MEDITERRANEAN ACTION PLAN
MED POL

UNITED NATIONS ENVIRONMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
(GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN)

RESEARCH ON THE EFFECTS OF POLLUTANTS ON MARINE COMMUNITIES AND ECOSYSTEMS (MED POL V)

RECHERCHE SUR LES EFFETS DES POLLUANTS SUR LES COMMUNAUTES ET ECOSYSTEMES MARINS (MED POL V)

FINAL REPORTS OF PRINCIPAL INVESTIGATORS
RAPPORTS FINAUX DES CHERCHEURS PRINCIPAUX

MAP Technical Reports Series No. 5

UNEP
Athens, 1986

For bibliographic purposes this volume may be cited as:

UNEP/FAO: Research on the Effects of Pollutants on Marine Communities and Ecosystems (MED POL V). MAP Technical Reports Series No. 5. UNEP, Athens 1986.

Pour des fins bibliographiques, citer le présent volume comme suit:

PNUE/FAO: Recherche sur les effets des polluants sur les communautés et écosystèmes marins (MED POL V). MAP Technical Reports Series No. 5. UNEP, Athens 1986.

MEDITERRANEAN ACTION PLAN
MED POL

UNITED NATIONS ENVIRONMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
(GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN)

RESEARCH ON THE EFFECTS OF POLLUTANTS ON MARINE COMMUNITIES AND ECOSYSTEMS (MED POL V)

RECHERCHE SUR LES EFFETS DES POLLUANTS SUR LES COMMUNAUTES ET ECOSYSTEMES MARINS (MED POL V)

FINAL REPORTS OF PRINCIPAL INVESTIGATORS
RAPPORTS FINAUX DES CHERCHEURS PRINCIPAUX

MAP Technical Reports Series No. 5

UNEP
Athens, 1986

This volume is the fifth issue of the Mediterranean Action Plan Technical Reports Series.

This Series will collect and disseminate selected scientific reports obtained through the implementation of the various MAP components: Pollution Monitoring and Research Programme (MED POL), Blue Plan, Priority Actions Programme, Specially Protected Areas and Regional Oil Combating Centre.

Ce volume constitue le cinquième numéro de la série des Rapports techniques du Plan d'action pour la Méditerranée.

Cette série permettra de rassembler et de diffuser certains des rapports scientifiques établis dans le cadre de la mise en oeuvre des diverses composantes du PAM: 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), in co-operation with the relevant specialized United Nations Agencies (FAO, WHO, WMO, IOC), presented to the Intergovernmental Meeting of Mediterranean countries (Barcelona, 1975) a proposal for a Co-ordinated Mediterranean Pollution Monitoring and Research Programme (MED POL).

MED POL was approved and UNEP was requested to implement the Programme, consisting of seven pilot projects, in close collaboration with the relevant specialized United Nations Agencies.

Its pilot phase (MED POL-Phase I) was designed as the precursor of a long-term programme for pollution monitoring and research in the Mediterranean (MED POL-Phase II) to be carried out according to the provisions of the legal component of the Mediterranean Action Plan.

The pilot projects approved at the 1975 Barcelona Meeting as parts of MED POL-Phase I were:

MED POL I: Baseline Studies and Monitoring of Oil and Petroleum Hydrocarbons in Marine Waters

MED POL II: Baseline Studies and Monitoring of Metals, particularly Mercury and Cadmium, in Marine Organisms

MED POL III: Baseline Studies and Monitoring of DDT, PCBs and Other Chlorinated Hydrocarbons in Marine Organisms

MED POL IV: Research on the Effects of Pollutants on Marine Organisms and their Populations

MED POL V: Research on the Effects of Pollutants on Marine Communities and Ecosystems

MED POL VI: Problems of Coastal Transport of Pollutants

MED POL VII: Coastal Water Quality Control

Subsequent to the 1975 Barcelona Meeting, several other projects were added or considered as collaterals to MED POL to broaden the scope of the programme and to provide the necessary support to it. They were:

MED POL VIII: Biogeochemical Studies of Selected Pollutants in the Open Waters of the Mediterranean

MED POL IX: Role of Sedimentation in the Pollution of the Mediterranean Sea

MED POL X: Pollutants from Land-Based Sources in the Mediterranean

MED POL XI: Intercalibration of Analytical Techniques and Common Maintenance Services

MED POL XII: Input of Pollutants into the Mediterranean Sea through the Atmosphere

MED POL XIII: Modelling of Marine Systems

Participants in the pilot projects were national research centres designated by the States participating in the Mediterranean Action Plan.

The co-ordination of the MED POL-Phase I (1975-1981) was carried out by UNEP as a part of the Mediterranean Action Plan (MAP).

The following United Nations Co-operating Agencies were responsible for the technical implementation of various pilot projects :

- The Food and Agriculture Organization of the United Nations (FAO) through the General Fisheries Council for the Mediterranean (GFCM) (MED POL II, III, IV and V),

- The United Nations Educational, Scientific and Cultural Organization (UNESCO) (MED POL IX and XIII),

- The World Health Organization (WHO) (MED POL VII and X),

- The World Meteorological Organization (WMO) (MED POL XII),

- The International Atomic Energy Agency (IAEA) (MED POL VIII and XI) and

- The Intergovernmental Oceanographic Commission (IOC) of UNESCO (MED POL I and VI)

This volume of the MAP Technical Reports Series is the collection of final reports of the Principal investigators who participated in the pilot project : "Research on the Effects of Pollutants on Marine Communities and Ecosystems (MED POL V)".

INTRODUCTION

Le Programme des Nations Unies pour l'environnement (PNUE), en coopération avec les organismes spécialisés compétents des Nations Unies (FAO, OMS, OMM, COI), a présenté à la Réunion intergouvernementale des pays méditerranéens (Barcelone, 1975), une proposition de Programme coordonné de surveillance continue et de recherche en matière de pollution dans la Méditerranée (MED POL).

Le MED POL a été approuvé, et il a été demandé au PNUE de mettre en oeuvre le programme qui se compose de sept projets pilotes, en étroite collaboration avec les organismes spécialisés compétents des Nations Unies.

Sa phase pilote (MED POL - Phase I) a été conçue comme le prélude d'un programme à long terme de surveillance continue et de recherche en matière de pollution dans la Méditerranée (MED POL - Phase II) à mettre en oeuvre conformément aux dispositions de l'élément juridique du Plan d'action pour la Méditerranée.

Les projets pilotes approuvés à la Réunion intergouvernementale de Barcelone, en 1975, dans le cadre de la Phase I du MED POL, comprenaient:

MED POL I: Etudes de base et surveillance continue du pétrole et des hydrocarbures contenus dans les eaux de la mer

MED POL II: Etudes de base et surveillance continue des métaux, notamment du mercure et du cadmium, dans les organismes marins

MED POL III: Etudes de base et surveillance continue du DDT, des PCB et des autres hydrocarbures chlorés contenus dans les organismes marins

MED POL IV: Recherche sur les effets des polluants sur les organismes marins et leurs peuplements

MED POL V: Recherche sur les effets des polluants sur les communautés et écosystèmes marins

MED POL VI: Problèmes du transfert des polluants le long des côtes

MED POL VII: Contrôle de la qualité des eaux côtières

A la suite de la Réunion de Barcelone de 1975, plusieurs autres projets ont été adjoints ou considérés comme subsidiaires au MED POL en vue d'étendre la portée du programme et de lui assurer l'appui indispensable. Ce sont:

MED POL VIII: Etudes biogéochimiques de certains polluants au large de la Méditerranée

MED POL IX: Rôle de la sédimentation dans la pollution de la mer Méditerranée

MED POL X: Polluants d'origine tellurique dans la Méditerranée

MED POL XI: Inter-étalonnage des techniques d'analyse et services communs d'entretien

MED POL XII: Polluants d'origine tellurique dans la Méditerranée

MED POL XIII: Modélisation des systèmes marins

Les participants aux projets pilotes étaient des centres nationaux de recherche désignés par les Etats prenant part au Plan d'action pour la Méditerranée.

La coordination de MED POL - Phase I (1975-1981) a été assumée par le PNUE dans le cadre du Plan d'action pour la Méditerranée.

Les organismes coopérants des Nations Unies qui étaient chargés de l'exécution technique des divers projets pilotes sont les suivants:

- Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO) par l'entremise du Conseil général des pêches pour la Méditerranée (CGPM) (MED POL II, III, IV et V).

- Organisation des Nations Unies pour l'éducation, la science et la culture (UNESCO) (MED POL IX et XIII).

- Organisation mondiale de la santé (OMS) (MED POL VII et X).

- Organisation météorologique mondiale (OMM) (MED POL XII).

- Agence internationale de l'énergie atomique (AIEA) (MED POL VIII et XI), et

- Commission océanographique intergouvernementale (COI) de l'UNESCO (MED POL I et VI).

Ce volume de la série des Rapports techniques du PAM rassemble les rapports finaux des chercheurs responsables qui ont participé au projet pilote intitulé: "Recherche sur les effets des polluants sur les communautés et écosystèmes marins (MED POL V)".

Contents/Table des matières

Principal Investigators/Chercheurs principaux	Pages
R. Semroud	1 - 5
A. Demetropoulos, M. Hadjichristophorou	7 - 20
M. L. El-Hehyawi	21 - 30
Y. Halim	31 - 42
D. Bellan-Santini	43 - 55
F. Blanc, M. Leveau	57 - 68
C. Bogdanos	69 - 75
M. E. Kattoulas	77 - 88
C. E. Vamvakas	89
C. E. Vamvakas	91 - 94
A. Kocatas	95 - 102
A. Benovic	103 - 113
T. Pucher-Petkovic	115 - 126
J. Stirn	127 - 135
D. Zavodnik	137 - 145

Centre de Recherche : Centre de recherches océanographiques et des pêches
ALGER
Algérie

Chercheur principal : R. SEMROUD

Période couverte par le rapport : janvier 1977 - mars 1980

INTRODUCTION

Le Centre de Recherches Océanographiques et des Pêches (C.R.O.P.), Alger, avait déjà réalisé de nombreux travaux concernant le plancton, le benthos par contre avait été peu étudié, à plus forte raison l'influence de la pollution.

CONSIDERATIONS METHODOLOGIQUES

ZONE(S) ETUDIEES

Notre travail a porté sur les baies d'Alger et de Bou-Ismaïl. La première étant une zone perturbée, la seconde une zone de référence.

a) La Baie d'Alger :

Elle mesure 15 kilomètres d'Est en Ouest et 7 kilomètres du Nord au Sud. La profondeur maximale y est d'une centaine de mètres. Elle reçoit de nombreux égouts, essentiellement dans sa partie Ouest. La cartographie a été réalisée à partir de 138 stations.

b) La Baie de Bou Ismaïl :

Située a l'Ouest de la Baie d'Alger, elle est beaucoup plus étendue. Notre étude se limite pour l'instant à une zone comprise entre le village de Foukha-Marine et la pointe de Sidi-Fredj, jusqu'à 100 mètres de fond. Une quarantaine de stations ont été réalisées au cours des différentes missions de la "Winnaretta Singer" (Monaco).

c) La Lac Mellah :

Le CROP a effectué, en juin 1979, décembre 1979, février et mars 1980 des missions de prélèvements au niveau d'une lagune située à proximité de la vallée d'El Kala. Cette lagune a une superficie de 800 hectares, sa profondeur maximale est de 5,5 mètres. Elle est reliée à la mer par un chenal et reçoit plusieurs petits oueds.

Elle présente un grand intérêt du fait qu'elle est située dans une zone à faible densité humaine, sans activité industrielle, donc elle échappe pratiquement à toute pollution ce qui est un cas rare pour les lagunes méditerranéennes.

A l'heure où les milieux lagunaires prennent une importance économiques accrue du fait du développement des activités d'aquaculture mais sont soumis à des pollutions plus ou moins importantes, l'étude de cette lagune pourrait permettre de mieux appréhender l'évolution des lagunes méditerranéennes.

La salinité de ce Lac Mellah ne semble pas descendre en dessous de 20 °/oo. Les températures varient entre 13° en hiver et 30° en été. En juin, un déficit en oxygène dissous très important en dessous de 2,5 m de profondeur entraîne que la partie la plus profonde du lac est azoïque.

La densité des peuplements benthiques de la zone littorale est très importante, de l'ordre de 10.000 individus/m^2.

Les communautés étudiées appartiennent aux peuplements benthiques de substrats meubles suivants :

- sables fins
- sables fins envasés
- vases sableuses
- vases pures
- graviers envasés
- sables vaseux de mode calme lagunaires

Polluants :

La Baie d'Alger, largement ouverte à l'influence du large, reçoit essentiellement dans sa partie Ouest les eaux usées de l'agglomération algéroise (appr. 2.000.000 d'habitants).

METHODOLOGIE

La plupart des prélèvements sont effectués à la benne Orange Peel (de 2 à 6 coupes de benne par station) sauf quand la nature du fond (sable) ne le permet pas. Le sédiment est passé sur un tamis de 1,5 mm de maille carrée. Le refus de tamis est formolé.

Tous les oragnismes sont recueillis, déterminés, comptés.

Les tableaux sont dressés selon la méthode de Picard (1965); l'indice de Shanon (diversité), les coefficients d'affinité de Sanders et de Sorensen sont calculés. La cartographie est établie d'après la méthode des cartes biosédimentaires de Chassé et Glemarec. La cartographie des peuplements a permis de définir 11 stations qui devaient être suivies tous les mois pendant une année. Les avaries puis le naufrage (avril 1978) du bateau du CROP n'ont pas permis de réaliser cette partie du programme.

RESULTATS

Communautés de la Baie d'Alger :

- Le peuplement des sables fins : Localisé dans les fonds s'étendant jusqu'à 15 mètres de fond, sauf dans les parties Est et Ouest de la baie où son extension est plus limitée et face à l'Oued Harrach où il s'étend jusqu'à -25 mètres. Les espèces le caractérisant sont _Ophuira texturata_ et _Donax semistriatus_. _Ovenia fusiformis_ est l'espèce la plus abondante. 90 espèces ont été recueillies, la densité est d'environ 800 individus par mètre carré. L'existence de différents aspects de ce peuplement selon la localisation a été mise en évidence. Il est toujours dominé par les sabullicoles.

- Le peuplement des sables fins envasés : Localisé entre -15 et -25 mètres, il remont jusqu'à -5 mètres à l'Est et à l'Ouest de la baie. Les espèces le caractérisant sont Lumbuneris impatiens et Tellina distorta. 60 espèces ont été récoltées. La sensité est d'environ 165 individus /m^2.

- Le peuplement des vases sableuses : Il fait suite au précédent et descend jusqu'à 55 mètres. Les espèces le caractérisant sont Chaetezone setosa et Tharyx marioni. 34 espèces ont été recueillies, la densité est de 159 individus/m^2. Les varicoles strictes constituent le stock le plus important.

- Le peuplement des vases pures : De 55 mètres à 100 mètres (limite inférieure étudiée). Apseudes sp. et Sternapsis scutata sont les espèces les plus caractéristiques; Chaetezone setosa est toujours très abondante. 52 espèces ont été récoltées, la densité est de 114 individus/m^2. Les varicoles strictes sont le groupe le mieux représenté.

- Le peuplement à graviers envasés : Localisé dans les secteurs Est et Ouest de la baie (pente assez forte) essentiellement dans le circallitoral. Amphuira chiagei est l'espèce la plus caractéristique. 54 espèces ont été récoltées, la densité est de 118 individus/m^2. Les varicoles tolérantes constituent le stock le mieux représenté.

Par rapport à la classification de Picard (1965), le peuplement des sables fins est référable aux SFBC (sables fins bien calibrés); celui des vases pures et une grande partie des vases sableuses sont référables à la VTC (vase terrigène côtière). Les sables vaseux et une partie des vases sableuses constituent une zone de transition. Les graviers envasés sont assimilables au D.E. (détrique en vase).

Communautés de la baie de Bou-Ismaïl :

Les travaux dans cette baie sont moins avancés que dans celle d'Alger. La situation est identique en ce qui concern les peuplement de sable fin, de sables envasés et de vase sableuse. Par contre, les vases pures occupent une surface réduite car ils sont limités par l'extension des graviers envasés qui, dans la zone étudiée, occupent le fond depuis 50-60 mètres jusqu'à -100 mètres (limit inférieure étudiée). Le peuplement à Amphuira chiagei est beaucoup plus riche que dans la baie d'Alger, du point de vue nombre d'espèces et densité.

DISCUSSION DES RESULTATS ET CONCLUSIONS

Les rejets effectués en baie d'Alger entraînent la formation de nappes polluées parfois très étendues, essentiellement dans la partie Ouest. Le peuplement des sables fins le plus proche des sources de rejet présente une diversité spécifique élevée, les espèces caractéristiques du peuplement, donc les plus sensibles à la pollution sont partout présentés. Il n'y a pas, ou très peu, d'indicatrices de pollution sauf au niveau d'Hussein Dey en juin 1978 (Capitella capitata).

Les fortes densités (en particulier d'Owenia fusiformis) sont probablement le signe d'un enrichissement en matière organique mais cela ne se traduit pas par une dégradation des peuplements. Pour la zone plus profonde (sables vaseux, vase sableuse et vase pure) la diversité spécifique et surtout les densités sont beaucoup plus faibles.

Il n'y a pas de différences notables entre ces peuplements dans les parties Ouest (la plus polluée) et Est de la baie (indices de diversité équivalents, coefficients d'affinité élevés).

Donc la baie d'Alger ne présente pas de secteurs où les peuplements benthiques sont perturbés par la pollution, sauf à proximité immédiate des rejets. L'hydrodynamisme important dans la baie d'Alger entraîne une dispersion des eaux usées dans toute la baie. De ce fait, l'influence de la pollution est peu sensible au niveau des peuplements benthiques, malgrés l'importance de cette pollution (Alger : 2.000.000 d'habitants).

La continuation de ces travaux est nécessaire car si une évolution se manifeste elle risque de concerner rapidement l'ensemble de la baie.

PUBLICATIONS

BAKALEM, A. et ROMANO, J. Etude de la dynamique des peuplements benthiques de la baie d'Alger. 1-résultats préliminaires. 1978. XXVI° Congrès CIESM, Antalya.

BAKALEM, A., HILY, C. et ROMANO, J. C. Cartographie et définitions des peuplements benthiques de la baie d'Alger. PELAGOS sous presse (1980).

BAKALEM, A. et ROMANO, J. C. Etude des peuplements benthiques d'un milieu saumatre en Algérie : le lac Mellah. Résultats de la mission de juin 1979. PELAGOS sous presse (1980).

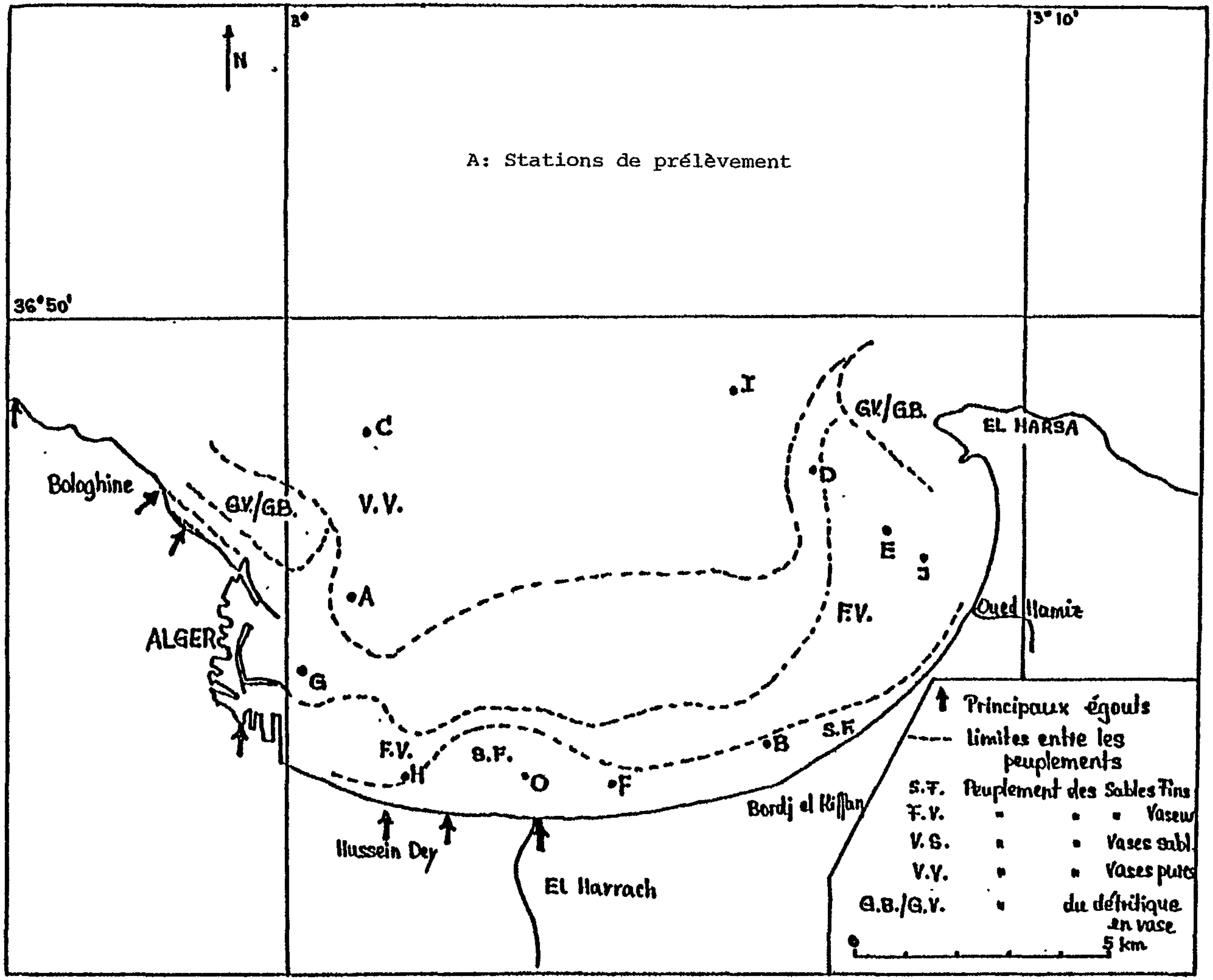


Fig. 1. Carte des peuplements benthiques de la Baie d'Alger

Research centre: Ministry of Agriculture and Natural Resources, Department of Fisheries
NICOSIA
Cyprus

Principal investigators: A. DEMETROPOULOS - M. HADJICHRISTOPHOROU

Period of reporting: November 1976 to March 1980

INTRODUCTION

The Department was involved in pollution work prior to its involvements in MED POL, mainly in the area of projects MED V and MED VI, and a similar study (on less sophisticated lines) was undertaken in Morphou Bay.

METHODOLOGICAL CONSIDERATIONS

Area:

Areas studied and location of sampling stations are shown in figure 1.

Two series of stations have been set up, one in Limassol Bay and the other in Episkopi Bay. Each series of stations consists of 7 stations at 5, 10, 20, 30, 40, 60 and 100 metres for benthos investigations, and 9 stations (all above plus 150 and 180 m) for environmental data. The sea beds at the stations set are as follows:

- Limassol Bay:

  Beach - sand with some shingle
  5 m - posidonia meadows/sand
  10 m - posidonia meadows/muddy sand
  20 m - muddy-sand with caulerpa
  30 m - mud with caulerpa
  40 m - mud with caulerpa
  60 m - mud with caulerpa
  100 m - mud, aphytal

- Episkopi Bay:

  Beach - sandy beach with low rocks
  5 m - sand with scattered posidonia outcrops
  10 m - sand with scattered posidonia outcrops
  20 m - sandy mud with caulerpa
  30 m - mud with caulerpa
  40 m - mud with caulerpa
  60 m - mud with caulerpa
  100 m - mud, aphytal

Limassol Bay (=Akrotiri Bay) (Station 2)

Limassol Bay faces south and is bounded on the west side by the Akrotiri peninsula and on the north by the mainland. On the bay is situated Limassol, a town of about 65,000 inhabitants; it has two commerical ports. There are no permanent rivers, only streams which flow during the rainy period. The increasing construction of dams also limits the quantity of water reaching the sea.

