-3} at Station 1, 819 ind. m^{-3} at Station 3 and 872 ind. m^{-3} at Station 9. The minimum abundance recorded was in June with 139 ind. m^{-3} at Station 3. Phyllopods were another numerous mesozooplankton group (Tables VI and VII).

Medusae were analysed in detail (Table VIII). In this region 12 species of hydromedusae were recorded; they were more abundant in November and April. Pelagia noctiluca was found only at the outer stations (1 and 9).

3.2.3 Macrozooplankton

The qualitative analysis of macrozooplankton indicates the dominance of coastal species with significant presence of open-sea representatives (Lucic, 1985). Increased numerical abundance was not found (Table IX). The highest values were those of the species Muggiaea kochi (Siphonophora) and Sagitta setosa (Chaetognatha) during the greater part of the year. Larvae of decapods were markedly dominant during the warm period, when the greatest number of mysids was also found.

4. CONCLUSIONS

On the basis of the plankton qualitative and quantitative data, the investigated region is characterized as a neritic ecosystem strongly influenced by the open sea waters. With respect to maximum-minimum distribution and the most frequent phytoplankton quantity, the analysed ecosystem might be described as weakly eutrophied. Moderate eutrophication is found only at the central station in the surface layer. The composition and quantity of plankton population is similar at all investigated stations. The number of copepodites ranged from 151 to 1,690 ind. m^{-3} with the highest values in July. Copepods were the most abundant in November (911 ind. m^{-3}) when Oncaea subtilis and O. media were the dominant species.

In terms of the qualitative analysis of mesozooplankton, the greatest diversity was recorded for copepods. Their high values were due to only two neritic species, Acartia clausi and Paracalanus parvus. Increased numerical abundance of macrozooplankton was not found.

Table V

The numberical abundance of microzooplankton groups in the Zupa Dubrovacka Bay in 1983/84
Net samples (no. ind. m^{-3}).

	DATE	10/11			05/04			15/06			28/07		
	STATION	1	3	9	1	3	9	1	3	9	1	3	9
FORAMINIFERA + RADIOLARIA		1105	534	48	17	85	76	13	17	14	4	21	25
TINTINNINA		1888	1276	1549	506	830	743	226	93	254	526	680	1596
NAUPLLI		6910	5204	4262	9343	10954	13753	1489	1820	1529	3914	6674	7679
COPEPODITES		607	196	151	177	423	414	319	356	543	704	1690	853
COPEPODS		911	200	194	8	42	100	24	22	54	47	218	117
OTHER METAZOA		405	605	633	76	98	75	55	98	70	175	317	262
	TOTAL	11826	8015	7210	10127	12432	15161	2126	2406	2464	5370	9600	10532

Table VI

List of species and population density (No. ind. m^{-3}) of mesozooplankton in November 1983 and April 1984 in the Zupa Dubrovacka Bay.

DATE	10/11/1983			05/04/1984		
SPECIES / STATIONS	1	3	9	1	3	9
HYDROMEDUSAE	2	2	5	3	8	
SIPHONOPHORAE	20	3	24	66	14	16
PHYLLOPODA						
Penilia avirostria	86	47	69	24	2	
Podon intermedius				3	6	7
Evadne spionifera	4	37		39	4	
Evadne tergestina					2	
COPEPODA						
Calanus helgolandicus	1					
Calanus tenuicornis				9		3
Nanocalanus minor	2		1			1
Mecynocera clausi	4	7	1	6		1
Paracalanus denudatus	10	10	7		2	3
Paracalanus nanus		3				
Paracalanus parvus	138	157	159	135	102	257
Calocalanus pavo	6		14			
Calocalanus contractus	2	1	1			1
Calocalanus styliremis	2	3	1			1
Ischnocalanus plumulosus	2	2	5			
Clausocalanus arcuicornis		3	5	6	2	37
Clausocalanus jobei	4	1	1		20	4
Clausocalanus paululus		3				
Clausocalanus furcatus	52	93	95	42	18	28
Ctenocalanus vanus	10		18	1	8	137
Pseudocalanus elongatus						3
Diaixis pygmoea	12	3				1
Centropages typicus	2	2	6	42	62	51
Temora stylifera	50	47	81		140	13
Candacia sp.	2					
Acartia clausi	14	20	29	549	262	93
Oithona helgolandica			6	24	72	99
Oithona nana	4			6		2
Oithona plumifera	88	30	60			1
Euterpina acutifrons		1				
Clytemnestra rostrata		3	1			
Oncaea spp.	12	67	12	3	2	13
Sapphirina sp.	1				1	1
Corycaeus sp.	76	23	44	21	46	51
Calanoid juv.	8	23	15	27	28	32
Copepodites			1	63	54	39
OSTRACODA	4	2				1
PTEROPODA	6	3	8	12	12	6
CHAETOGNATA	40	24	142	15	6	19

Table VI (continued)

DATE	10/11/1983			05/04/1984		
SPECIES / STATIONS	1	3	9	1	3	9
APPENDICULARIA	78	7	68	18	32	39
DOLIOLIDA	20		10	12	16	8
LARVAE						
Pisces	4	1	3			
Decapoda	10		1		4	1
Ophiurida			4			
Echinida			1		2	
Bivalvia	10		2	3	6	9
Tornaria					38	12
Ova Pisces	14		5	3		4
Noctiluca milliaris			2	6	4	
COPEPODA	502	502	563	934	819	872
PHYLLOPODA	90	84	69	66	14	7
LARVAE	24	1	11	3	50	22
OTHER GROUPS	184	41	264	135	92	93
TOTAL	800	800	907	1138	975	994

Table VII

List of species and population density (No. ind. m^{-3}) of mesozooplankton in June and July 1984 in the Zupa Dubrovacka Bay.