Surface sea-water temperatures (08.00 hours) reach a maximum of approximately 27.0°C and a minimum of around 14.5°C. During the summer months the thermocline is formed at about 25-30 metres depth. Salinity varies from about 38.6°/oo. The content of dissolved oxygen during winter is approximately 5.5 ml/l to a depth of 50-75 metres. During summer the content of dissolved oxygen is approximately 5 ml/l reaching the same maximum at the same depths. Analyses for suspended solids show 0-400 ppm. Summaries of physical and chemical parameters are shown in various tables and figures as annexed to the original report. The area of the continental shelf for Limassol Bay is approximately 42 square miles (down to 100 fathoms, approximately 200 m) and has a gentle slope, becoming steeper near Cape Gata.

Episkopi Bay (Station 1)

Episkopi Bay, on the other hand, lies west of Limassol Bay on the other side of the Akrotiri peninsula. There is no habitation in close proximity to the sea. The area of the continental shelf of Episkopi Bay is 67 square miles (down to 100 fathoms, or 200 m) and is similar in topography to Limassol Bay. Summaries of physical and chemical parameters are shown in tables and figures as annexed to the original report.

Communities:

All macrobenthic communities plus demersal fish were studied from the shore down to 100 metres, while fish were observed at 40 fathoms (80 m) only.

Pollutants:

(a) Limassol Bay. Industrial pollution, with few exceptions, is restricted to organic pollution. Local industries pollute Limassol Bay with about 100 tonnes suspended solids, mainly organic in origin requiring about 170 tonnes of oxygen (as BOD_5) per year for their breakdown. These 100 tonnes of suspended solids are contained in approximately 210.000 m^3 of effluent.

(b) Episkopi Bay. No pollution series exist in this area and it is therefore considered to be "unpolluted".

METHODOLOGY

(a) Trawling: From the Department R/V Triton (16 m o.a.l. 240 BHP) with bottom trawl. Fish were measured and weighed on board.

(b) Benthos:

Infauna was sampled mainly with orange peel grab. Samples were preserved in 4 per cent formalin after being screened at 1.5 mm mesh. 100 l samples were used for the data given. This was decided on after a cumulative curve showed this to be the minimum required. Dry weight determination was carried out after drying for 24 hours at 100°C and repeated until consistent results were obtained.

Epifauna sampling was undertaken with a beam dredge and a sledge or a triangular dredge of equal dimensions. The results given are the sum of three hawls, 5 minutes each for each series of samplings. Samples were preserved in 4 per cent formalin sea-water.

(c) *Sediments:* An orange peel grab was used and 5 samples were taken at each station.

(d) *Environmental data: Standard oceanographic methods were used.*

DISCUSSION OF RESULTS

Environmental sedimentological and faunistic data are given in the annex as attached to the original report. Summarized data on species diversity and biomass of benthic communities comparatively, for investigated transects (stations) 1 and 2 are given in attached tables I and II. Comparative data between the number of the species at the same stations are presented in figures 2 and 3: species diversity in figures 4 to 8, and organic carbon in sediments in figure 9.

The results have not been completely evaluated yet. It is, however, apparent that there is an enrichment of Limassol Bay (Station 2) from the organic material entering it. There is obviously a larger diversity of organisms in this bay, as well as a larger number of organisms and a greater biomass as far as the benthic organisms are concerned. This is contrary to what was expected and the reasons for this are being looked into. Nonetheless, it is obvious that some species are absent from Limassol Bay and that the distribution of species is different. It was also noted that there are larger numbers of particular species in Limassol Bay, e.g. Holothuria tubulosa at about 10-30 m, while some other species are notably absent.

The results are also interesting in that many dozens of species have been recorded for the first time in Cyprus. The results, especially those from Episkopi Bay, are also considered to be good baseline material for future use.

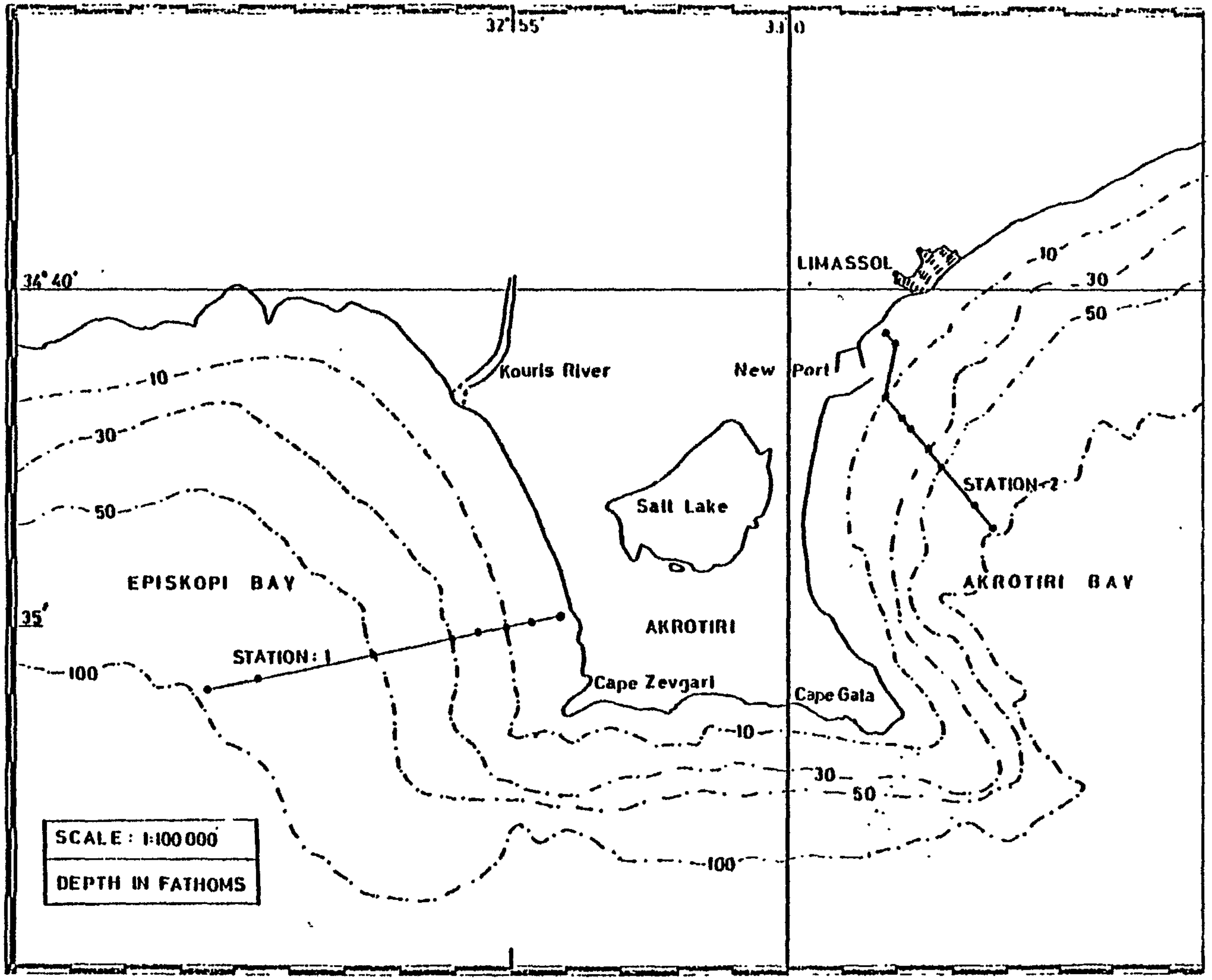


Fig. 1. Areas studied

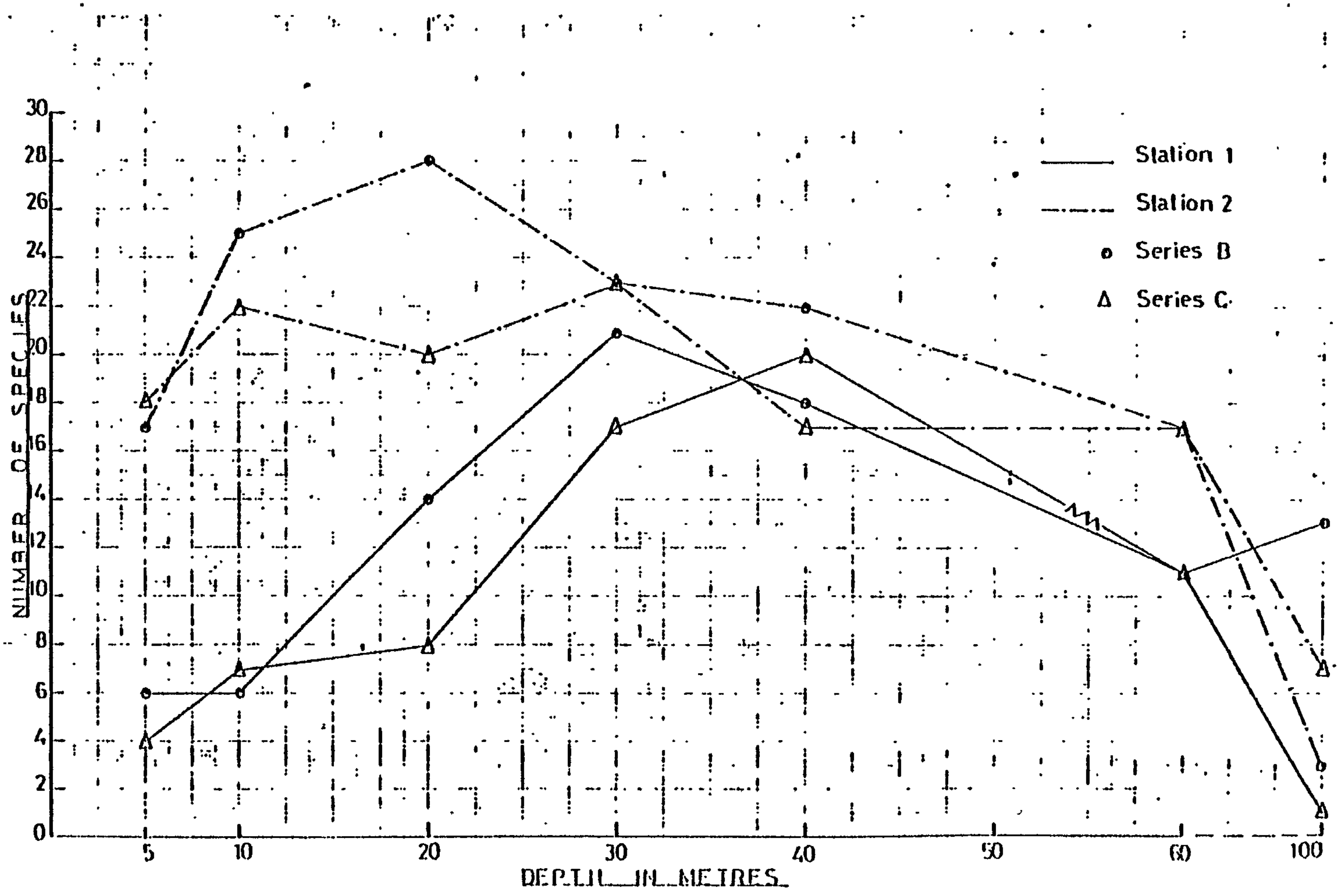


Fig. 2. Comparisons between stations 1 and 2. Number of species/100 l sample. Data from sampling with an orange peel grab

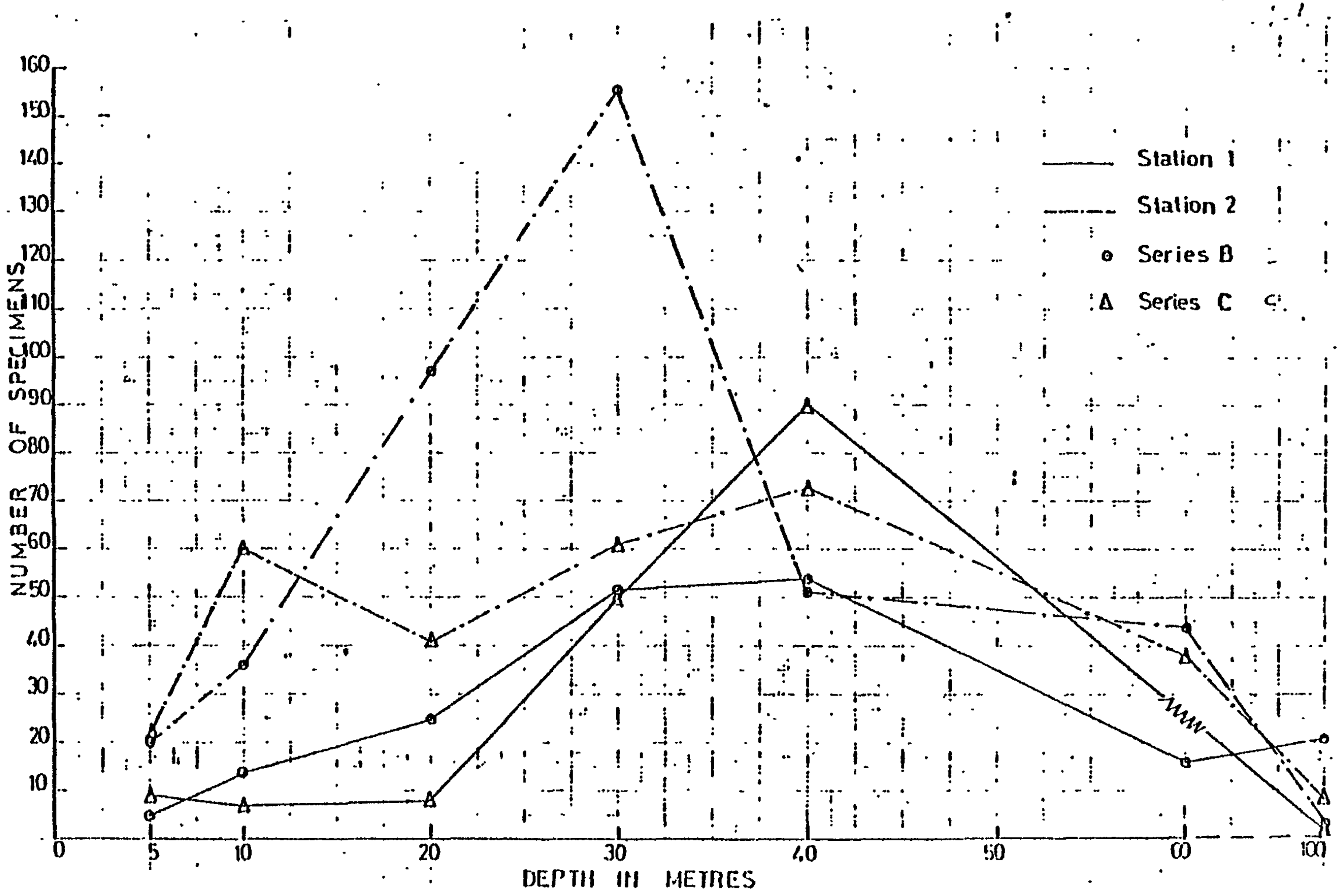


Fig. 3. Comparisons between stations 1 and 2. Number of specimens/100 l sample. Sampler - orange peel grab.

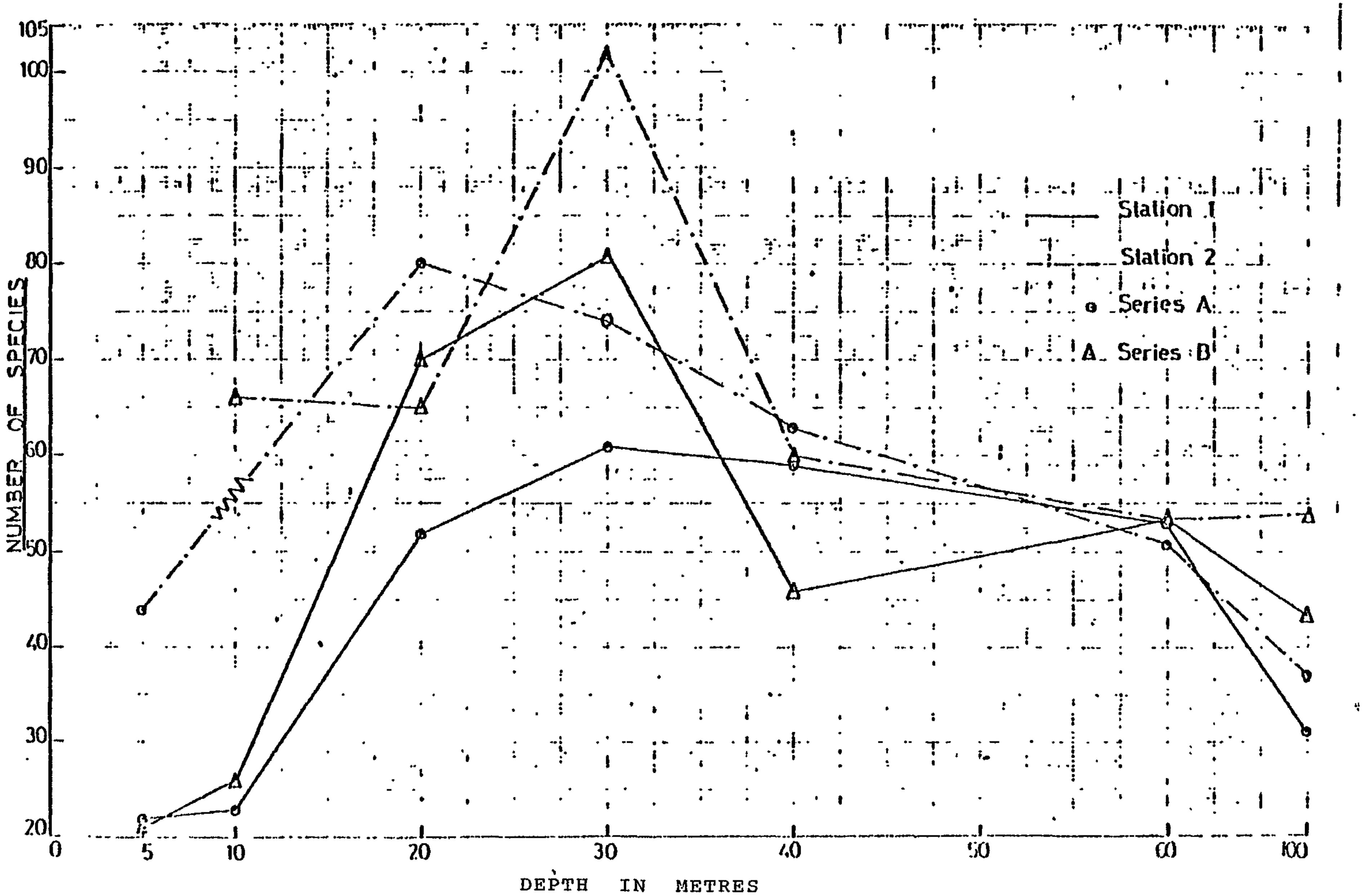


Fig. 4. Comparisons of two series of samplings A and B with triangular sledge and beam dredges for species diversity at stations 1 and 2

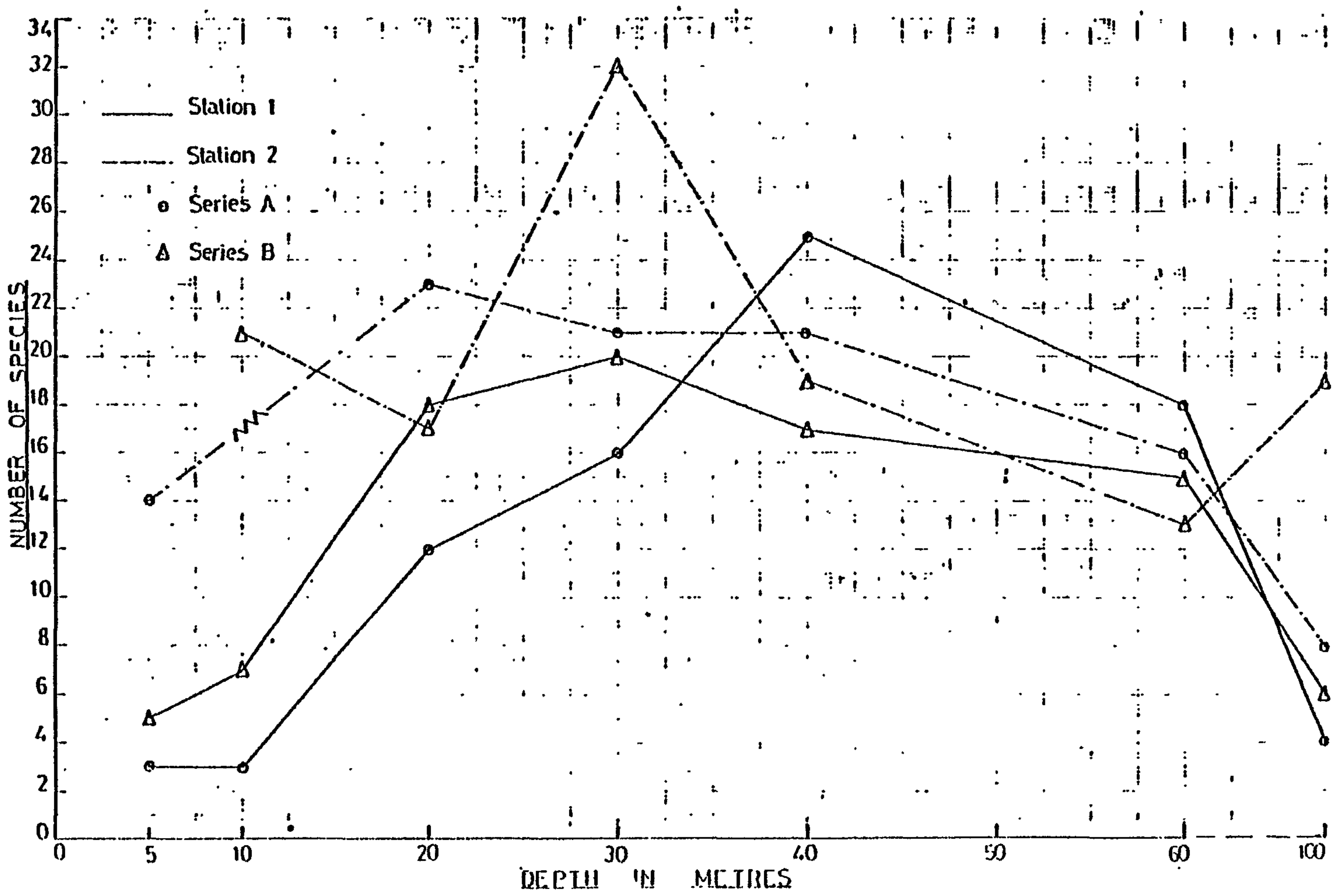


Fig. 5. Comparisons of diversity at stations 1 and 2 by sampling with triangular sledge and beam dredges. Sampling - series A and B.
a) Crustacea

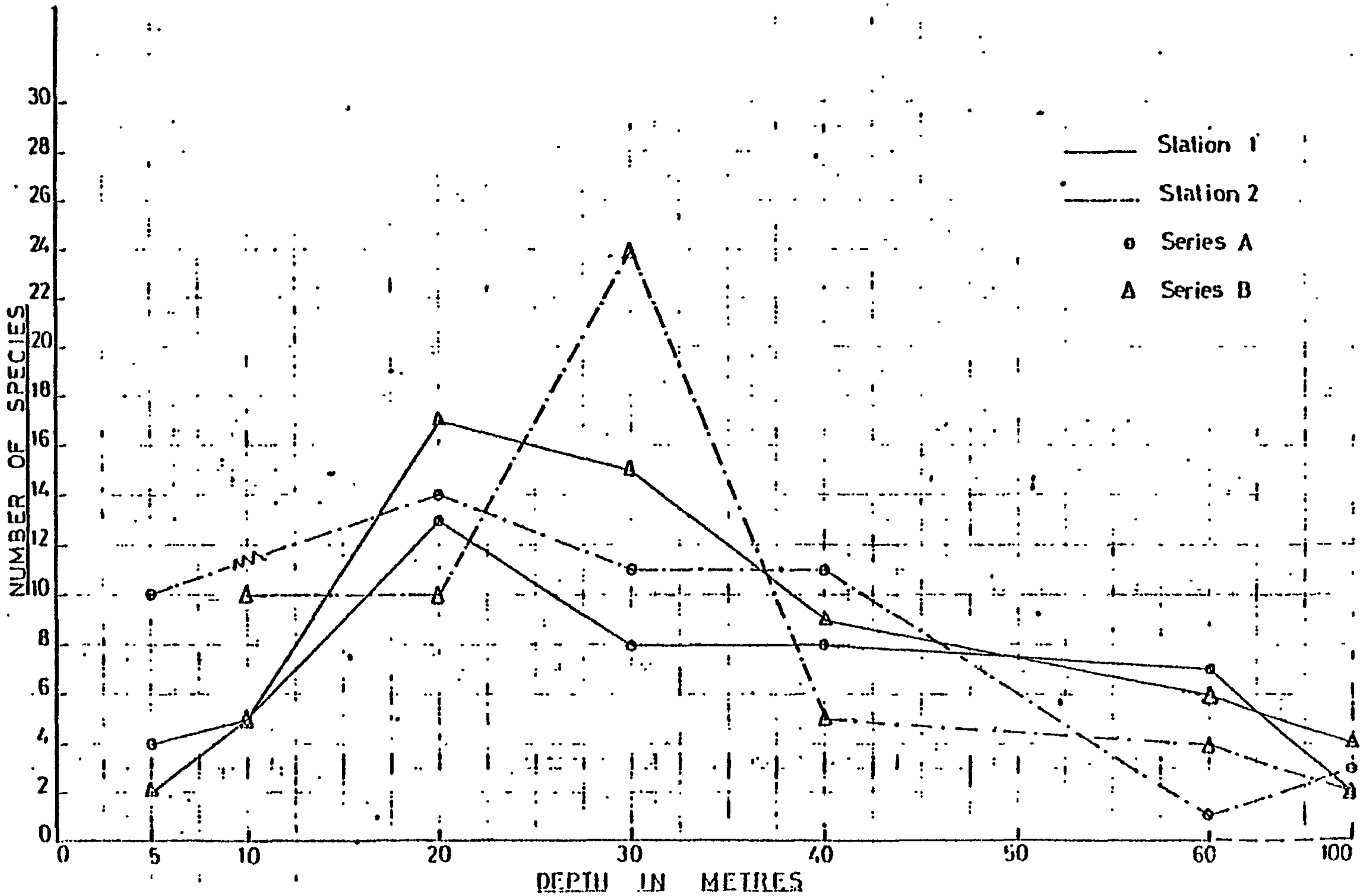


Fig. 6. Comparisons of diversity at stations 1 and 2 by sampling with triangular sledge and beam dredges. Sampling - series A and B.
b) Gastropods

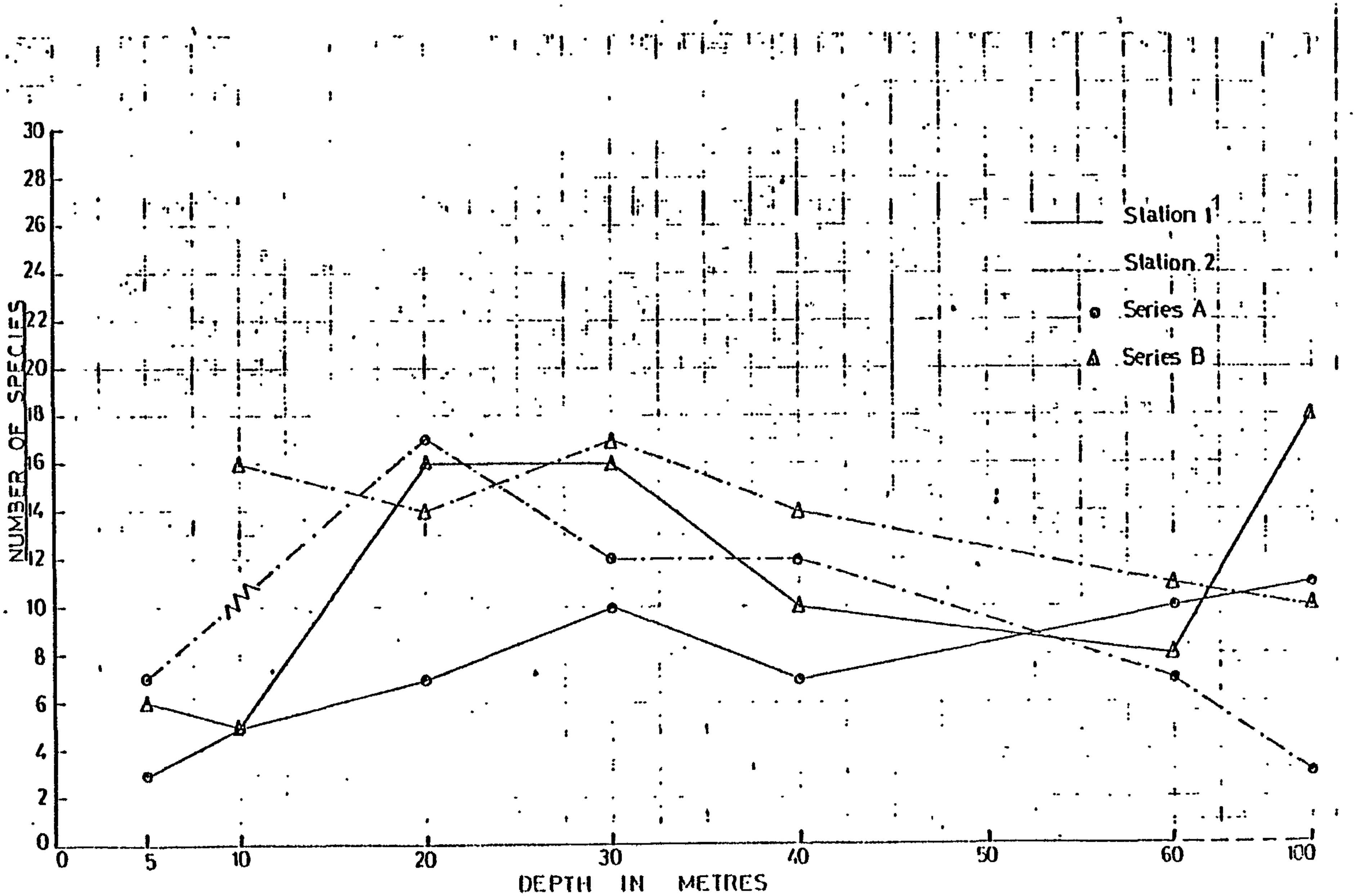


Fig. 7. Comparisons of diversity at stations 1 and 2 by sampling with triangular sledge and beam dredges. Sampling - series A and B.
c) Lamellibranchiata

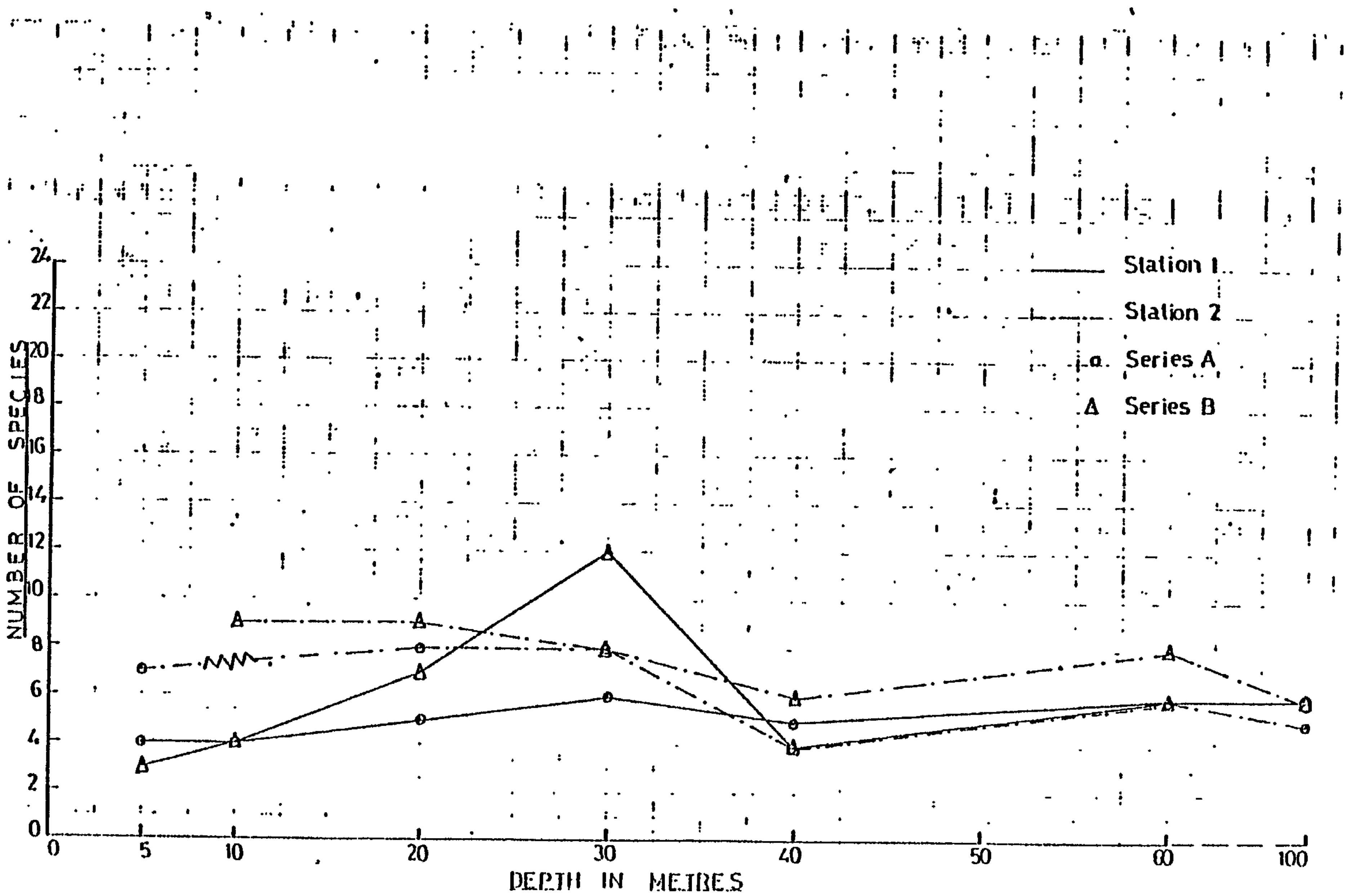


Fig. 8. Comparisons of diversity at stations 1 and 2 by sampling with triangular sledge and beam dredges. Sampling - series A and B.
d) Echinodermata

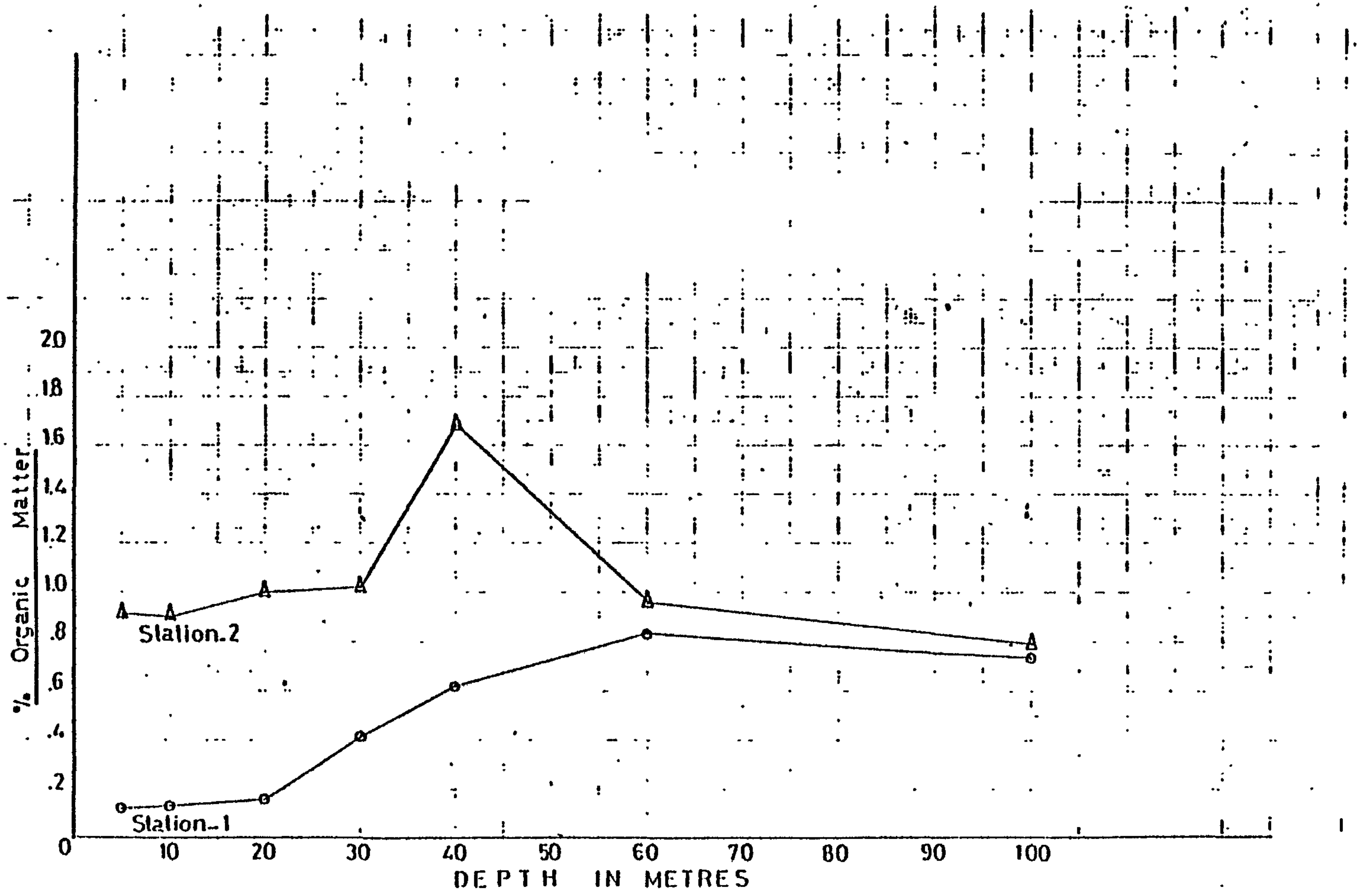


Fig. 9. Organic carbon in sediments.
Sampling with orange peel dredge

Table I : Summary of Statistics from stations 1 and 2

	5		10		20		30		40		60		100	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Biomass (Animal) Mean Wet Weight (g) per 100 l sample	8.74	27.25	1.54	23.4	1.98	30.88	7.94	28.17	21.68	30.99	14.27	25.19	4.65	4.67
Biomass (Total) Mean Wet Weight (g) per 100 l sample	14.79	202.91	3.04	490.65	6.04	245.93	120.64	175.81	401.62	109.58	250.32	146.15	4.65	4.67
Biomass (Total) Dry Weight (g) per 100 l sample	6.20	42.08	1.06	81.52	1.38	47.98	20.54	36.48	72.61	24.77	28.23	33.87	1.21	1.89
Abundance Mean No./100 l sample	7	21	20.5	48	16.5	69	51	108	72	62	16	41	11.5	5.5
Species (Infauna) Mean No./100 l sample (orange peel)	5	18	6.5	23.5	11	24	19	235	19.5	19.5	11	17	7	5
Species (Epifauna) Beam/Sledge dredge Mean of 6 Hauls	21.5	44	25	67	66	72.5	71	88.5	52	61.5	52.5	52	36.5	45

Table II: Biomass comparisons between stations 1 and 2
Weight (g)/100 l sample (Animals only)

(Mean figures for series B and C)

Depth in metres	Wet Weight		Dry Weight			
			Total		Decalcified	
	St. 1	St. 2	St. 1	St. 2	St. 1	St. 2
5	8.74	27.25	5.60	10.29	5.27	5.05
10	1.54	23.4	0.89	11.03	0.69	3.38
20	1.98	30.88	0.69	11.36	0.58	8.00
30	7.94	28.17	3.35	13.73	2.35	9.00
40	21.68	30.99	12.76	12.79	2.38	10.08
60	14.27	25.19	1.98	9.18	2.97	7.89
100	4.65	4.67	1.21	1.90	0.73	0.46

Research Centre: Institute of Oceanography and Fisheries
ALEXANDRIA
Egypt

Principal Investigator: M. L. EL-HEHYAWI

INTRODUCTION

From 1960 to date, the Institute has been involved with ecosystem investigations in coastal S.E. Mediterranean waters. Hydrology and fisheries have been studied in detail, and the results are published in the Bulletin of the Institute of Oceanography and Fisheries, in particular No. 5. The effects of pollutants on the ecosystem and animal communities constitute a recent trend of research and facilitate the evaluation of change in shallow coastal water fisheries.

METHODOLOGICAL CONSIDERATIONS

Areas studied:

The work plan of the project is based on observations of the Abu-Qir Bay and Alexandria shallow nearshore waters of the S.E. Mediterranean (figure 1). The area is located between the Rosetta Nile mouth in the east and the Arab Gulf in the west, with co-ordinates between Long. 29°14' and 30°28' E, and Lat. 31°06' and 31°32' N. Abu-Qir Bay has a semi-circular configuration of the coast which is connected from its northern side with the open Mediterranean Sea. The bay has an area of about 650 km^2 and a depth of about 12 m. The samples were to be collected bi-monthly at two stations inside Abu-Qir Bay, one station in each of the localities north of Abu-Qir Bay, Alexandria and and El-Mex, and, whenever possible, at one station in the Arab Gulf. Some changes were made during August 1977, and a trip was made to Abu-Qir Bay, and the samples were collected from ten stations in it.

Communities:

The zooplankton and ichthyoplankton in the water surface layer were the main components which have been investigated in detail. Special care was given to the abundance of fish eggs and larvae in the hyponeuston. The species composition and zooplankton abundance in the hyponeuston were determined. Benthic organisms were collected and identified whenever possible. Changes in fish landings were recorded.

Pollutants:

The surveys indicated that about 2 km^2 of coastal water area surrounding the Rosetta mouth of the Nile branch are constantly pervaded with brackish water, as a result of an annual outflow of 2-5 km^3 of Nile freshwater mixing with sea-water. As a general rule, such water flows in a north-westward direction; however, there could be a limited south-westerly anticurrent flow which influences the adjacent localities of Abu-Qir Bay.

Drain and lake waters discharge from Lake Edku outlet in the south-eastern part of Abu-Qir Bay and flow eastwards, mixing with sea-water, and thus attaining well-defined chemical characteristics for about 3 km^2.

Paper mill wastes exceeding 3 x $10^6 m^3$/year are discharged from the El-Tabia pump outlet at the south-western part of Abu-Qir Bay. The polluted water flows towards the south-east from the outlet, polluting 3 km^2 of the coastal area mentioned.

About 85 x $10^6 m^3$/year of domestic wastes and sewage water are discharged at four points located in the shallow coastal area north of Alexandria. The highly affected area is about 1 km^2 at each point and could be considered as the source of domestic wastes spreading eastwards.

Metallurgical, petroleum and chemical industries discharge about 12 x $10^6 m^3$/year of wastes into the northern shallow water at El-Mex. About 3 x $10^6 m^3$/year of domestic wastes are also discharged at these localities.

The western coastal area of El-Mex is not influenced by any pollutant, except from ships passing on their way to Alexandria. Pollution by maritime traffic is of only minor significance.

METHODOLOGY

Environmental measurements and hydrochemical analyses were made by standard oceanographic methods as given in Strickland and Parsons (1968).

The collection of hyponeuston was made with a surface-towed standard net of the Russian type P.N.S. Other zooplankton hauls for qualitative determinations were carried out by a conical zooplankton net with a circular opening of 50 cm diameter and 1 m length. The mesh size of the net is 0.33 mm. The zooplankton was usually preserved in 10 per cent formaline solution. The samples for ichthyoplankton analysis were preserved in 2 per cent formaline solution. Accurate weights of vacuum-dried zooplankton samples and other identified organisms were digested with nitric acid and their heavy metal content was determined using AAS (Varian Techtron, model 1250).

RESULTS

Environmental conditions:

Salinity. The above-mentioned points of discharge were found to distribute mixed waste waters of lower salinity than the water of the Mediterranean proper. The polluted waters at all source localities were found to spread eastwards. During the winter, the minimum salinity values, 20.0, 36.7 and 38.5‰, characterized the source localities north of the Rosetta outlet of the Nile, the outlets in Abu-Qir Bay and those north of Alexandria successively. During the warm seasons, the salinity of the polluted water decreased to about 19.5, 35.0 and 37.5‰. As a rule, the values mentioned increase rapidly in the seaward direction until they can hardly be detected from the values (38.9 - 39.4) of the proper Mediterranean sea-water.

pH values:

The proper Mediterranean sea-water attains pH values of about 7.91 - 8.21. Changes between 6.57 and 8.38 were found to occur seasonally in the zones most influenced by the Nile discharge at Rosetta. The polluted water attained higher (8.60 and 9.20) values in Abu-Qir Bay as a result of the outflow of Lake Adku water and the paper mill wastes in the bay. The sea-water north of Alexandria and El-Mex attained a pH of 7.20 - 8.30, particularly at source localities, as a result of pollution by domestic and industrial wastes.

Oxygen concentration:

The maximum dissolved oxygen value was found to be about 6.60 ml/l during the winter, and 4.17 during the summer in the vicinity of the Nile outlet at Rosetta. The values indicated a maximum saturation of about 104 per cent, with a minimum of 82 per cent, at the southern localities of Abu-Qir Bay; the water attained concentrations fluctuating between 2.90 and 5.10 ml/l, attributed to the influence of the lake and drain water mixing with sea-water. The corresponding saturation values were 66 per cent and 88 per cent. However, the concentration in the polluted waters of the south-western localities varied from 1.00 to 4.10 ml/l, with saturation values between 21 per cent and 71 per cent. Apparently, consumption was at its lowest level as a result of pulp mill discharges (figure 2).

The sea-water in the localities at about 0.5 - 1.5 km north of Alexandria attained 3.25 - 4.34 ml/l dissolved oxygen, and its saturation ranged between 73 per cent and 98 per cent. This suggests higher biological activity than in the polluted locality of Abu-Qir Bay.

West and north of El-Mex the oxygen content increased to 4.60 - 5.40 ml/l, indicating saturation at 97 - 102 per cent. These values were slightly lower than 4.50 - 5.80 ml/l and saturation at 96 - 106 per cent which characterized the waters in the Arab Gulf.

Phosphate variations:

It is well known that the proper Mediterranean waters attain low phosphate-phosphorus concentrations which vary slightly from 0.10 µg-at/l. Seasonal variations of the phosphate-P in the mixed Nile sea-water were found to be between 0.35 and 1.98 µg-at/l. It dropped to 0.05 - 0.40 µg-at/l in the zone surrounding Lake Edku outlet and to about 0.15 - 0.30 µg-at/l in the vicinity of the El-Tabia pumps outlet. Apparently, the disposal of domestic wastes north of Alexandria elevates the phosphate-P content of sea-water north of Alexandria to the range 0.05 - 0.60 µg-at/l. Concentrations not exceeding 0.09 were found in the waters north and west of El-Mex.

Nitrate-nitrogen:

The Nile-discharged water was associated with significant seasonal fluctuations of the nitrates-N from 0.04 to 2.0 µg-at/l. This range appeared much higher than that of 0.10 - 0.2 µg-at/l found in the vicinity of the Lake Edku outlet and that of 0.30 - 0.50 µg-at/l in the water polluted by pulp mill wastes at the El-Tabia pumps outlet. Values of 0.07 - 4.50 µg-at/l were attained by the polluted shallow waters of Alexandria. The concentration decreased to 0.90 µg-at/l in El-Mex waters.

Silicate-silicon:

Proper Mediterranean sea-waters have reactive silicon concentrations of about 1.0 - 3.0 µg-at/l. Values fluctuating between 6.0 and 250.0 µg-at/l were observed seasonally in the mixed river-sea-water at Rosetta outlet. They dropped to 2.0 - 37.0 µg-at/l in the vicinity of the Lake Edku outlet and to 3.0 - 16.0 µg-at/l in the waters mixed with the pumps' discharge in Abu-Qir Bay. Alexandria-polluted waters attained 8.0 - 15.0 µg-at/l and decreased to 3.0 - 6.9 µg-at/l in El-Mex waters.