DATE	15/06/1984			27/07/1984		
SPECIES / STATIONS	1	3	9	1	3	9
SIPHONOPHORAE	7		1	2	2	1
PHYLLOPODA						
Penilia avirostria		1	1	43	49	
Evadne sp.	66	12	15	14	3	9
Podon sp.		1	1	4	15	11
COPEPODA						
Calanus tenuicornis						2
Calanus helgolandicus	1		1			1
Mecynocera clausi	1		1		1	1
Paracalanus denudatus	1	1	1			
Paracalanus parvus	43	3	36	60	4	4
Calocalanus pavo					2	1
Calocalanus contractus	1				1	
Calocalanus styliremis					1	
Ischnocalanus plumulosus						1
Clausocalanus arcuicornis	3	1	1	6	3	1
Clausocalanus jobei	1	1	1	1		2
Clausocalanus furcatus	1		1	2	2	4
Euchaeta hebes						1
Ctenocalanus vanus	2		2	2	1	18
Diaixis pygmoea	1		1		1	
Centropages kroeyeri	63	8	19	2	10	35
Centropages typicus	1	1	2	5	2	
Temora stylifera	2		1	1	4	9
Temora longicornis	1		1	23	5	
Acartia clausi	270	114	58	99	701	14
Oithona helgolandica	4	1	3	20	7	4
Oithona nana	3	1	3	1	2	2
Oithona plumifera	4	2	3	11	3	16
Microsetella norvegica	1		1		1	
Clytemnestra rostrata		1		1		
Oncaea spp.		1	1	2	4	1
Sapphirina sp.		1	1			1
Corycaeus sp.	14	1	1	20	9	75
Calanoid juv.	2	1	1	8	3	5
Copepodites	3	1	1	4	8	3
OSTRACODA		1			1	1
PTEROPODA						
Creseis acicula	1	1				
Ostali	9	4	3	3	45	1
CHAETOGNATA	6	1	4	30	16	3

Table VII (continued)

DATE	15/06/1984			27/07/1984			
SPECIES / STATIONS	1	3	9	1	3	9	
APPENDICULARIA	14	1	4	68	89	5	
DOLIOLIDA	6	1	1	6	2	4	
LARVAE							
Pisces	3	1	1		2	2	
Decapoda	2	1	1		5	4	
Ophiurida			1				
Bivalvia	1		9		7	2	
Ova Pisces	1	1	1				
COPEPODA	421	139	141	266	776	200	
PHYLLOPODA	66	14	17	61	67	20	
LARVAE	7	3	13		14	8	
OTHER GROUPS	43	9	43	109	154		14
TOTAL	537	165	214	346	1011	242	

Table VIII

List of species and total number of Medusae in the Zupa Dubrovacka Bay (net 250 um)

SPECIES	DATE / STATION	10/11/1983			05/04/1984			15/06/1984				27/07/1984			
		1	3	9	1	3	9	1	3	9	3	1	3	9	3
		25-0	30-0	60-0	25-0	30-0	60-0	40-0	30-0	60-0	Surface	25-0	30-0	50-0	Surface
HYDROMEDUSAE															
Sarsia gemmifera					2	1				1		2			
Rhysomedusa pomponina							1								
Podocoryne minima			1	2		1				3					
Podocoryne minuta				1								18	6		57
Obelia spp.			4	6	34	33	26					1			
Phinlidium hemisphaericum		3	5	6			2								
Liriope tetraphylla		14	24	41	19	34	7	5		1					
Aglaura hemistoma		33	77	120	15	90	31	7		2					
Persa incolorata							3								
Rhopalonema velatum		4		14	2	3	12	6				1	1		
Somaris leucostyula			19				1								
Solmundella bitentaculata				7											
SCYPHOMEDUSAE															
Pelagia noctiluca (Ephyrae)				6	1										
	TOTAL	54	130	203	73	162	83	18	0	7	0	22	7	0	57

Table IX

List of species and population density (No. ind. 10 m^{-3} of macrozooplankton at Station 9 in the Zupa Dubrovacka Bay.

SPECIES	10/11/1983	05/04/1984	15/06/1984	26/07/1984
SIPHONOPHORAE				
Miggiaea kochi	65	9	39	18
Lensia sp.		24	4	8
Eudoxioides spirallis		4		
Chelophyes appendiculata		1		
POLYCHAETA				
Tomopteris helgolandica		1	8	
MYSIDACEA				
Siriella clausi		2	7	28
Siriella jaltensis	+	+		2
Anchialina agilis	2	4	43	40
Haplostylus lobatus	2	+	39	27
Leptomysis gracilis	1	2	2	4
CUMACEA				
Cumella limicola			4	1
ISOPODA				
Eurydice truncata	3	1	6	1
CHAETOGNATA				
Sagitta setosa	99	8	130	80
Sagitta minima	3		4	2
Sagitta inflata		2		
DOLIOLIDA	12	8	52	16
DECAPOD LARVAE	17	8	153	432
PISCES LARVAE	7	3	17	11

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