Ammonia-nitrogen:

Abu-Qir Bay-polluted waters indicated the presence of about 5.5 and 6.5 µg-at/l of ammonia nitrogen at the Lake Edku and El-Tabia outlets. These values were markedly lower than those for the waters north of Alexandria (7.0 - 22.0 µg-at/l).

Biochemical Oxygen Demand:

The oxygen demand was equivalent to 1.6 ml/l in the mixed Nile-sea-water and increased to about 4.3 ml/l in the waters north of the lake-sea connection, and to about 3.8 ml/l at the El-Tabia pumps outlet. Alexandria's sewage disposal was distinguished by a 4.23 ml/l biochemical oxygen demand.

The influence of pollution on the zooplankton:

The samples collected revealed common forms of copepoda, including Paracalanus spp., Isias sp., Clausicalanus sp., Centropagus spp., Acartia sp., Ctenocalanus sp., Oithona sp., Euterpina sp., Oncea sp. and Corycaeus spp.

Other constituents such as medusal veligers, Oikopleura spp., Sagitta sp., Noctiluca, etc., were found frequently. The Cladocera, Tintinnidae, Siphonophora, Amphipoda, Foraminifera, Decapoda larvae, Salpa spp. and polychaete larvae were scarce. In addition to pollution, they were influenced by depth, season and locality.

The seasonal fluctuations made it difficult to detect the influence of pollution on their abundance, except in the waters highly polluted with industrial wastes.

During spring the zooplankton abundance varied from 25.0 - 40.0 counts/m^2 to 2.0 - 8.0 counts/m^2 in the hyponeuston of Abu-Qir Bay. Values between 523.0 and 17.0 counts/m^2 were found north of Alexandria and in El-Mex waters. Some increase in abundance could be detected in the localities influenced by domestic wastes, while it dropped sharply with the intensity of industrial wastes' disposal. In addition, there was high mercury content, i.e. 0.5 - 6.6 ug/gm dry weight of the body of the mero-planktonic forms and Euterpina sp. from Alexandria waters.

The catch of eggs and largae represented Sardinella sp., Trigla sp., Serranus sp., Mullus sp., Trachurus sp., Engraulis sp., and other non-dentified species. The larvae of the family Mugilidae, as well as sardine eggs were frequently found during winter. The others appeared during the warm seasons. The abundance of fish eggs was found to vary from 0.25 to 11.0 counts/m^2 in unpolluted waters. They were absent in the pollution source regions (e.g. pulpmill wastes at Abu-Qir).

Modifications of fish populations as indicated by fish landing statistics:

Since this chapter deals with long-term observations made prior to MED V activities, it is annexed to this report.

DISCUSSION OF RESULTS

About 7 sources of pollution with different kinds of wastes could be detected with respect to the influence on shallow coastal waters of the regions investigated. The flow of the polluted waters was generally noticed in an eastward direction along the coast. This is in agreement with the dominant water current flow path. Variable magnitude distribution and location of pollutants suggested that the area investigated could be divided into three kinds of grounds relative to mixing with sea-water and the effect on living organisms and communities.

The first are highly polluted zones. They include the points of industrial waste disposal which result in sharp drops in abundance of all living organisms. This was noticed in zones highly polluted by paper mill waste discharge at Abu-Qir Bay and at chemical industry discharge points in the El-Mex region. The area was estimated to exceed 5 km^2. Other intense pollution by domestic wastes from 15 - 17 points distributed at nearly equal distances north of Alexandria was observed to elevate the nutrient content and the abundance of organisms. The corresponding area was estimated to vary from 5.0 to 8.0 km^2. This area is open to the influence of annually dominating north-westerly winds. Turbulence of water, which results from about 95 days of strong storm surges per year, is very effective in preventing any stagnation of these wastes. Drain and lake water discharges at Abu-Qir Bay were not considered to be harmful. The Lake Edku basin probably helped through physical, chemical and biological processes, the degradation or adsorption of the pollutants. Evident abundance of euryhaline organisms was found in these localities.

The second is the polluted area. It included the area of spreading and mixing of the pollutants with sea-water beyond the highly polluted zone. A frontal line could clearly be detected between them as a sharp change in colour of the sea surface. Its polluted water characteristics did not adversely influence the survival of the organisms. This area was estimated to be bordered by a northern parallel line at about 5 miles from the coast. It extended from the El-Mex to Rosetta outlet and enveloped the highly polluted zones. Clear indication was found of high abundance of some zooplankton species from Alexandria waters and distinguishable mercury content in their bodies.

The third is the slightly polluted area. Its location was identified by the slightly deviated values of the chemical characteristics from those of the proper Mediterranean waters. Modifications in the community structure of living organisms depend upon other seasonal or geographical changes, rather than on direct influence by the concentration of pollutants. This area was found to be located between 7 - 10 miles north of the shore. It was also clear that the limits of polluted shallow water areas were liable to change under disturbed climatic and sea-water conditions, as well as seasonally.

The exploitable stock of fish and prawns could not be considered safe for consumption in the polluted and slightly polluted area. In the future, pollution may increase according to the planned increase in industrial production and the lack of control on waste disposal.

PUBLICATIONS AND REFERENCES

AL-KHOLY, A.A. and EL-WAKEEL, S.K. (1975). Fisheries in the south eastern Mediterranean Sea along the Egyptian coast. Soviet-Egyptian Expedition 1970-71. Bull. of the Inst. Oceanogr. Fish., vol.5:1-279.

AZCHER, N. (1970). Fishery research of Azcher Niro in the Red and Mediterranean Seas in 1964-1966 years. Azov-Brack Sea Research Institute of Fishery and Oceanography, Transaction No. 30, special issue (in Russian).

EL-ZARKA, S. and KOURA, R. (1965). Seasonal fluctuations in the production of the important food fishes in the UAR waters of the Mediterranean Sea. Notes and Memoires No. 74, Hydrobiol. Dept., 1-69.

HALIM, Y., GUERGUES, S.K. and SALEH, H.H. (1967). Hydrographic conditions and plankton in the south east Mediterranean during the last normal Nile flood. Int. Rev. ges. Hydrobiol., 52(3):401-25.

LOTFI EL-HEHYAWI, M. (1979). New data on the distribution of pollutants and their effects on some hyponeuston constituents in the S.E. Mediterranean. Comm. int. Explor. sci. Mer. Médit., VI[es] Journées Etud. Pollutions, Antalya, pp. 301-5.

MARINARO, F.Y. (1971). Contribution à l'étude des oeufs et larves pelagiques de poissons Mditerranéens. V. Oeufs pelagiques de la baie d'Alger. Pelagos, 3(1):1-118.

STRICKLAND, J.D.H. and PARSONS, R.R. (1968). A practical handbook of sea-water analysis. Bull. Fish. Res. Board Canada, p. 167.

ANNEX

MODIFICATIONS OF FISH POPULATIONS AS INDICATED BY FISH LANDING STATISTICS

The fish catch of several species present before the construction of the Aswan High Dam, and the consequent change in the hydrology of the water characteristics are indicated in table I. About 43 species were recorded before 1965 in Abu-Qir Bay and the adjacent Alexandria regions (El-Zarka and Koura, 1965).

Table I : The landings of different taxons from Abu-Qir Bay

Year	Annual catch (ton)			
	All forms	Bony fish	Cartillagenous fish	Crustacea
1966	460.1	196.6	0.6	189.8
1968	480.3	629.6	4.5	187.5
1970	123.3	65.8	0.7	40.4
1972	56.0	50.0	0.0	8.2
1974	76.0	55.4	2.5	15.1
1975	98.6	71.0	0.4	21.4
1976	83.0	61.0	1.1	15.3

Dominantly landed species were Sardinella aurita (C. and V.), Sardinella eba (C. and V.), Sciaena aquila (Risso), Trichurus aumela (Forsk), Saurida tumbil (Bleemer), Mullus barbatus (L.), Solea Vulgaris (L.), Epinephelus gigas (C. and V.), Serranus scriba (C. and V.), Pagrus vulgaris (L.), Pagellus erythrinus (L.), Mugil cephalus (Cuv.), Mugil capito (C. and V.), Temnodon saltator (Cuv.), Chrysophrys auratus (Cuv.), Merluccius merluccius (L.), Sphyraena sept (Lacep.) and Morone labrax (L.).

During 1968, the El-Maadia centre, which is located near the Lake Edku outlet, recorded 2004 tons landed from the grounds at Abu-Qir Bay. Each of the species mentioned formed 1 - 30 per cent of the total weight of the catch.

Since 1965, a sharp decline in the fish landings has been observed. The catch of the different species dropped during 1966-72 to 5 - 25 times less than before 1965 (see table I).

The catches also indicate a decrease in the dominant species to about one-fifth of those recorded before 1965. There was a significant percentage of Atherina and other small euryhaline fish in catches of recent years (table II).

Table II : The percentage composition of the dominant species of fish landed in El-Maadia waters

Species	Annual percentage in catch						
	1966	1968	1970	1972	1974	1975	1976
Sardinella spp.	3.8	7.2	0.2	0.0	0.0	0.1	0.0
Atherina and small fish	16.7	16.4	2.2	25.0	20.0	21.6	21.6
Mugil sp.	5.9	3.4	2.1	12.9	8.4	9.3	7.3
Saurus sp.	9.8	11.8	14.0	4.8	5.9	11.0	14.0
Sciaena aquila	2.5	3.2	1.6	9.2	9.9	8.1	6.3
Trachurus trachurus	0.1	0.3	0.1	0.0	4.6	6.8	11.3
Pagrus sp.	0.0	0.0	0.2	0.0	4.9	2.3	2.8
Mullus barbatus	0.3	5.2	14.7	-	5.0	2.7	2.9
Solea sp.	0.2	3.0	5.8	4.1	9.5	7.7	4.0

This may reflect the influence of an increase in brackish water flow from the source points in the coastal regions and the aggregation of these fishes in the corresponding limited area.

Other forms such as Sciaena aquila, Trachurus trachurus, Pagrus vulgaris, Mullus barbatus and Solea vulgaris appeared of significance in the last few years' catches. Some of their eggs were found away from the heavily polluted zones in Abu-Qir Bay and Alexandria nearshore waters. The salinity and pollutant content in the region of their distribution appeared to be within the range of the organisms' tolerance. Chemical analysis of water in these regions suggested that the area should be characterized as polluted to slightly polluted.

The main forms of crustacea in the catches were crabs and prawns such as Metapenaeus stebbingi (Nobili), Metapenaeus monoceros (Fabr.), Penaeus trisulcatus (Leach), Penaeus japonicus (Bate) and Penaeus semisulcatus (De Haan).

Heavy pollution by industrial wastes is no doubt harmful to organisms, while this is doubtful for pollution by domestic wastes and drainage discharge. The lake water outflow carries silt and a rich load of organic particles which favour the survival of prawns. However, it is difficult to conclude that the standing stock of fish and prawns is at its healthy level in the slightly polluted regions.

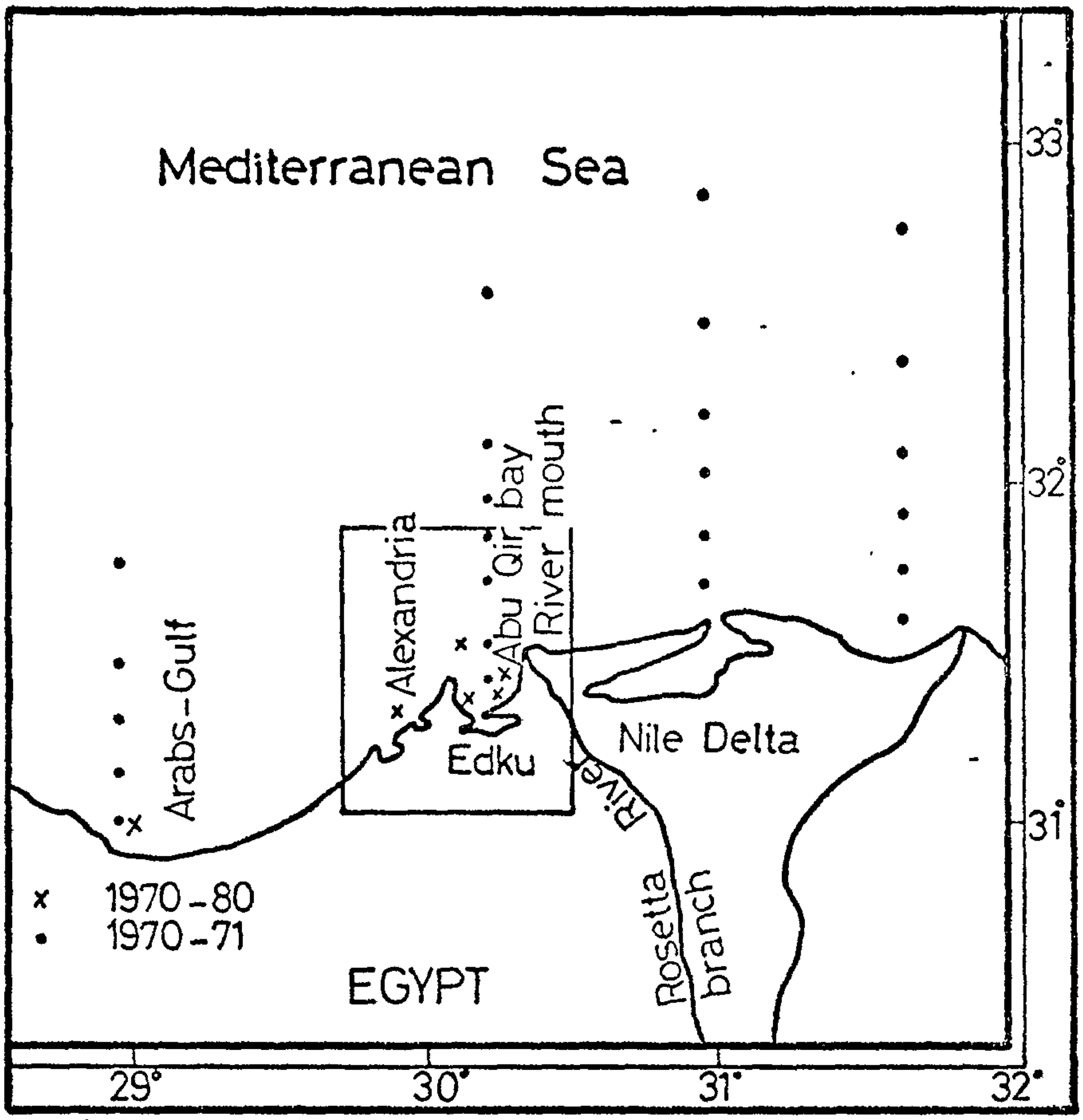


Fig. 1 The research area

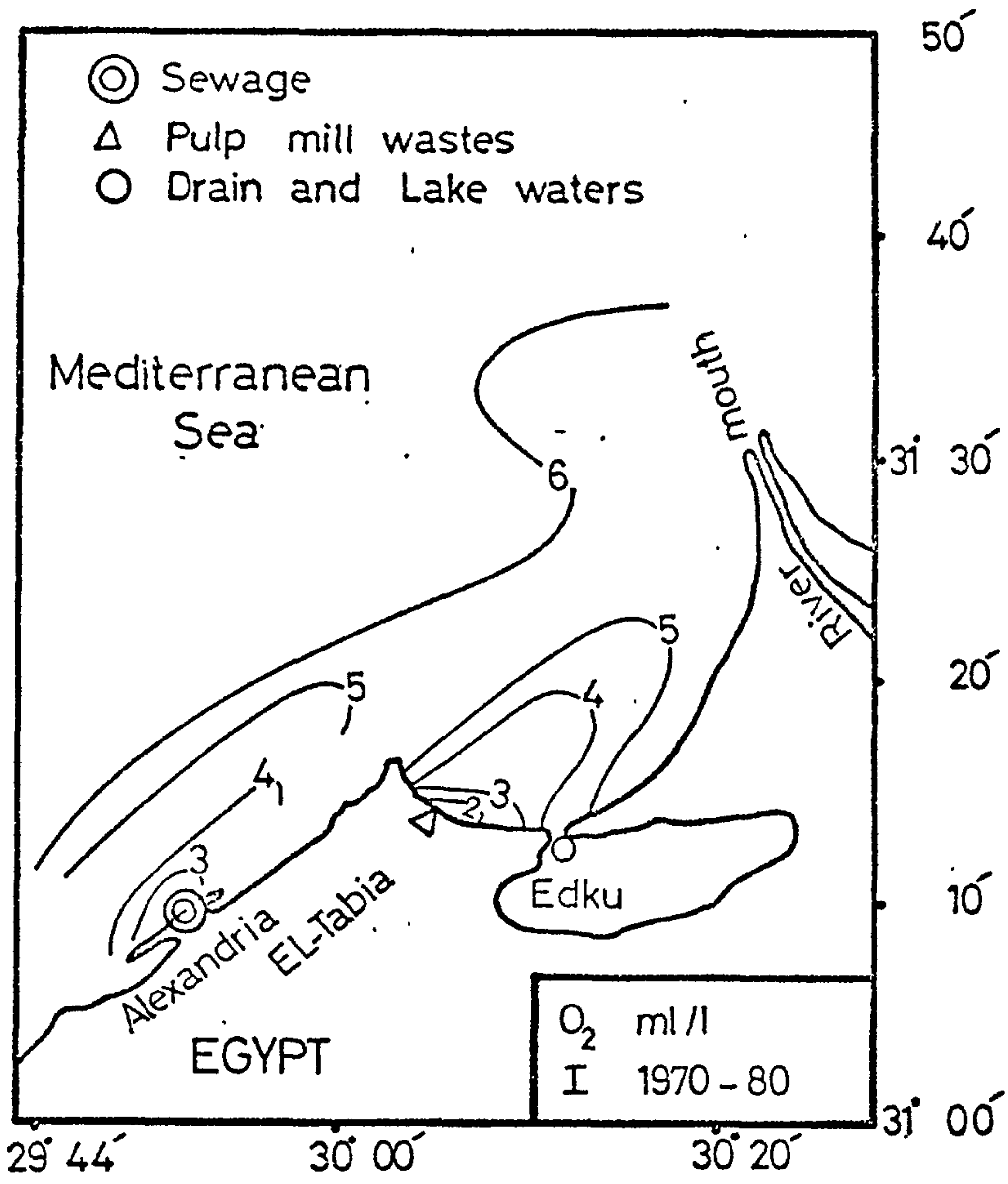


Fig.2. The oxygen concentrations in the research area.

Research Centre: Center for Postgraduate Studies
Alexandria University
ALEXANDRIA
Egypt

Principal Investigator: Y. HALIM

Period of Reporting: April 1979 to March 1980

INTRODUCTION

Most of the previous investigations of ecosystem modifications as induced by pollution stresses as well as by hydrological changes (as occurred after the Asswan High Dam became functional) were focused on the dynamics of phytoplankton populations. In this connection the variations of standing crop in the Eastern Harbour of Alexandria have been studied over cycles of several years: 1956-57, 1965-66, 1972-73 and 1977-78, as reported below.

The sequence of these observations reveals a steady trend of change resulting from the absence of Nile water outflow after the High Dam, accompanied by the intensified pollution.

- In 1956-57, long before the High Dam was in place, the standing crop was typical of all Egyptian neritic waters. The cycle was bimodal with an outstanding "Nile bloom" in autumn and a small late winter bloom.

- In 1965-66, the Nile outflow was already reduced by half. The cycle was still bimodal, but the "Nile bloom" dropped to about 10%.

- In 1972-73, in the absence of any "Nile bloom" the cycle was still bimodal, but the relative importance of the two peaks were reversed. The spring bloom now became the major one, as happens regularly in most Mediterranean localities. As will be shown in this report, the dynamics are again modified.

METHODOLOGICAL CONSIDERATIONS

Area(s):

(a) Eastern Harbour of Alexandria is a relatively small, semicircular bay surrounded by the city, except on its northern side, where it communicates with the sea through two channels. Although the E.H. is not the main port of Alexandria, fishing docks occupy a small area in the N.W. corner of the bay. Surface circulation is anticlockwise. Surface temperature ranges from 16.5°C to 28.5°C.

The average salinity is lowest in the inner part, 37.96^{o}/oo, directly affected by discharges, increasing to 38.10^{o}/oo and 38.25^{o}/oo respectively towards the outer part.

The Secchi disc readings ranged from 50 cm to 350 cm, the lowest reading being in summer, due to thick bloom of the dinoflagellate <u>Alexandrinum minutum</u> <u>Halim</u>.

Three stations (I to III) along the pollution gradient, were investigated for one year. In addition, samples of sessile diatoms were collected from a number of stations around the E.H., from rock and algal substrates. Plankton was collected by means of reversing water bottles, from the surface and the sub-surface water. The standing crop was determined by the Utermöhl method. Grab samples for the study of sessile diatoms were taken from the same stations. Salinity and temperature were also determined.

(b) Lake Menzaleh, an extensive but shallow coastal lake, located east of Damietta Nile branch, derives its waters from agricultural drainage which ultimately flows out to the Mediterranean through four lake-sea connections. Its approximate flushing time is three months. Sixteen stations covering the whole lake, except for its western-most part, were investigated monthly for 15 months (Fig. 1). Water samples were collected from the surface and the layer overlying the bottom by means of a Ruttner sampler. The samples were analyzed for oxygen, phosphate, chlorosity and the pH. Temperature and the Secchi depth were measured at each station. Oxygen was determined according to the Winkler method and its relative saturation calculated with reference to the tables of Green and Carrit (1967). Quantitative photoplankton and zooplankton samples were collected from all stations, and the standing crop, the biomass and the species composition obtained (Guerguess, 1980).

Communities:

Pelagic communities in marine neritic and brackish-lagoonary environments were studied. Research on bionomy of Posidonia beds has been initiated.

Pollutants:

(a) Eastern Harbour of Alexandria.

Municipal waste water is released intermittently from several outfalls on the southern embankment. This, added to the dock and ship wastes, creates eutrophic conditions in the inner bay, and primary productivity is abnormally high (Halim et al., in press). Towards the bay inlets, however, the effect of the outfalls is reduced by dilution with inflowing sea-water. In the inner bay, the bottom is muddy and smells of H_2S.

(b) Lake Menzaleh

About 110 x 10^6 m^3 of treated and diluted sewage water are discharged monthly into its SE basin. Nearly anoxic and azoïc conditions prevail around the outfall, but rapid recovery follows the heavy development of plant life within a few kilometres: submerged macrophytes (Potamogeton, Ceratophyllum) with a dense growth of epiphtic diatoms, and phytoplankton (diatoms and green algae). The dissolved oxygen rises to near saturation but the Euglena/phytoplankton index is high, 1:25, compared to that of the remote lake basins, 1:300.

DISCUSSION OF RESULTS

(a) Eastern Harbour of Alexandria

When considering diatom communities which were sampled in a one year cycle (monthly) at 3 stations (L-III), No.1 being heavily polluted, a number of observations and conclusions can be made.

The total number of species and the species composition showed a significant zonation, reflecting the pollution gradient from the inner bay to the inlets. This is particularly obvious for the benthic psammophytic species.

Of the 49 psammophytic species obtained from the bay sediments, 29 appear to be repelled by the anoxic conditions of the muddy bottom in the inner bay and do not extend beyond stations II and III.

The species common to both the anoxic muddy bottom of the inner bay and to the muddy sand bottom were less numerous (17 species). Most of them were rare at station I, but two appear to be more abundant at this station: *Diploneis fusca* and *Melosira granulata v. angustissima*. Three psammophytic species were found to be restricted to the inner bay. They were *Cymatosira belgica*, *Navicula distans* and *Amphora grevilleana constricta*. The latter three species together with *Diploneis fusca* and *Melosira granulata v. angustissima* constitute, therefore, the characteristic psammophytic community of the heavily polluted inner bay.

Eighty-eight planktonic species were recorded from the bay (including the tychopelagic), 23 of which were absent from the inner polluted zone. These are mostly offshore species carried in by the inflowing sea-water and unable to survive in the conditions of the inner bay. The distribution of planktonic forms, however, is unlikely to present a distinct zonation in such a small bay because of mixing and mechanical transport. Two species were met with only in the inner zone, though the occurrence was occasional: *Surirella ovata* and the brackish *Synedra ulna v. aequalis*. The occurrence of some fresh-water *Chlorophyceae* should also be mentioned.

Compared to the outer zone or zone of "recovery", therefore, the eutrophic inner zone is characterized not only by an impoverished population - both benthic and planktonic - and by the presence of some brackish and tolerant forms of rate occurrence, but also by the permanent dominance of a small community of blooming species.

When considering phytoplankton standing crop dynamics as discussed already in the introduction to this report with recently obtained data, it is evident that the quantitative cycle reflects both the absence of the Nile outflow of autumn and of the increased eutrophication, and does not follow any seasonal trend. Instead of a bimodal cycle, it is characterized by successive blooming pulses at 2 to 3 month intervals. Blooms occurred in early and in late spring, in early and late summer and mid-winter.

The total average cell size, for all observations, was significantly higher in the inner zone of the bay, respectively 1.25, 0.27 and 0.24 x 10^3 μ^3 at Stations I, II and III. On the average, smaller cells are found in the "recovery" zone than in the inner, heavily polluted zone. The standing crop was unexpectedly low, particulary in comparison with the conditions in the western part of the bay. The "recovery" zone (Stations II and III) was more productive than the inner zone, due to the heavy bloom of *Chaetoceros socialis* in December, reaching almost 7 million cells/l. *Skeletonema costatum* was the major species throughout the year. This species is known to be dominant in the Eastern harbour as well as in other diluted, organically polluted waters (Pucher-Petkovic, *et al.*, 1978). Five other species contributed substantially to the standing crop: *Lithodesmiu undulatum*, *Chaetoceros curvisetus*, *Ch. socialis*, *Biddulphia alternans* and *Leptocylindrus danicus*.

(b) Lake Menzalah

Attention was focused on the distribution of dissolved oxygen as an index of the health of the lake. The space and time distribution pattern of oxygen in lake Menzalah displayed distinctive characteristics: under-saturation except within the macrophyte beds, short term fluctuations and a considerable dispersal in the diurnal relative saturation.

An overload in oxygen demand is created by the quality of water supply in addition to the reducing effect of the bottom sediments.

The east to west horizontal distribution (Basins I to IV) reflects the input of poorly oxygenated agricultural run-off along the southern margin, and in the first place, the overload of the effluent in the south-east basin (Basin I). There is a high positive gradient from the outfall and the drain inlets towards the lake. On the average, their respective oxygen content is in the ratio of 1 to 12 to 20 (Fig. 2). The phosphate gradient is opposite (Fig. 3). The recipient basin for the outfall (Basin I) acts as a recovery zone. Healthy conditions are rapidly restored due to the heavy growth of primary producers. A peripheral zone of maximum oxygen content surrounds this basin from west and north (Fig. 4). At times, this front of maximum oxygen content becomes displaced by the wind-induced circulation in the lake.

The monthly variations in the relative oxygen saturation point to no seasonal trend (Fig. 5). Short-term fluctuations are observed, particularly in the eutrophic Basin I, at approximate intervals of one month. The peaks correspond to the phytoplankton pulses (Halim and Guerguess, 1978), though the correspondence is less clear for other basins.

Under-saturation appears to be the rule for all Nile Delta lakes, despite their high productivity. For lake Borullos as an instance, the yearly average is of the order of 75% (Darrag, 1974). The average for lake Menzalah is lower, being 67%. Earlier determinations of dissolved oxygen in the Delta lakes were done by various authors at various times of the day, often not stated, disregarding the large diurnal variations. Wahby (1961) followed the diurnal cycle at two different localities in lake Maryut. In the macrophyte beds, the oxygen content increased from 1.47 ml/l at 05,10 to 10.73 ml/l at 15.35. In the open lake, away from the plant beds, it increased from 1.82 ml/l at 05.45 to 5.77 ml/l at 18.20.

Since, for obvious logistic reasons, the oxygen measurements could not be performed simultaneously at all stations, diurnal variations are expected to reduce their comparability. For this reason, the diurnal cycle for the lake as a whole was investigated in two ways, disregarding regional variations and using all the available data.

As the recorded relative saturation values fall within the wide range of zero to 160%, frequency curves were constructed for the lake as a whole taking into consideration the time of observation (Fig. 6). Most of the lake waters remain under-saturated at all times of the day, lying within the range of 40% to 80%. As expected, the values spread towards saturation and super-saturation between mid-day and the early afternoon but only about 20% of the lake waters are saturated from 11 a.m. to 5 p.m.

In fig. 7, the relative saturation values are related to the time of observation during the day. A broad scatter is observed, particularly around 14:00, as can also be expected from the frequency curves. Thus, two trends can be discerned. In addition to the dome-shaped diurnal curve, a large number of values gather round a horizontal line, showing no appreciable diurnal change. The respective regression equations for the ascending and descending lines and for the horizontal line were obtained as follows:

$$O_{2\%} = 17.1\ t^{0.62}$$

$$O_{2\%} = 91.4 \times 10^{2}\ t^{-1.69}$$

$$O_{2\%} = 51.4 + 0.4\ t$$

$O_{2\%}$ being the relative oxygen saturation and t the real time. The $D_{OS\ r}$ or diurnal oxygen saturation range increases in the localities and at the times of higher productivity. The lowest $D_{OS\ r}$ is found in the least eutrophic Basin IV, where most of the oxygen values fall around the horizontal line, at about 60% (Table I).

Table I. $D_{os\ r}$ (diurnal relative oxygen saturation range) and other parameters

Stations and Basin	$D_{os\ r}$	Mean Secchi depth (cm)	Mean Phytopl. Cells/l 10^6	Mean surface Phosph. µg. d^a./l	Macroph. density
I, St. 2, 3, 4	138.6	37.0	10.7	2.7	Dense beds
II, St. 5, 6, 7	98.0	37.5	4.6	2.3	
III, St. 11, 12, 13	87.0	45.5	4.1	0.8	Dispersed patches
IV, St. 14, 15	59.6	46.5	2.9	0.5	
V, St. 8, 5, 10	63.8	46.5	2.8	0.5	Free from macrophytes

The $D_{os\ r}$ is very significantly correlated to the density of the phytoplankton and the macrophytes and to the phosphate content. It is negatively correlated to the Secchi depth (Table II).

Table II. Correlations of the $D_{os\ r}$ with phytoplankton density, phosphate and secchi depth

$D_{os\ r}$ vs phytoplankton	0.95
$D_{os\ r}$ vs phosphate	0.91
$D_{os\ r}$ vs Secchi depth	-0.87

Posidonia beds: The "Posidonia" beds have been intensively investigated in the West Mediterranean along the French and Italian coasts, but very little is known about the eastern Mediterranean beds.

Large beds grow in the infra-littoral zone along the Alexandria coast and a preliminary investigation was started in the summer of 1979. The study is planned as a comparative investigation and involves, at this stage, the rate of growth of the plant, its total leaf area per square metre, the biomass and the structure of the epizoan fauna.

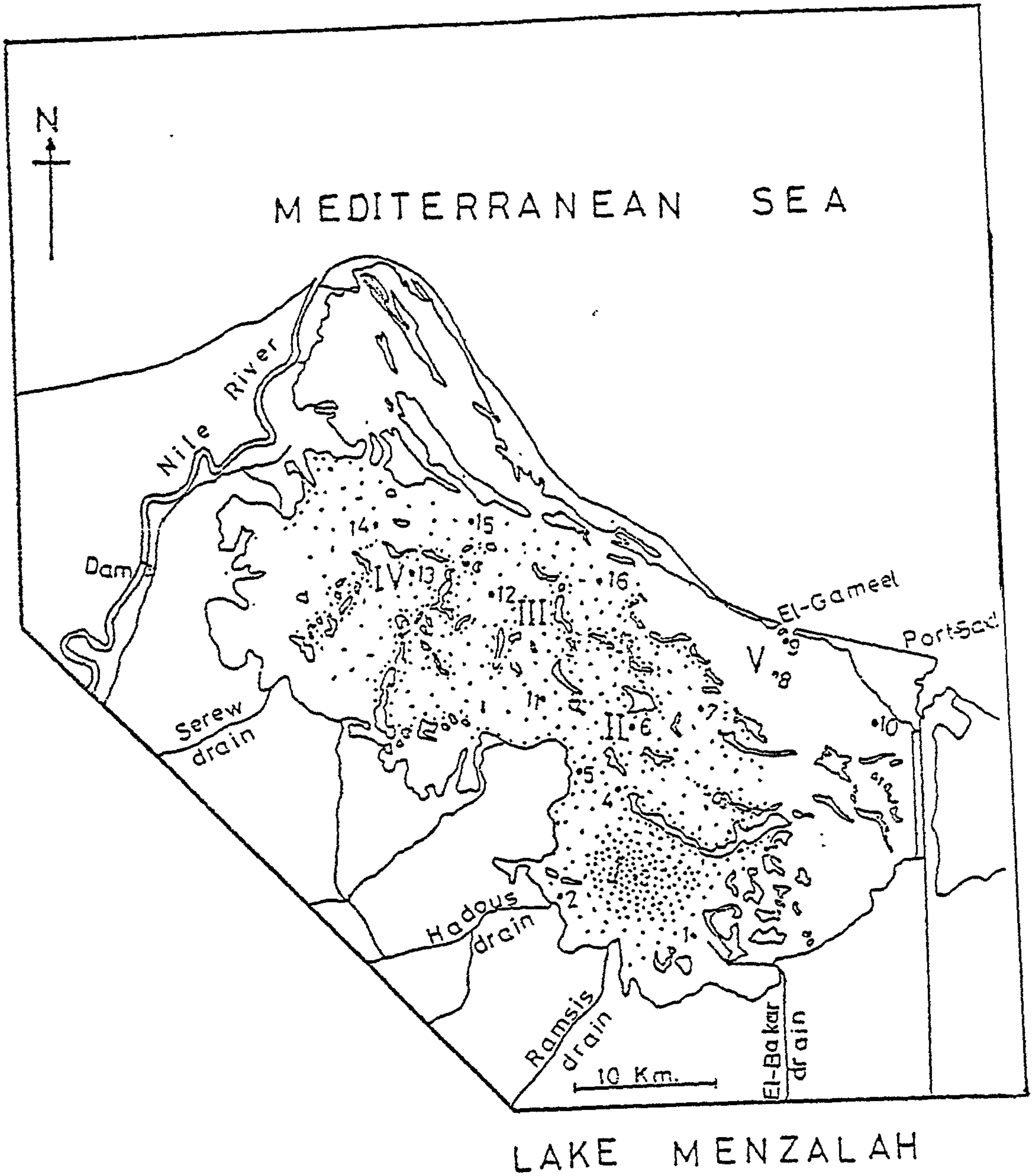


Fig. 1. Lake Menzalah (Basins I to V, Stations 1 to 16). The dotted areas show the distribution of the macrophytes and their density

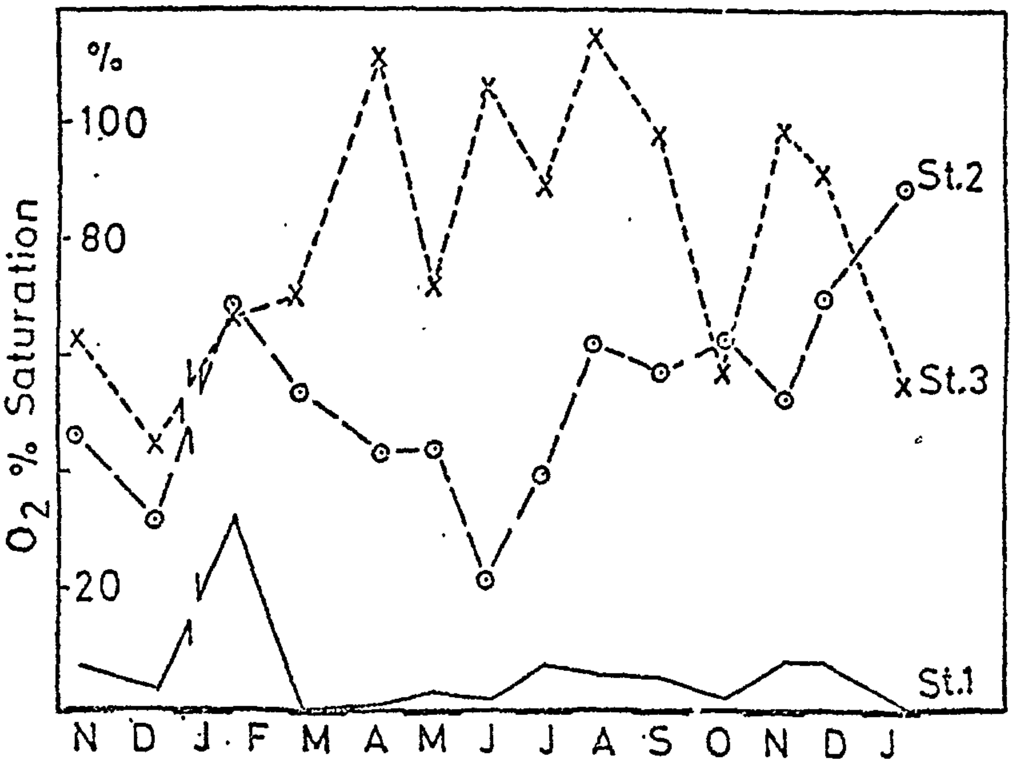


Fig. 2. Relative oxygen saturation

St. 1: the outfall
St. 2: inlet of an agricultural drain canal
St. 3: mid-basin

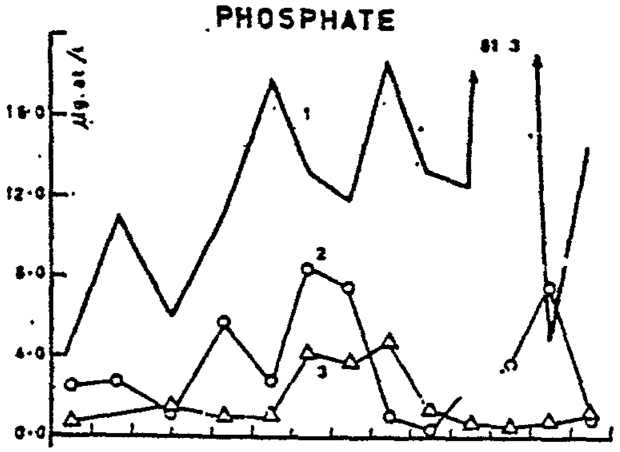


Fig. 3. Dissolved phosphate,
St. 1 to 3

Fig. 4. Horizontal dissolved oxygen distribution (ml/l)

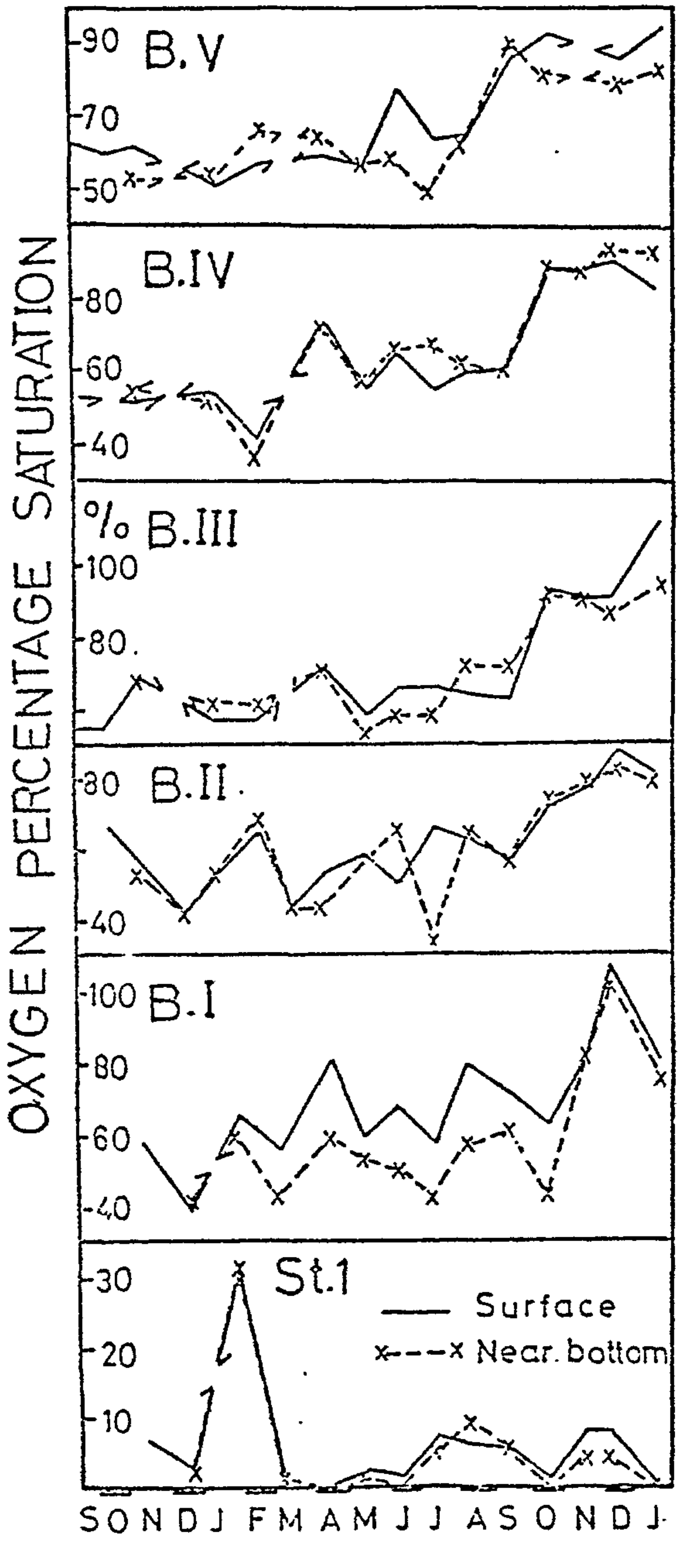


Fig. 5. Monthly variations of surface and near bottom relative oxygen saturation in Basins I to V and St. 1, L. Menzalah

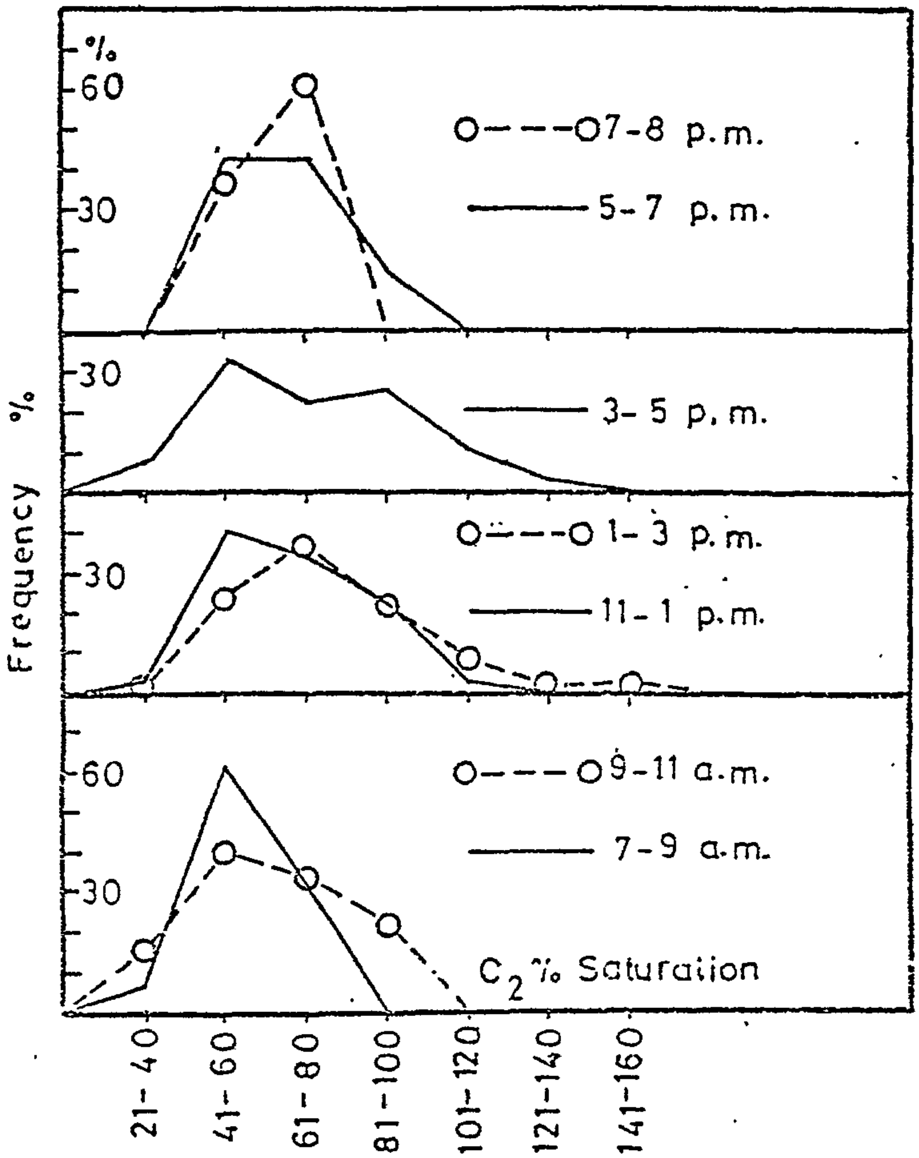


Fig. 6. Percent frequency of the relative oxygen saturation values at two hours intervals

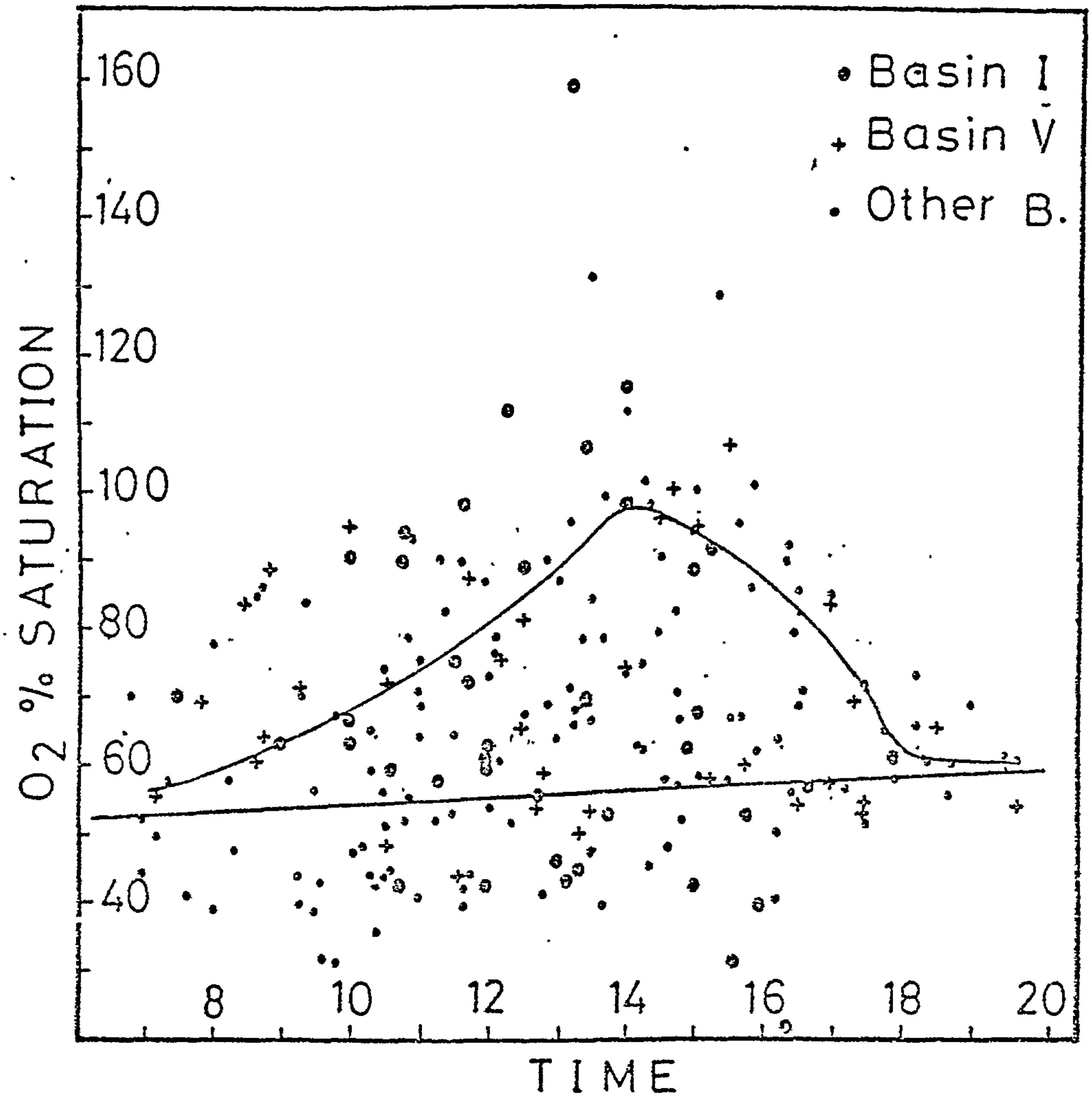


Fig. 7. Relative oxygen saturation values against time of observation

Centre de recherche : Station marine d'Endoume et centre d'Océanographie
MARSEILLE
France

Chercheur principal : D. BELLAN - SANTINI

INTRODUCTION

Les chercheurs de la Station marine d'Endoume travaillent depuis 30 ans sur les communautés tant benthiques que planctoniques et depuis plus de 15 ans sur l'action des pollutions sur celles-ci. Comme son champ d'action est essentiellement la mer Méditerranée, l'ensemble des problèmes pris en compte dans le projet pilote MED V a été traité bien avant que naisse le MED POL.

CONSIDERATIONS METHODOLOGIQUES

Zones étudiées :

La zone concernée couvre l'ensemble des côtes provençales, soit du delta du Rhône au golfe de Cannes compris.

Les communautés étudiées appartiennent aux trois étages suivants :

- Infralittoral : ce sont surtout les communautés de substrat dur ou demi-dur qui ont été étudiées : Biocènose des Algues Photophiles, Herbier de Posidonies. En ce qui concerne les substrats meubles nous citerons les Sables Fins bien calibrés et les Sables Vaseux de Mode Calme.

- Circalittoral et Bathyal : à l'exception du Coralligène, ce sont surtout des communautés de substrats meubles qui ont été étudiées : Détritique côtier, Détritique envasé, Détritique du Large, Vase térrigène côtière.

Les Polluants :

Les communautés benthiques étudiées et altérées par la pollution sont soumises, en général, à une pollution diffuse émanant d'un secteur à très forte concentration humaine et industrielle, mais plus particulièrement en ce qui concerne deux secteurs, à une pollution à dominance industrielle (raffinerie, pétroléochimie) dans le golfe de Fos et domestique (matière organique, détergents) dans le secteur de Cortiou.

METHODOLOGIE

L'échantillonnage a été réalisé suivant des méthodes différentes mais comparables sur les substrats durs et les substrats meubles.

Substrats durs : prélèvements de l'ensemble du peuplement vivant sur 400 cm^2, en plongée libre ou scaphandre. Des séries de 5 ou 10 prélèvements ont été effectuées à chaque station et le plus souvent à deux périodes de l'année, été et hiver. En ce qui concerne les macroéchinodermes : les comptages directs en plongée sur des surfaces de 1-10 - 50 m^2 ont été effectuées selon des radiales perpendiculaires à la côte.

Substrats meubles : 3 méthodes ont été utilisées, comparables mais adaptées aux différents milieux prospectés et aux buts recherchés.

a) Prélèvements à la benne "orange-peel" : 5, 10 ou 40 dm^3 ont été pris en compte suivant l'importance du volume minimum de la communauté étudiée. Ces quantités sont obtenues par des prélèvements en série à chaque station.

b) Prélèvements à la "drague Charcot modifiée Picard" : 50 litres ont été étudiés par station.

c) Prélèvements à la "drague Spatangue" : cette drague écrème la surface du sédiment sur quelques cm d'épaisseur et permet d'une part, de récolter la faune superficielle et, d'autre part d'obtenir la couche superficielle du sédiment.

RESULTATS

Substrats durs :

Infralittoral : deux très importants travaux ont été effectués (G. Desrosiers 1977, G. Bitar 1980). Le premier dans le golfe de Fos soumis à une pollution à dominance industrielle, le second dans la région de Cortiou, soumis à une pollution à dominance domestique. Les deux travaux aboutissent à des résultats comparables : destruction progressive de l'équilibre des peuplements au fur et à mesure que l'on se rapproche des foyers de pollution avec :

- disparition des espèces les plus sensibles;

- remplacement de stocks trophiques par d'autres : remplacement de brouteurs par des mangeurs de détritus, développement important et sporadique dans certaines zones, de pollutions monospécifiques tolérantes correspondant à une condition locale bien particulière;

- diminution des indices de diversité lorsque la pollution croît.

Certains groupes zoologiques ont été plus particulièrement étudiés et des indices biologiques de pollution ont été mis au point : utilisant la balance quantitative voire qualitative qui s'institue dans les peuplements soumis à pollution (G. Ballan 1979, D. Bellan-Santini 1979).

En ce qui concerne les macroéchinodermes, 19 espèces ont été inventoriées dans 3 zones : Fos, Cortiou et Port Cros (comme station référence d'eau pure). Leur distribution tant qualitative que quantitative a été étudiée, des mensurations de taille de 3 espèces ont permis aussi de mettre en évidence l'évolution du facteur croissance (Harmelin, Bouchon, Hong, 1980).

L'influence d'une pollution domestique se traduit par une forte augmentation de la densité globale avec une particulière abondance de l'Ophiure Ophiocomina nigra et d'une pullulation des oursins qui s'accompagne d'une diminution spectaculaire de la taille. La richesse spécifique est maximale à la périphérie de la zone polluée et décroît fortement à proximité du foyer. Sous un gradient de pollution industrielle, on observe une diminution de la richesse spécifique et de la densité globale d'autant plus accentuée que la profondeur est importante.

Circalittoral : un travail très important sur l'altération subie par les concrétionnements biogènes de type Coralligène s'achève (Hong 1980). Il chiffre l'altération qualitative subie dans le golfe de Fos par les formations Coralligènes.

Herbiers de Posidonies : l'épifaune sessile des feuilles, tiges et rhizomes soumis à la pollution a fait l'objet d'un travail (Eugène Ch. 1978). Dans les zones non dégradées, les herbiers de profondeur moyenne présentent une épifaune plus riche et plus diversifiée que dans les herbiers profonds. Dans les zones dégradées, l'action conjuguée des facteurs abiotiques (taux de sédimentation important, phénomènes hydrodynamiques atténués, ennoyage sédimentaire et rhizomes) et de facteurs biotiques (absence de substrats durs et de massifs de concrétionnement avoisinants) défavorables ne permet ni l'installation, ni le développement ni le maintien des épibiontes. Dans les herbiers profonds (limite en profondeur des herbiers), ces facteurs défavorables s'intensifient.

L'étude qualitative du peuplement montre un net appauvrissement de l'épifaune dans les zones dégradées : 96 espèces ont été recensées dans l'herbier de profondeur moyenne non dégradé et 18 espèces dans l'herbier le plus dégradé; 75 espèces ont été recensées dans l'herbier profond non dégradé et 11 espèces dans l'herbier profond le plus dégradé.

Substrats meubles :

Deux secteurs ont été plus particulièrement étudiés : L'étang de Berre et le golfe de Fos. Le secteur de Cortiou (débouché de l'émissaire des égouts de Marseille). Dans un premier temps, un résumé des résultats obtenus sur l'ensemble de la zone étudiée (Rhône-golfe de la Napoule) sera fourni. Puis, il sera procédé à une étude plus particulière du secteur de Cortiou.

Résultats généraux :

Il a été achevé durant la période correspondant au projet pilote MED V, la mise en place pour les substrats meubles, d'un dispositif destiné à détecter et à suivre les modifications du benthos, tant naturelles que provoquées par l'homme, sur les côtes de Provence depuis le delta du Rhône jusqu'aux îles d'Hyères, ce qui n'exclut pas des interventions ponctuelles, plus lointaines (golfe de la Napoule, par exemple).

Ont été plus particulièrement étudiés : les processus accélérés d'envasement des biocoenoses depuis le delta du Rhône jusqu'au golfe de Marseille; les atteintes des milieux naturels par les perturbations d'origine humaine de tous ordres depuis le golfe de Marseille jusqu'à la baie de la Ciotat; l'impact de facteurs naturels (hydrodynamisme et sédimentation) ou non dans des milieux encore partiellement épargnés par les divers apports polluants parvenant au rivage entre la Ciotat et les îles d'Hyères; le rôle d'un égoût sous-marin sur la répartition de pollutions urbaines et l'évolution spatio-temporelle des peuplements dans le golfe ouvert de la Napoule. Ces études s'articulent avec celles menées dans les milieux à intense pollution par matières organiques, ainsi qu'avec les recherches entreprises sur les peuplements établis sur substrats solides et sur les Herbiers de Phanérogames, dans des milieux sains ou perturbés.

Enfin, progressivement, mais systématiquement, à la collaboration classique avec les sédimentologistes, est venue s'ajouter, comme il a été dit, l'intégration dans ces recherches des caractéristiques chimiques (notamment polluants et facteurs liés à la pollution) des sédiments eux-mêmes.

Les résultats marquants que l'on peut dégager sont les suivants :

Dans l'Etang de Berre l'influence du déversement massif des eaux de la Durance dans la partie Nord de l'Etang a entrainé l'apparition d'un gradient très net, N-S, de la teneur en matières organiques, de la salinité et de divers polluants. Dans ce milieu lagunaire, soumis à un apport d'eau douce permanent mais de débit variable, les variations brusques de salinité déclenchent des mortalités massives et brutales. Ces mortalités, irrégulièrement réparties dans le temps suivant les stations, sont indépendantes des saisons et masquent en grande partie les variations saisonnières. Les espèces présentent une capacité de recolonisation, d'un trimestre à l'autre, particulièrement marquée bien que variable suivant les années. Ce phénomène tend à montrer que, plus qu'un niveau global de pollution, ce sont les effets synergiques créés par des variations brutales des conditions de milieu qui entraînent la disparition des espèces au niveau des différentes stations à tel point que les peuplements sont les plus stables et les moins pauvres dans un secteur où les taux moyens de polluants présents dans le sédiment sont les plus élevés, mais où les variations de la salinité (et l'apport de limons) sont les plus atténués, c'est-à-dire dans la partie sud-ouest de l'Etang.

En zone franchement marine l'autonomie d'une biocoenose du détritique envasé s'intégrant dans une séquence d'envasement dynamique (liée probablement à la régularisation du cours du Rhône) détritique côtier - détritique envasé - vase terrigène côtière a été confirmée, tandis que l'étude des marges de contact entre ces biocoenoses a permis de préciser où se situe, sur le gradient d'envasement l'apogée de certaines espèces parmi les plus représentatives. Concuremment, il a été montré que, dans ces secteurs perturbés, les espèces caractéristiques des biocoenoses régressaient quantitativement au bénéfice d'espèces à large répartition écologique ou opportunistes. Le problème du bilan production de CO_3Ca/envasement a été suivi, de même que le rôle de la déficience, puis la recrudescence du mistral à l'est de la Ciotat sur l'envasement des fonds, l'évolution subséquente des peuplements, l'extension des fonds de maërl, etc... jusque et y compris les processus de contamination des biocoenoses entre bassins côtiers voisins. Dans le même ordre d'idées, la disposition des unités de peuplement en fonction de l'hydrologie et de la sédimentation induites par le relief des fonds de la rade, relativement polluée, de Toulon a été examinée.

Bien que toujours liés à des phénomènes hydrodynamiques et sédimentologiques au niveau des fonds meubles, mais plus spécifiquement en relation avec l'influence des activités humaines et plus particulièrement des pollutions urbaines, des recherches ont contribué : d'une part, à mettre en évidence l'extension des perturbations liées aux égouts de Marseille-Cortiou et de la Ciotat par "résorption" des "rentrants" de milieux sains (par exemple, atteinte par la pollution des parages de la balise de la Cassidaigne); d'autre part, à détecter l'origine exogène de l'accroissement rapide des fonds de décantation dans les parages de l'île Maïre, en utilisant comme "traceur" le déplacement des eaux turbides engendrées par des travaux de remblaiement de la plage du Prado de Marseille; enfin, à vérifier "expérimentalement", quatre ans après sa mise en service, qu'un égout sous-marin débouchant par -85 m à la tête d'un Canyon, avait déplacé vers le nord-ouest du golfe de la Napoule, l'impact sur les peuplements benthiques des rejets urbains de Cannes, provoquant une dégradation considérable, notamment au niveau d'une cellule de décantation, des peuplements dans la partie ouest du golfe, tandis que la partie est était protégée. On a, aussi, pu constater que les populations de poissons (Mullus barbatus notamment) étaient sensiblement plus abondantes dans la partie occidentale, la plus polluée, du golfe.

Appuyées sur des recherches dans des milieux indemnes des perturbations liées à l'activité humaine, recherches poursuivies depuis 30 ans, et prenant en en compte des données climatologiques, hydrodynamiques, sédimentologiques et géochimiques, les études passées et en cours ont permis de présenter un essai de synthèse sur les modalités de répartition en Méditerranée nord-occidentale des peuplements benthiques des sédiments côtiers soumis à des pollutions à dominante organique. Les modalités mises en évidence peuvent ainsi être résumées : Par rapport à la position d'une source de pollution globale à dominante de rejets domestiques, on peut reconnaître plusieurs modalités différentes de la localisation topographique des peuplements soumis à cette agression.

a) Au voisinage immédiat d'une source "concentrée" de pollution de ce type, l'abondance et la constance de l'apport polluant sont telles que les actions hydrodynamiques locales ne peuvent en assurer la dispersion et que le processus naturel de recyclage de la matière organique ne suffit pas à résorber l'excès de celle-ci; les peuplements les plus pollués sont alors au contact même de la source de pollution (exemple : le débouché de l'égout de Marseille-Cortiou).

b) Quand l'apport massif de matières organiques est entraîné plus ou moins loin de l'émissaire par une circulation locale orientée dans une direction préférentielle, les peuplements les plus pollués correspondent à des fonds de décantation préexistants, situés plus ou moins loin de la source de pollution (exemples : la rade de Cannes-La Napoule, et les parages de l'île Maïre de Marseille).

c) Quand les apports de matières organiques proviennent de sources d'importance minime, mais multiples, et que leur dispersion est entravée par l'existence de digues de protection vers le large, les peuplements les plus pollués se disposent en "mosaïque" partout où existent des obstacles à la libre circulation des eaux susceptibles d'assurer la diffusion et la dilution de ces polluants (exemple : les grands ports, tels Marseille).

d) Quand il y a stockage dans les sédiments de l'excès de matière organique, dont le recyclage paraît bloqué par l'intervention de polluants chimiques adsorbés par les argiles avant leur décantation, ou par un abaissement de la salinité de l'eau surmontant les sédiments, les peuplements benthiques pollués occupent alors des surfaces parfois très étendues, qui correspondent à l'extension même des masses d'eau perturbées (exemples : les fonds côtiers au large du collecteur de Marseille, Cortiou, et les fonds de l'Etang de Berre).

Cortiou (Fig. 1. Tab.1). Un certain nombre de conclusions générales peuvent être extraites de l'étude menée dans le secteur Cortiou depuis la fin 1976.

a) Au voisinage du débouché lui-même, la zone "polluée" à Capitella capitata et Scolelepis fuliginosa n'a que peu évolué depuis 1975. L'essentiel des modifications s'est fait ressentir plus au large, dans la zone subnormale dont une large fraction a été étudiée en détail dans ce qui correspond à une sorte de grand golfe sous-marin.

b) Le golfe sous-marin de Cortiou-Riou. L'étude du substrat et du peuplement du golfe sous-marin de Cortiou nous a permis de mettre en évidence :

- L'envasement progressif des fonds du golfe, lequel, en deux ans, a augmenté de 10% dans une station (E1). Cette vase, chargée de polluants (Pb, Ar, Cu, Hg, PCB, etc.) occupe tout le plateau à partir de H 3, située à environ 1 km au sud de l'embouchure de l'égout, atteint la pointe Est de l'île Riou, vers le Sud et le Cap Morgiou vers L'Est;

- L'entrée, à travers les passes existantes entre les îles de Jarre et Plane d'un courant de fond provenant du large qui pénètre profondément dans le golfe atteignant la station G3. D'autres courants de fond se font sentir de manière plus ou moins marquée selon les facteurs pris en considération, l'un provenant du Sud-Est et dirigé vers le Nord-Ouest, qui pourrait être une dérive du courant Ligure (Castelbon, 1972), l'autre provenant du Sud-Ouest et dirigé vers le Nord-Est, qui pourrait provenir d'un contrecourant chargé d'apports rhodaniens;

- L'influence des apports rhodaniens dans le golfe qui se traduit par des taux élevés du complexe Chlorite-Illite, particulièrement aux stations situées au Sud-Ouest de l'embouchure de l'émissaire;

- La dégradation probable de la Smectite en interstratifiés due à l'apport de matières organiques provenant de l'émissaire. Ceci se traduit par les faibles teneurs en Smectite des stations plus proches de l'émissaire, tandis que les interstratifiés (10-14s et 14c-14s) apparaissent occupant une bande d'environ 3 km de large autour dudit émissaire (Chamley 1977);

- Une première zone, qui occupe un rayon inférieur à 2 km autour de la sortie de l'émissaire, à forte concentration en polluants, dans laquelle peut se distinguer, partant de l'égout et légèrement inclinée vers le Sud-Ouest, vers la station G 3. Une deuxième zone où se décantent des sédiments beaucoup moins chargés, mais dont le potentiel polluant est loin d'être négligeable. La propagation des divers polluants commandée par le transport des masses d'eau se concrétise par une extension continue de la pollution dans tout le secteur situé à l'Est et au Sud-Est de l'émissaire (Arnoux 1979);

- Le remplacement, dans le secteur situé au Nord de la radiale E, des espèces caractéristiques du détritique côtier, par des espèces caractéristiques du détritique envasé et de la vase terrigène côtière;

- La remontée d'espèces caractéristiques du détritique du large et de la vase profonde;

- La faible représentativité des espèces caractéristiques, du point de vue qualitatif, mais surtout quantitatif, faiblesse qui traduit l'aggravation des conditions du milieu, au point que les espèces caractéristiques présentes pourraient être considérées comme des reliques;

- La dominance indiscutable des espèces à large répartition écologique et sans signification précisée ainsi que les dominances relativement élevées des espèces indicatrices de dégradation, surtout dans le secteur Nord du golfe, mais qui restent néanmoins élevées jusqu'aux abords de l'isobathe 100 m, soulignent l'envahissement de tout le golfe par un peuplement représentatif de la zone subnormale.

- La grande homogénéité voire même la grande monotonie du peuplement dans son ensemble dans toute l'aire prospectée, ce qui se traduit, notamment par :

  (i) la dominance considérable d'un petit nombre d'espèces (24, soit 6% de l'ensemble des espèces recueillies) présentes dans au moins 75% des stations, regroupent à elles seules de 48,85 à 69,39% des individus présents dans les stations (sauf F 1 : 40,01%, E 1 : 42,09% et D 1 : 27%);

  (ii) des coefficients de similitude de Sanders bien regroupés; dans 65,7% des cas, ce coefficient est supérieur à 40% et inférieur à 20% dans seulement 1,7% des cas;

  (iii) des indices de diversité de Margalef et de Sanders très proches les uns des autres.

- On peut toutefois distinguer deux sous-entités dans cet ensemble, en se basant essentiellement sur les aspects quantitatifs du peuplement. La première englobant les stations de la radiale F et celles de la partie Ouest de la radiale E (jusqu'au niveau de E 3 - E 4), la seconde comprenant toutes les stations des radiales D (à l'exclusion de D 1), C, B et A.

Nous distinguons donc deux sous-zones où la progression de la pollution se fait sentir différemment. Une première zone qui occupe le secteur Nord du golfe, au Nord d'une ligne Est de Riou-cap Morgiou où la limite de structuration des Biocoenoses observées par Bellan, Kaim-Malka et Picard (1976) a été dépassée : on est en pleine dégradation du peuplement, ceci se traduit au niveau du peuplement par la disparition des espèces indicatrices d'instabilité (strictes), remplacées par des espèces indicatrices de dégradation. Celles-ci disparaîtront à leur tour, dans la mesure où la pollution continue d'augmenter, pour laisser la place aux espèces indicatrices de la zone polluée. Ce phénomène est observable au niveau de la station F 1. On peut penser que les prélèvements ont été effectués au moment où toute cette zone atteignait le point culminant de l'instabilité, basculant ensuite dans un peuplement représentatif de la zone polluée, avec comme uniques espèces présentes les espèces indicatrices de pollution telles Capitella capitata, Scolelepis fuliginosa, Nereis caudata et Dorvillea rudolphii.

Dans la deuxième zone qui comprend les stations situées au Sud de cette limite que constituerait la radiale E, l'influence de l'émissaire se fait sentir jusqu'aux abbords de l'isobathe 100 m, ceci se traduit par la dominance des espèces à large répartition écologique et des espèces sans signification précisée représentatives du peuplement de la zone subnormale. L'absence d'espèces indicatrices de pollution ainsi que les dominances relativement élevées par rapport à l'éloignement de la source de pollution, des espèces indicatrices de dégradation amène à penser que nous sommes bien en présence d'un peuplement qui arrive à la limite de la structuration Biocoenotique.

L'influence de la dérive du courant Ligure qui passe au large de l'archipel de Riou et les contrecourants provoqués par cette même dérive, ainsi que l'éloignement de la source de pollution peuvent être la cause du blocage de la progression de cette même pollution au niveau de la radiale E et de son étalement plus progressif vers l'Est et le Sud-Est. On notera : a) que si l'on compare les coefficients de similitude de Sanders entre ces deux groupes de stations, ceux-ci sont supérieurs à 40% dans 38,28% des cas; à 35% dans H 57,03% des cas et inférieurs à 20% dans 2,34% seulement; et b) que les indices de diversité de Margalef et de Shannon sont, sauf exception, respectivement inférieurs à 15 et 5 dans la sous-zone "nord" et supérieurs à 15 et 5 dans la sous-zone "sud" (les stations B et A ayant des indices de diversité affaiblis, plus probablement en raison de la profondeur que de l'action de la pollution).

DISCUSSION DES RESULTATS

Des idées très générales peuvent être tirées de l'ensemble de ces travaux et des autres, conduits en Méditerranée et qui ont paru dans la littérature, ainsi d'ailleurs que ceux correspondant à d'autres régions dans le globe :

- altération des peuplements;

- appauvrissement spécifique et baisse des indices de diversité;

- balance spécifique par remplacement d'espèces aux exigences strictes par des espèces à large potentialité écologique;

- pour une pollution par les matières organiques, qualifiée de moyenne on assiste à un enrichissement numérique mais pas spécifique;

- appauvrissement de la diversité des communautés et tendance fréquente à l'envasement;

- accumulation des altéragènes.

PUBLICATIONS

ARNAUD, P.M., BELLAN-SANTINI, D., HARMELIN, J.G., MARINOPOULOS, J., ZIBROWIUS, H., 1981. Impact des rejets d'eau chaude de la centrale thermo-électrique E.D.F. de Martigues Ponteau (Méditerranée nord occidentale) sur le zoobenthos des subtrats durs superficiels. 2e Journées de la thermoécologie EDF, Direction Equipement: 701-724.

ARNOUX, A., STORA, G., 1979. Distribution de quelques altéragènes présents dans l'étang de Berre : leur influence sur la répartition de la macrofaune benthique. XXVI° Congrès CIESM, Antalya, Comité "Etangs salés et lagunes" Rapp. Comm.intern. Mer. Medit. 25-26 (3): 149-150.

BELLAN, G., 1978. Une tentative sérieuse de réduction de la pollution marine en Méditerranée : l'émissaire sous-marin de la ville de Cannes. Tech. de l'eau : 380-381.

BELLAN, G., 1979. Polychaetous Annelids collected from rocky substrata in polluted environment along the French Provençal Coast. Am. Soc. of Zoologists Annual Meeting, Tampa, Fu., Am. Zool.

BELLAN, G., BELLAN-SANTINI, D., PICARD, J., 1979. Les modalités de répartition, en Méditerranée nord-occidentale des peuplements benthiques des sédiments côtiers soumis à la pollution par matières organiques dominantes. XXVI° Congrès CIESM, Antalya, Comité Pollution : 351-358.

BELLAN, G., BELLAN-SANTINI, D., PICARD, J., 1980. Mise en évidence de modèles écobiologiques dans des zones soumises à perturbations par matières organiques Oceanologica acta. (Sous presse).

BELLAN-SANTINI, D., 1979. The relationship of pollution to amphipods Crustaceans in Mediterranean Sea. Congrès de l'American Society of Zoologists, Tampa. American Zoologist. 19 (3) : 79.

BELLAN-SANTINI, D., DESROSIERS, G., 1977. Distribution du benthos de substrat dur dans un golfe soumis à de multiples pollutions (golfe de Fos). III° Jour. Et. poll. mar., CIESM : 153-157.

BELLAN-SANTINI, D., DESROSIERS, G., 1977. Action du rejet thermique de l'usine de Martiques-Ponteau sur les peuplements de substrats durs à dominance de zoobenthos dans la partie supérieure de l'étage infralittoral. Téthys, 8 (1) : 83-92.

BELLAN-SANTINI, D., DESROSIERS, G., 1977. Action d'un rejet thermique sur le zoobenthos installé sur substrat dur (site de Ponteau). Journées de la thermo-écologie. Centre Océanologique de Bretagne, 15-16 novembre 1976. EDF. Direction Equipement : 235-250.

BOURCIER, M., NODET, C., JEUDY DE GRISSAC, A., TINE, J., 1979. Répartition des biocoenoses benthiques en fonction des substrats sédimentaires de la rade de Toulon. Téthys 9 (2) : 103-112.

BITAR, G., 1980. Etude de l'impact de la pollution par un émissaire urbain (collecteur de Cortiou) sur les peuplements infralittoraux de substrats durs de la côte sud de Marseilleveyre (Marseille). Thèse de Doctorat 3° Cycle en Océanographie. Fac. Sciences Marseille II : 137 p. + tableaux.

DESROSIERS, G., 1977. Contribution à l'étude de l'influence de la pollution sur les peuplements de substrats durs dans le golfe de Fos. Thèse de Doctorat 3³ Cycle Océanographie biologique. Fac. Sciences Marseille II : 90 p. + tableaux.

EMDADI, I., 1979. Impact des récents travaux d'aménagements sur le macrobenthos des sables fins de la baie du Prado. Thèse Doctorat 3° Cycle. Univ. Aix-Marseille II : 93 p. + tableaux.

EUGENE, Ch., 1979. Epifaune des Herbiers de Posidonies du littoral provençal dans des secteurs pollués et non pollués. XXVI° Congrès CIESM, Antalya, Comité Benthos : 213-214.

EUGENE, Ch., 1978. Etude de l'épifaune des Herbiers de *Posidonia oceanica* (L.) Delile du littoral provençal. Thèse de Doctorat 3° Cycle Océanographie biologique. Fac. Science Marseille II : 129 + tableaux.

HARMELIN, J.G., BOUCHON, Cl., HONG, J.S., 1980. Impact de la pollution sur la distribution des Echinodermes des substrats durs en Provence (Méditerranée nord-occidentale). Téthys. 10(1) : 13-36.

HARMELIN, J.G., HONG, J.S., 1979. Données préliminaires sur le peuplement d'un fond de concrétionnement soumis à un gradient de pollution. I - Généralités. II - Faune Bryozoologique. XXVI° Congrès CIESM, Antalya, Comité Benthos : I : 173-174, II : 175-176.

HONG, J.S., 1980. Etude faunistique d'un fond de concrétionnement de type coralligène soumis à un gradient de pollution en Méditerranée nord-occidentale (golfe de Fos). Thèse de Doctorat 3° Cycle Océanographie biologique. Fac. Sciences Marseille II. 145 p.

OLIVARI-JOAJURIA, A., 1980. Peuplements benthiques de substrat meuble dans le couloir d'écoulement des eaux usées de la ville de Marseille. Relations polluants-peuplement. Thèse Doctorat Université, Aix-Marseille II : 116 p. + tableaux.

PICARD, J., 1978. Impact sur le benthos marin de quelques grands types de nuisances liées à l'évolution des complexes urbains et industriels de la Provence occidentale. Oceanis 4 (3): 214-225.

ROMANO, J.Cl., 1979. Etude des peuplements benthiques de substrats meubles au large du débouché en mer du grand collecteur de Marseille. I - Données générales sur le milieu et les peuplements. Téthys 9 (2) : 113-121.

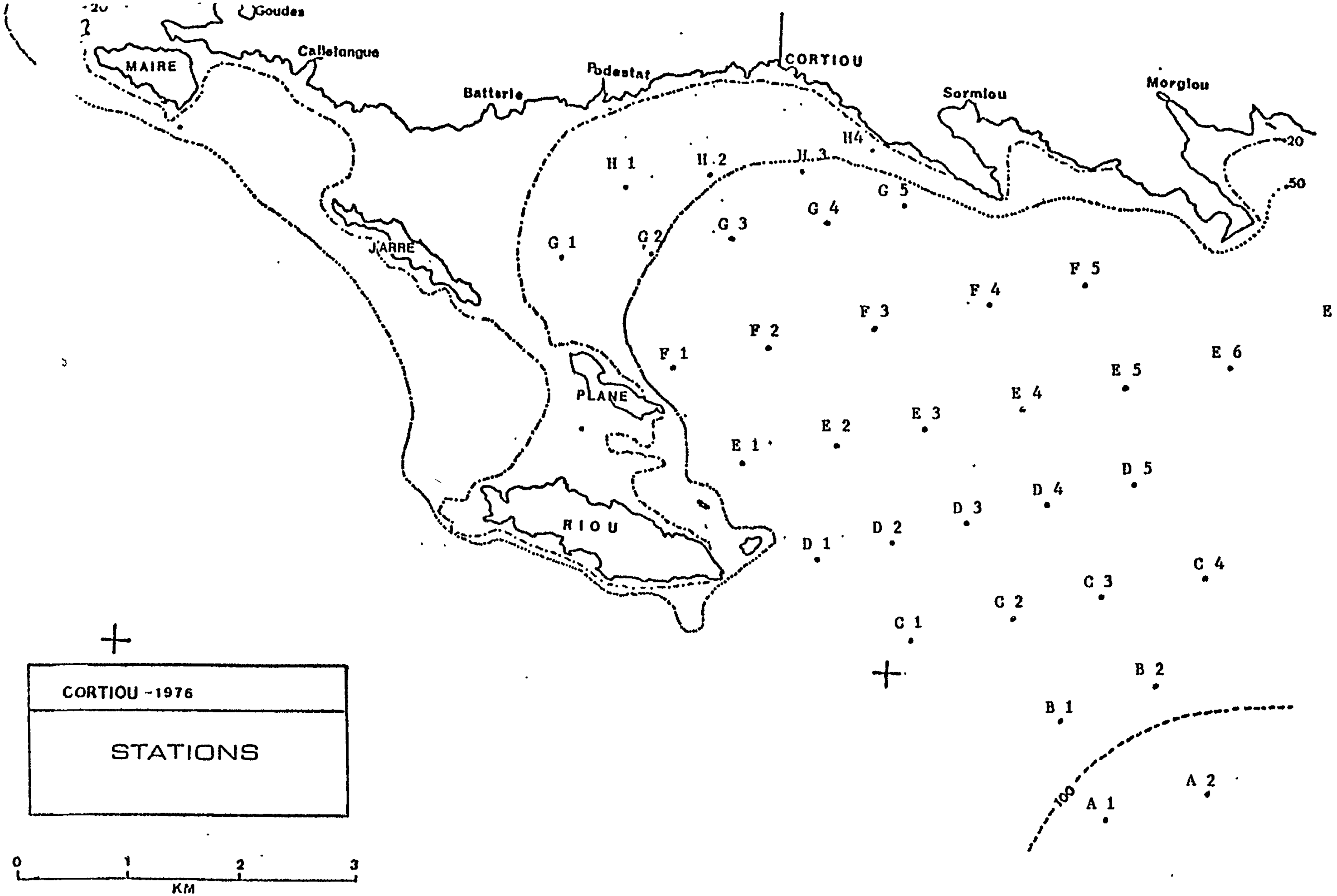


Fig. 1. Le secteur Cortiou

	F 1	F 2	F 3	F 4	F 5	E 1	E 2	E 3	E 4	E 5	E 6	E 7
Teneurs en vase % < 63µ	41,50	36,80	38,5	22,50	37,50	46,60	41	44,30	35,40	33	31,10	29
1,1 m > sable %> 63µ	50,20	58	64,20	72,90	56,9	48,8	54,80	43,50	642	63,70	65,10	65,80
Hg µ G⁻¹.........	0,82	1,36	0,97	0,64	0,60	0,88	0,88	0,86	0,70	0,74	0,50	0,40
Cu µG⁻¹.........	27,50	42	29	18,50	18	22,50	24,50	27	15	28,50	13	10
µ. DDT nG G⁻¹.....	5	26	16	11	1	12	5	19	10	7	2	5
PCB nG G⁻¹.......	139	297	176	68	94	246	114	128	70	43	34	30
Carbone organique G %................	1,41	1,51	1,22	0,70	0,90	1,86	1,13	1,13	0,54	0,600	57	0,45
Σ% espèces caractéristiques...	8,60	13,26	14,54	8,41	13,08	11,23	12,12	10,35	11,65	12,62	11,47	7,40
Σdes dominances des espèces caracté-ristiques..........	3,11	5,04	14,18	59,80	3,69	4,07	4,29	4,76	4,72	3,91	5,04	4,80
Σdes dominances des L. R. E. de S. M...............	24,59	26,56	23,74	35,11	28,67	21,77	38,53	27,05	30,89	31,05	24,33	32,52
Σdes dominances des espèces présentes dans 3/4 des stations...........	40,01	48,85	54,49	54,19	57,08	42,09	61,67	51,40	60,59	60,67	51,50	49,53
Indice de diversité de MARGALEFF.......	13,26	13,94	15,33	14,90	15,17	13,62	14,33	12,16	15,31	15,01	16,99	16,62
de SHANNON.........	4,22	4,26	5,03	4,79	4,97	4,85	4,91	4,96	5,58	5,13	5,52	5,56

LEGENDE : Pour chaque station sont fournis, à titre d'exemple : les teneurs en vase (% de la fraction des particules du sédiment de diamètre < 63µ), en sable (particules de diamètre compris entre 1,1 mn et 63µ , en mercure, cuivre, D.T.T., polychlorobiphényls, en % de Carbone organique, somme des pourcentages et somme des dominances des espèces caractéristiques d'une biocoenose *quelconque*, somme des dominances des espèces à Large Répartition écologique dans les substrats meubles (L. R. E. de S. M.), somme des dominances des espèces présentes dans au moins les 3/4 des stations, indice de diversité de MARGALEF et SHANNON.

	D I	D 2	D 3	D 4	D 5	C I	C 2	C 3	C 4	B I	B 2	A I	A 2
Teneurs en vase % < 63µ	31,20	27,30		33	242	32	28,30		29,20	29,70	33,50	30,20	
1,1 m > sable %> 63µ	24,20	67,20		61,60	73,50	64	67		67,50	64,30	66,10	67	
Hg µ G-1.........	1	0,68	0,56	0,58	0,50	0,50	0,36	0,50	0,50	0,50	0,40	0,58	0,38
Cu µG-1.........	23	54	14,50	24	14	23	14	20,50	14	15,50	16,50	13,50	12
µ.DDT nG G-1.....	14	2	40	4	6	4	9	2	2	8	4	4	2
PCB nG G-1.......	110	26	59	56	20	16	48	30	23	20	15	16	5
Carbone organique G %...............	0,95	0,38	0,44	0,60	0,63	0,52	0,54	0,81	0,57	0,42	0,55	0,54	0,49
Σ% espèces caractéristiques...	9,60	9,14	12,87	10,68	15,07	8,04	13,83	15,48	14,33	9,57	14,06	10,71	6,66
Σ des dominances des espèces caractéristiques..........	5,23	7,65	7,15	3,63	6,67	6,11	8,36	9,94	6,13	4,99	6,16	2,73	1,35
Σ des dominances des L. R. E. de S. M...............	36,36	34,40	31,42	33,36	32,52	31,90	32,82	25,40	27,51	28,48	34,90	39,17	33,97
Σ des dominances des espèces présentes dans 3/4 des stations...........	27	50,52	50,52	54,35	66,33	57,90	53,64	50,40	57,22	59,11	66,75	69,39	59,59
Indice de diversité de MARGALEFF.......	18,24	14,93	16,40	16,17	14,94	13,96	15,57	14,83	12,81	15,17	11,22	13,01	12,51
de SHANNON.........	5,12	5,53	5,85	5,41	5,04	5,14	5,22	5,49	4,76	5,18	4,71	4,73	4,71

LEGENDE : Pour chaque station sont fournis, à titre d'exemple : les teneurs en vase (% de la fraction des particules du sédiment de diamètre < 63µ), en sable (particules de diamètre compris entre 1,1 mm et 63µ , en mercure, cuivre, D.T.T., polychlorobiphényls, en % de Carbone organique, somme des pourcentages et somme des dominances des espèces caractéristiques d'une biocoenose *quelconque*, somme des dominances des espèces à Large Répartition écologique dans les substrats meubles (L. R. E. de S. M.), somme des dominances des espèces présentes dans au moins les 3/4 des stations, indice de diversités de MARGALEFF et SHANNON.

Centre de recherche : Station Marine d'Endoume et Centre d'Océanographie
MARSEILLE
France

Chercheurs principaux : F. BLANC et M. LEVEAU

Période couverte par le rapport : avril 1977 - mai 1979

INTRODUCTION

Marseille est l'une des grandes villes du bassin occidental de la Méditerranée, avec plus d'un million d'habitants en 1977. C'est également un centre industriel d'importance. Son réseau d'assainissement a considérablement évolué au cours des dernières décennies (réseau séparatif, nombreux raccordements au réseau principal, etc.); la construction de la station d'épuration complétera ces améliorations. Cependant, aujourd'hui comme depuis près d'un siècle, les effluents domestiques et industriels de la ville et de ses environs sont rejetés à la mer après un simple dégrillage dans l'anse de Cortiou (massif de Marseilleveyre), Fig. 1.

A la pollution esthétique d'un site naturel d'une grande beauté, s'ajoute la destruction de l'équilibre des écosystèmes benthiques et pélagiques. Si les fonds marins ont été, depuis une vingtaine d'années, étudiés méthodiquement et régulièrement, ainsi que les conséquences néfastes exercées sur eux par le rejet, il n'en est pas de même pour le domaine pélagique. C'est pourquoi nous avons envisagé son étude suivant une voie pluridisciplinaire afin de cerner au mieux la nature du déversement et le devenir des effluents dans le milieu marin. L'équipe regroupait ainsi des spécialistes des sels minéraux, des produits polluants, des populations planctoniques et des microorganismes. L'impact du rejet sur le milieu était ainsi considéré sous un angle plus synthétique.

CONSIDERATIONS METHODOLOGIQUES

Zones étudiées :

Au cours de ce projet la zone néritique sud et du Golfe de Marseille a été systématiquement étudiée (Fig. 1 et 2).

Les communautés étudiées appartiennent à l'écosystème pélagique néritique.

Polluants : Le réseau d'assainissement actuel draine un bassin de 603 km^2 et déverse à Cortiou, par l'intermédiaire du grand émissaire :

- les eaux usées de l'agglomération marseillaise et de quelques communes environnantes (un million d'habitants en 1977);

- les rejets liquides des industries réparties sur ce bassin : cinq grosses usines (industries alimentaires et brasseries, huiles et solvants, produits antiparasitaires, traitement des déchets d'abattoirs) étaient il y a encore peu d'années, responsables de 90% de l'effluent industriel. Ces dernières années, les eaux usées de quelques-unes de ces usines sont épurées avant d'être rejetées dans le réseau principal ou dans l'Huveaune. Cependant, outre les établissements recensés par l'agence de bassin, on observe de nombreux rejets clandestins plus ou moins importants;

- le ruisseau des Aygalades, encore très pollué car recevant de nombreux rejets d'origine mal définie;
- les eaux de pluie recueillies dans la partie centrale de la ville équipée d'un réseau unitaire;
- enfin, jusqu'à cette année (1979), l'Huveaune était déviée tous les étés dans le Grand Collecteur (à l'exception de l'été 1978) de façon à limiter la pollution des plages de Marseille. Elle l'est maintenant définitivement depuis juin. Le débit de l'émissaire est donc augmenté de 1 à 2 m^3/s en débit d'étiage, le débit maximal acceptable étant de 30 m^3/s. La charge polluante de ce cours d'eau correspond à 80 000 équivalent en habitants, soit environ 10% du Grand Emissaire en débit moyen.

Au total, la charge polluante évacuée correspond à une population d'un million et demi d'habitants (rapport ville de Marseille, 1977). La quantité d'effluent varie considérablement durant la journée. Le débit moyen journalier est de 4,5 m^3/s, en heure de pointe il atteint 5,8 m^3/s.

MATERIELS ET METHODES

Trois stratégies d'échantillonnage ont été utilisées. La plus classique, qui consiste en un quadrillage a été utilisée lors des missions I (20/04/77, par vent de NW) et III (27/09/77, par vent d'E). La méthode de suivi de la masse d'eau par marquage à l'aide d'une drogue a été pratiquée pour la mission II (27/04/77 par temps calme). Enfin, la mission IV (17-17/05-78) a été effectuée en station fixe à 1000 m dans l'ouest-sud ouest de l'émissaire. Les opérations I, II et IV ont concerné les eaux de surface; l'opération III a porté également sur les eaux de subsurface et proches du fond (Fig. 2). De la phase initiale de l'investigation il en résulta des données sur les paramètres physiques et chimiques (salinité, température, turbidité, oxygène dissout, éléments nutritifs ($P-PO_4$, $N-NO_3$, $N-NO_2$, $N-NH_4$ sur les paramètres biologiques (l'importance en bactéries, en phytoplanctons, des indices de diversité, les chlorophylles a et la phaeophytine, les adénylates telles que ATP, ADP, et AMP, le carbone organique, le zooplancton) et sur les polluants (les aromatiques et les hydrocarbures du pétrole, les phénols, les détergents et métaux lourds tels que cadmium, zinc, cuivre et plomb).

Des méthodes statistiques standard furent utilisées pour définir la structure spécifique (les associations spatio-temporelles et les interactions avec les polluants) de la communauté planctonique.

RESULTATS

L'étude du milieu fluide, à peu près inexistante jusqu'en 1975, a été largement développée, ce qui est normal puisque tout ce qui est contenu dans l'effluent y transite, avec dilution, ou sédimentation sur le fond.

La liste des paramètres étudiés est très importante. Elle comporte, outre les paramètres physiques et chimiques classiques, le dosage d'un certain nombre de polluants et l'évaluation de paramètres biologiques; ces derniers ont été particulièrement considérés puisque, outre la chlorophylle a (qui avec certaines réserves, traduit l'importance de la biomasse phytoplanctonique) on a cherché à obtenir une approche des caractères majeurs des peuplements planctoniques en général, tant au plan physiologique (par l'étude de la charge énergétique) qu'au plan de la dynamique et du fonctionnement du système, en fonction du gradient de pollution. En ce qui concerne ce dernier point, on a pu mettre en évidence des structures-types (composition spécifique et indice de diversité) et des espèces caractéristiques des différentes situations créées dans le système planctonique par certains groupes d'altéragènes contenus dans l'effluent.

Paramètres physiques et chimiques :

Il convient de rappeler que le débit de l'émissaire, fonction du cycle des activités de la population de l'agglomération, présente des fluctuations de période approximative de 6 heures, avec des maxima vers 6h., 11h.30, 18h., et 23h.30, qui se répercutent avec 2 à 3 heures de retard (Fig. 3 et 4) dans le milieu marin. Ces fluctuations sont nettement perceptibles au vu des courbes de variation sur 24 heures de la salinité de surface, ainsi que des teneurs en urée et détergents, par exemple. La corrélation des fluctuations de débit avec les taux d'oxygène dissout est moins nette et les valeurs observées dans la couche de surface ne sont en général que de peu inférieures à la saturation. La turbidité est extrêmement élevée au voisinage immédiat du rejet, mais la dispersion y est extrêmement rapide également et dès que l'on atteint la "cuvette" de Cortiou, elle est fortement diminuée (disparition du disque de Secchi à 14 m). Certaines poussées particulièrement marquées du débit de l'émissaire peuvent conduire à la formation de "lentilles" plus ou moins étendues et épaisses d'eaux légères (mélange médiocre eau de mer-effluent) et qui peuvent dériver en conservant une certaine individualité par rapport à la masse d'eau marine jusqu'à une distance assez importante de l'émissaire, transportant ainsi plus ou moins loin tous les polluants contenus dans l'effluent ainsi que de nombreuses bactéries. Les teneurs en urée ne sont véritablement élevées (5 uatg l^{-1}) qu'au voisinage immédiat de l'émissaire, mais ne paraissent pas atteindre le seuil de toxicité; elles sont étroitement corrélées aux teneurs en seston (ensemble du matériel particulaire -vivant ou non- en suspension) et la dilution (attestée aussi par les mesures de salinité) paraît relativement rapide; les teneurs en nitrates (max. 25 uatg l^{-1} au voisinage immédiat de l'émissaire) décroissent également rapidement en direction du large. L'ammoniaque NH_4, très abondant dans l'effluent, sous forme adsorbée sur les particules de taille inférieure à 0,45 um, désorbe dès son arrivée en mer et l'on observe dans la zone d'épandage des teneurs - non toxiques - de l'ordre de 30 à 70 uatg l^{-1}. Par contre, la forme NH_3, très toxique au delà de 1 uatg l^{-1}, se rencontre à des teneurs dangereuses pour l'écosystème pélagique jusqu'au Bec de Sormiou par vent de NW et jusqu'au Plateau des Chèvres par temps calme ou régime d'Est. Les phosphates présentent un comportement analogue à celui de NH_4.

Polluants chimiques :

Le devenir en mer des polluants contenus dans l'effluent a fait l'objet de toute l'attention compatible avec les moyens analytiques disponibles.

En ce qui concerne les détergents anioniques qui apparaissent comme un excellent traceur de la pollution urbaine, il semble que la dispersion soit relativement rapide. Les teneurs relevées dans les eaux de surface sont en général inférieures à 1 ppm et, par conséquent, non létales. Par contre, les teneurs sublétales (parfois aussi faibles que 20 ppb) sont assez largement répandues et une action néfaste, notamment sur les larves planctoniques, n'est pas à exclure. Les phénols posent certainement un problème plus grave, car des teneurs de 100 et 200 ppb ont été relevées, parfois à des distances de quelques kilomètres de l'émissaire (notamment dans les "lentilles"). Or, des teneurs de l'ordre de quelques dizaines de ppb sont connues pour affecter la physiologie de nombreuses espèces. Il y a donc là un danger non négligeable, surtout pour l'écosystème planctonique. On peut dire des hydrocarbures ce qui vient de l'être pour les détergents et les phénols, à savoir que les doses sublétales (inférieures à 1 ppm) mises en évidence expérimentalement pour de nombreux organismes marins (surtout pour diverses algues et larves planctoniques) sont, en général, nettement dépassées dans la cuvette de Cortiou et parfois même au delà.

De l'étude des quatre métaux lourds (Zn, Cd, Cu, Pb) qui ont été dosés dans les eaux on ne peut guère tirer de conclusion quant-à une nocivité éventuelle. Si les teneurs relevées sont, en général, voisines des normes américaines ou supérieures à celles-ci, on ignore la proportion de ces métaux qui est chélatée, ainsi que les éventuels phénomènes de transfert avec accumulation graduelle au long de la chaîne alimentaire. Néanmoins, il faut souligner que certains de ces métaux (notamment Cd) existent à des doses non négligeables assez loin de l'émissaire.

Les bactéries :

La destinée des bactéries telluriques en mer, sujet d'âpres controverses scientifiques, a été étudiée avec une attention aussi grande que le permettait le caractère très onéreux que revêt une telle recherche lorsque l'on veut qu'elle apporte des résultats véritablement significatifs.

Dans l'ensemble de la zone comprise entre la côte et l'archipel de Riou, les teneurs en bactéries entériques, toujours très élevées (10^2 à 10^6 ml^{-1}) condamnent à priori toute utilisation du milieu marin à des fins récréatives et de pêche. Les bactéries telluriques sont présentes, principalement, dans la couche 0-10 m affectée par une certaine dessalure. A l'extérieur de cette zone, on ne trouve plus de coliformes fécaux. Néanmoins, les streptocoques fécaux, qui paraissent liés aux eaux de salinité diminuée, persistent dans les lentilles d'eau dérivantes, ce qui permet de les considérer comme de meilleurs indicateurs de contamination fécale que les coliformes. Au sein de ces lentilles, les bactéries proprement marines se développent activement. Il convient de rappeler également que les vibrions et les salmonelles résistent beaucoup mieux en mer que les germes habituellement utilisés comme germes-test. Ainsi apparaît-il qu'il faudrait peut-être, pour arriver à définir de façon fiable les aires de contamination fécale, étudier non des germes-test, mais la structure des communautés bactériennes, notamment sous l'angle de leur indice de diversité et des potentialités métaboliques, ainsi que, bien entendu des proportions des différents types de bactéries de contamination.

Phytoplancton :

De l'étude de la fraction végétale du sytème planctonique, on peut dégager quelques conclusions de valeur pratique. Tout d'abord, on ne peut apprécier l'impact de l'effluent sur le système par le simple dosage de la chlorophylle a ainsi que cela se pratique fréquemment. En effet, dans la zone la plus proche du rejet on trouve des teneurs particulièrement élevées en chlorophylle a, alors que les populations phytoplanctoniques sont excessivement pauvres. Tout permet de penser que cette anomalie apparente est due à l'abondance de débris végétaux dans l'effluent, débris au sein desquels la dégradation de la chlorophylle serait plus ou moins inhibée par la diminution d'éclairement due à la turbidité élevée. L'étude de la composition, de la structure et de la dynamique des populations phytoplanctoniques a été rendue délicate par les fluctuations naturelles liées aux séquences météorologiques. Alors qu'en Manche ou en Mer du Nord, par exemple, l'on observe une poussée printanière nette, dont le déclenchement est conditionné par la conjonction de divers facteurs (dont l'élévation de la température et de l'éclairement), en Méditerranée nord-occidentale, si l'on observe quand même une poussée printanière, le démarrage et l'intensité non pas d'une mais de plusieurs poussées végétales et leur densité dépendent largement de l'apparition et de la durée des diverses séquences météorologiques, et, ont, donc,un caractère aléatoire assez marqué. Néanmoins, il semble que l'on puisse tenir pour acquis les points suivants en ce qui concerne la zone de Cortiou :

a) dans l'ensemble, la densité des populations est faible;

b) on observe fréquemment dans la zone dite très polluée, la plus proche de l'émissaire, à turbidité très élevée, un peuplement à très faible densité comprenant uniquement des espèces indicatrices de pollution, mais il n'est pas démontré que ce peuplement soit permanent;

c) dans le secteur un peu plus éloigné de l'émissaire (parfois jusqu'à 5 km de celui-ci) dit zone polluée, ou l'effluent est plus dilué la composition spécifique du peuplement (à dominance de Diatomées opportunistes) est proche de celle du peuplement néritique normal, mais la densité est faible et l'étude de la charge énergétique montre que le peuplement est physiologiquement perturbé, vraisemblablement par des polluants chimiques;

d) les Cyanophycées sont parfois abondantes, surtout dans la zone très polluée;

e) au-delà, on retrouve le peuplement phytoplanctonique normal dans la zone néritique - relativement oligotrophe - du littoral provençal, bien que les teneurs en sels nutritifs témoignent d'une certaine eutrophisation;

f) il est possible que l'effet eutrophisant se manifeste plus au large encore, mais les opérations n'ont pas été conduites suffisamment loin du rivage pour que l'on puisse l'affirmer.

Zooplancton :

On a, en gros, trouvé la même zonation mise en évidence par le phytoplancton, mais un fait essentiel est à signaler. Alors que l'on ne constatait pas de développement particulièrement important du phytoplancton, le zooplancton et plus spécialement l'espèce Acartia clausi atteint des effectifs relativement élevés (3700 ind m^{-3}). Il convient aussi de noter que certaines espèces de l'hyponeuston comme les Pontellidés se sont révélées être des indicateurs très sensibles de la pollution.

Paramètres physiologiques globaux:

Adénylates 5' phosphates, charge énergétique et indice de diversité apparaissent comme de bons indicateurs de l'état de stress de l'écosystème pélagique. Ainsi, lors de la mission Cortiou II, le tracé de la charge énergétique et de l'indice de diversité (Fig. 5) au cours de la dérive de la masse d'eau marquée au débouché de l'égout, a permis de montrer une restructuration progressive des populations planctoniques au fur et à mesure de l'éloignement de l'égout en direction du golfe de Marseille. Alors que ces indices pris isolément en un point sont difficiles à interpréter, l'allure de leur évolution le long d'une direction spatio-temporelle privilégiée est pleine d'enseignements.

DISCUSSION DES RESULTATS ET CONCLUSIONS

L'étude d'impact d'émissaires urbains sur les écosystèmes pélagiques doit passer par l'étude d'un nombre important de paramètres physiques, chimiques et biologiques, ce qui nécessite une assez grosse équipe pluridisciplinaire. Malgré l'effort que nous avons fait dans cette voie, nous sommes conscients des lacunes qui existent dans notre travail, notamment au niveau de la courantologie (malgré les travaux existants de la SOGREAH). Cette lacune devra être comblée surtout si l'on veut arriver à la mise au point de modèles biologiques prédictifs. Dans l'approche de la structure et du fonctionnement des systèmes pélagiques soumis à une pollution urbaine, il convient de souligner la nécessité d'utiliser des paramètres globaux (CE,ID) qui permettent, lorsqu' ils sont convenablement échantillonnés, de décrire l'évolution du stress des populations et de cerner d'une manière relativement satisfaisante le moment où ces populations reviennent à un état "normal". D'autres paramètres de ce type doivent être mis au point notamment pour le zooplancton; notre équipe étudie en ce moment le problème pour ce qui concerne les adénylates et les proteinogrammes et enzymogrammes de certaines espèces zooplanctoniques.

Pour ce qui est de la stratégie d'échantillonnage, l'échantillonnage suivant des directions spatio-temporelles fonction des conditions météorologiques doit être couplé à l'étude d'une ou deux stations de référence en milieu propre et d'une station en milieu pollué au cours de l'année (à raison d'un échantillonnage par quinzaine) pour pouvoir recaler les différentes poussées planctoniques très fluctuantes au cours du temps dans nos régions méditerranéennes.

PUBLICATIONS

Groupe E.P.O.P.E.M., 1978. Système planctonique et pollution urbaine : présentation du site néritique de Cortiou, Calanque de Marseilleveyre. IV^{es} Journées Etud. Pollutions, pp. 365-369, Antalya, CIESM.

Groupe E.P.O.P.E.M., 1978. Système planctonique et pollution urbaine : populations phytoplanctoniques. IV^{es}. Journées Etud. Pollutions, pp. 371-375, Antalya, CIESM.

Groupe E.P.O.P.E.M., 1978. Système planctonique et pollution urbaine : populations zooplanctoniques. IV^{es} Journées Etud. Pollutions, pp. 377-379, Antalya, CIESM.

Groupe E.P.O.P.E.M., 1978. Bilan et impact des détergents anioniques sur un écosystème. IV^{es} Journées Etud. Pollutions, pp. 381-384, Antalya, CIESM.

Groupe E.P.O.P.E.M., 1978. Evolution des populations bactériennes autochtones et allochtones au débouché du grand collecteur de la ville de Marseille. IVes Journées Etud. Pollutions. pp. 385-390, Antalya, CIESM.

Groupe E.P.O.P.E.M., 1979. Système planctonique et pollution urbaine : présentation du site néritique de Cortiou, Callanque de Marseilleveyre. Téthys, 9 (1) : 23-30.

Groupe E.P.O.P.E.M., 1979. Etude de l'évolution des populations bactériennes d'origine tellurique, entérique et marine dans des systèmes planctoniques soumis à une pollution urbaine. Traitement mathématique des données. Can. Jour. of Microbiology, 25 (9) : 1073-1081.

Groupe E.P.O.P.E.M., 1979. Système planctonique et pollution urbaine : un aspect des populations zooplanctoniques. Oceanologica Acta, 2.

LEVEAU, M. et BLANC, F., 1979. Impact des arrivées d'eau douce en mer. Association française de Limnologie, Congrès national, 28-31 mai, Marseille.

BLANC, F. et LEVEAU, M., 1979. Impact des arrivées d'eaux douces sur les populations planctoniques néritiques. Association française de Limnologie, Congrès national, 28-31 mai, Marseille

BLANC, F. et CALMET, D., 1979. Le traitement mathématique des variables temporelles en écologie marine ou limnique. Association française de Limnologie, Congrès national, 28-31 mai, Marseille.

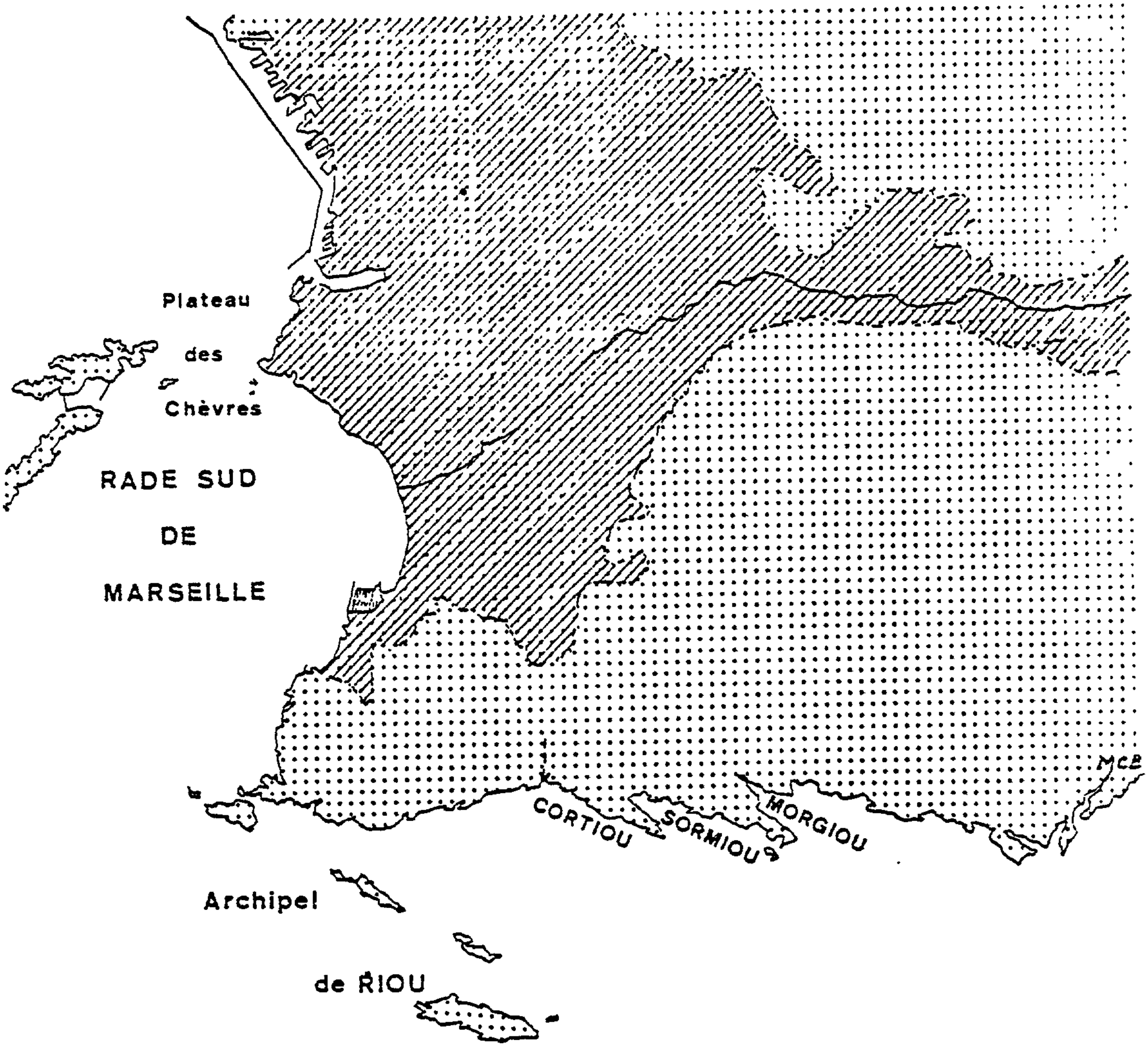


Fig. 1. Situation de la cuvette de Cortiou par rapport
à l'agglomération marseillaise

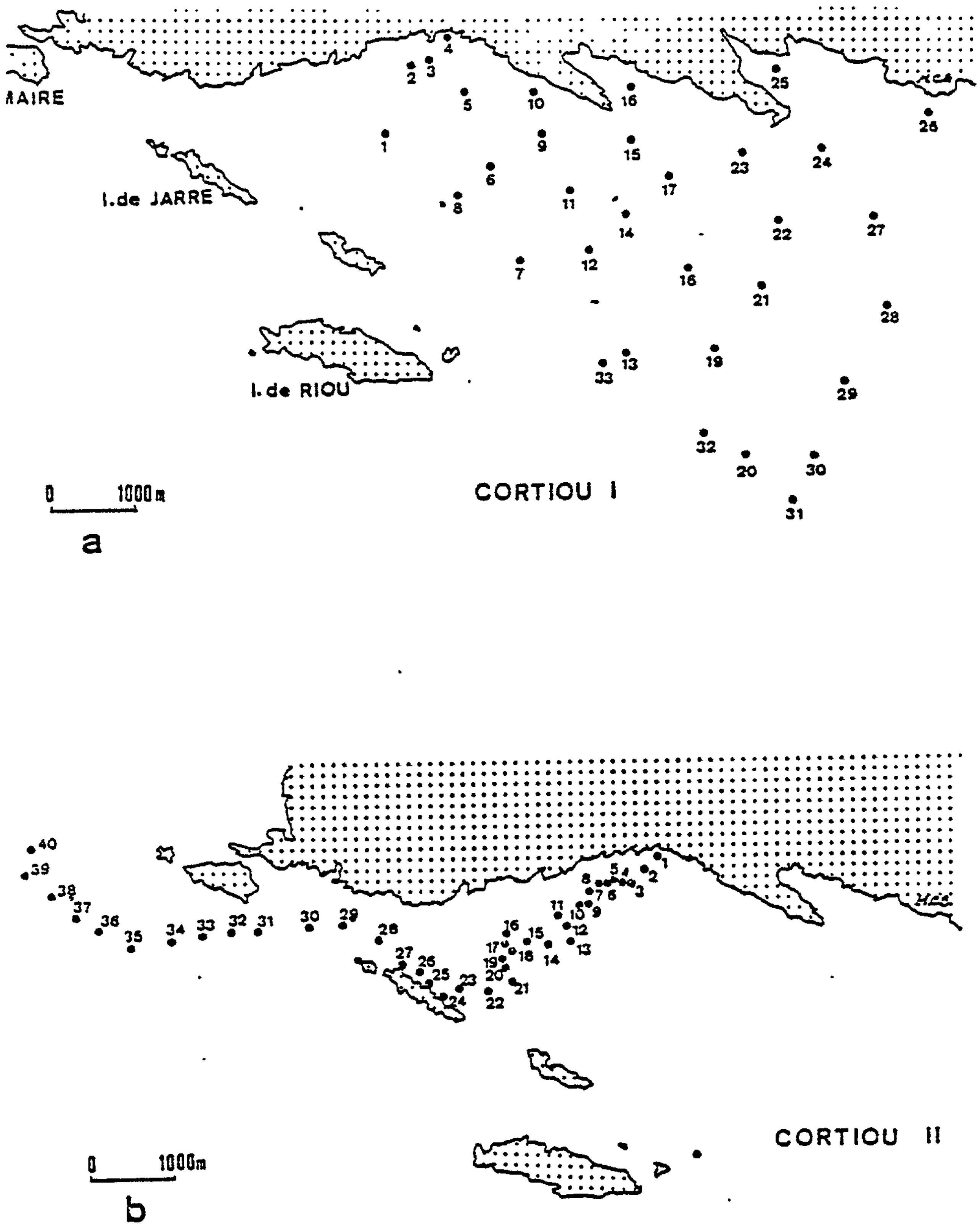


Fig. 2. a) Réseau de stations de prélèvement lors de la mission CORTIOU I
b) Dérive de la bouée et stations de prélèvement lors de la mission CORTIOU II

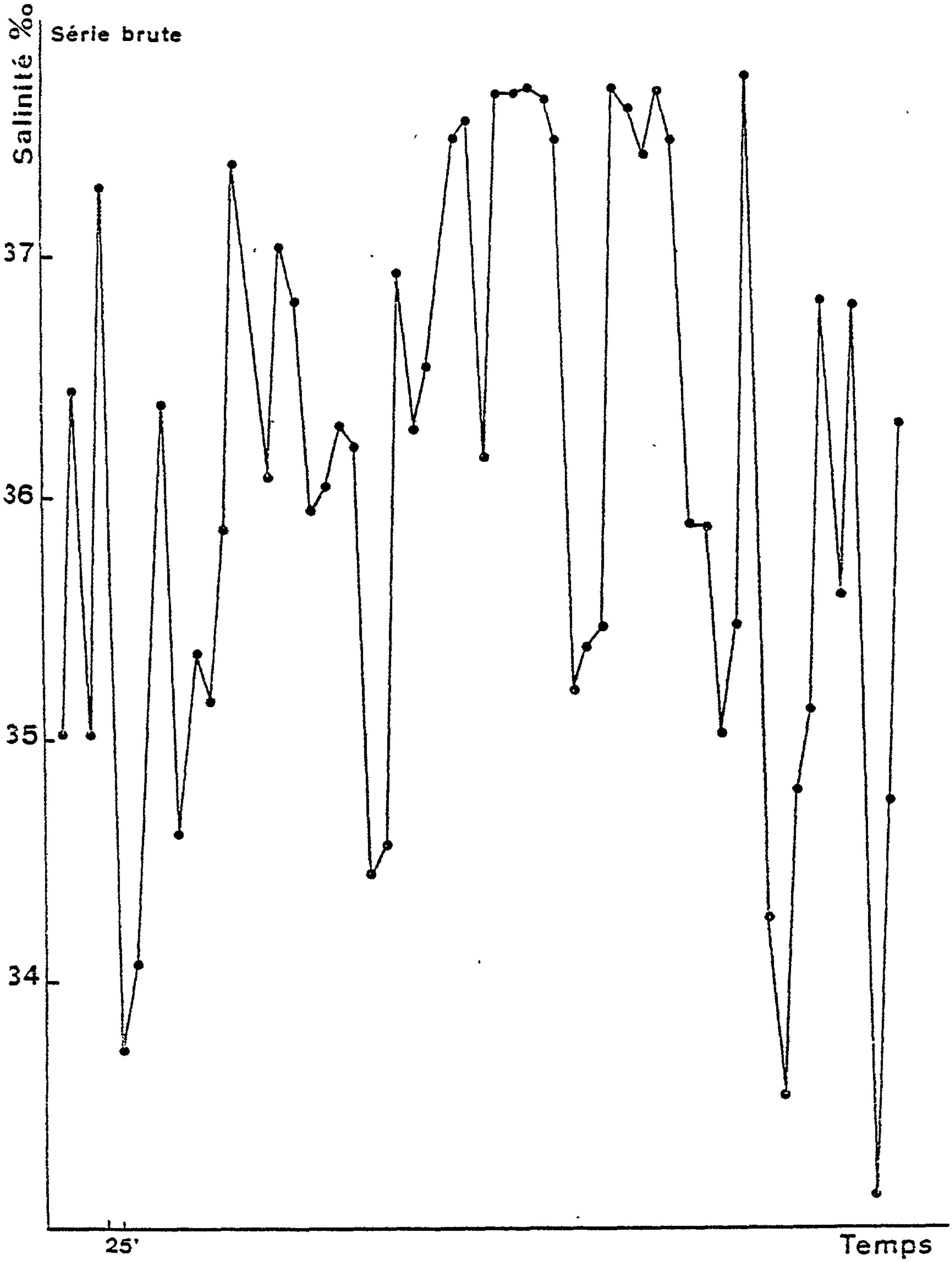


Fig. 3. Evolution de la salinité en fonction du temps (série brute)

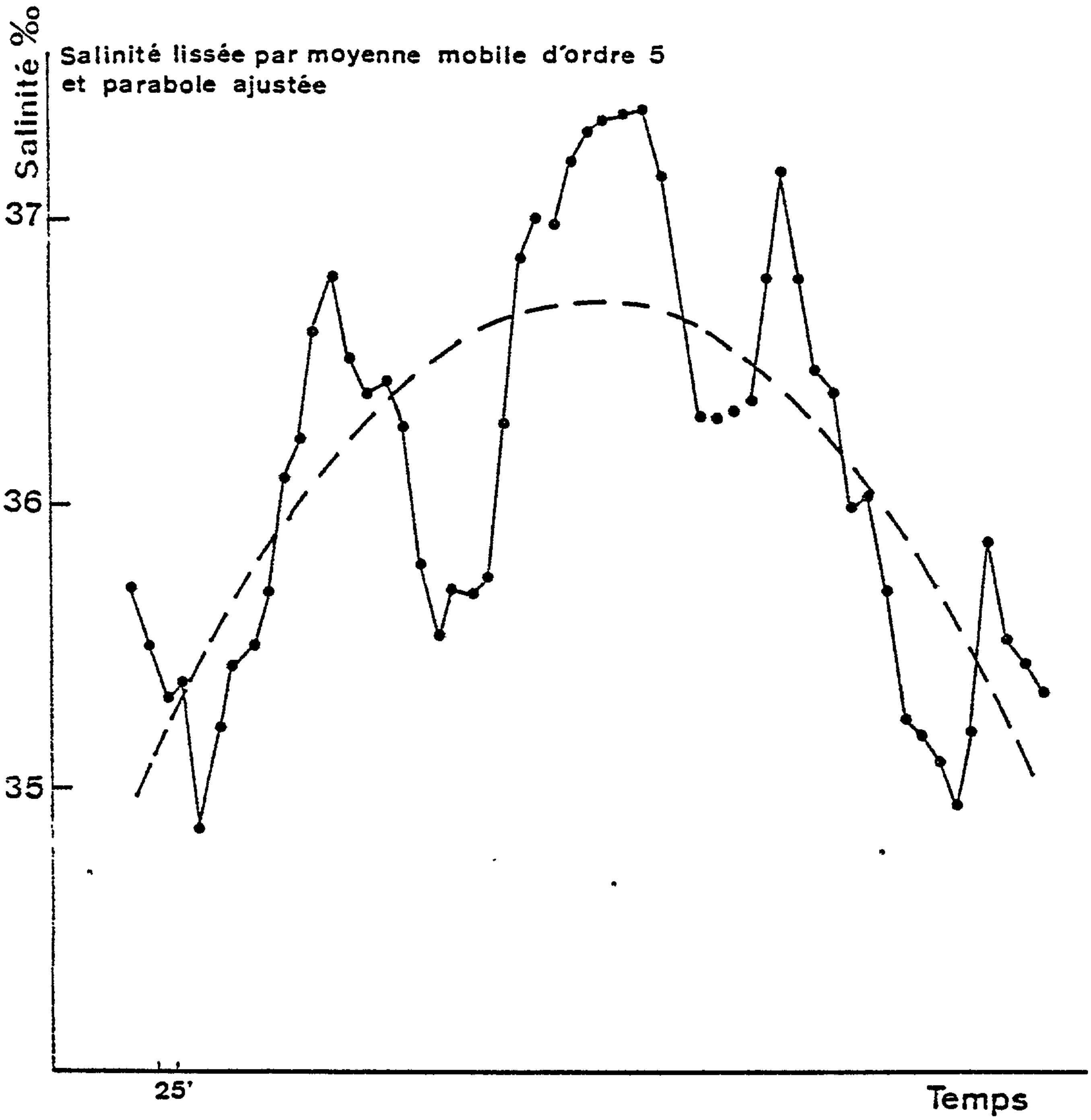


Fig. 4. Evolution de la salinité en fonction du temps
(lissée par moyenne mobile)

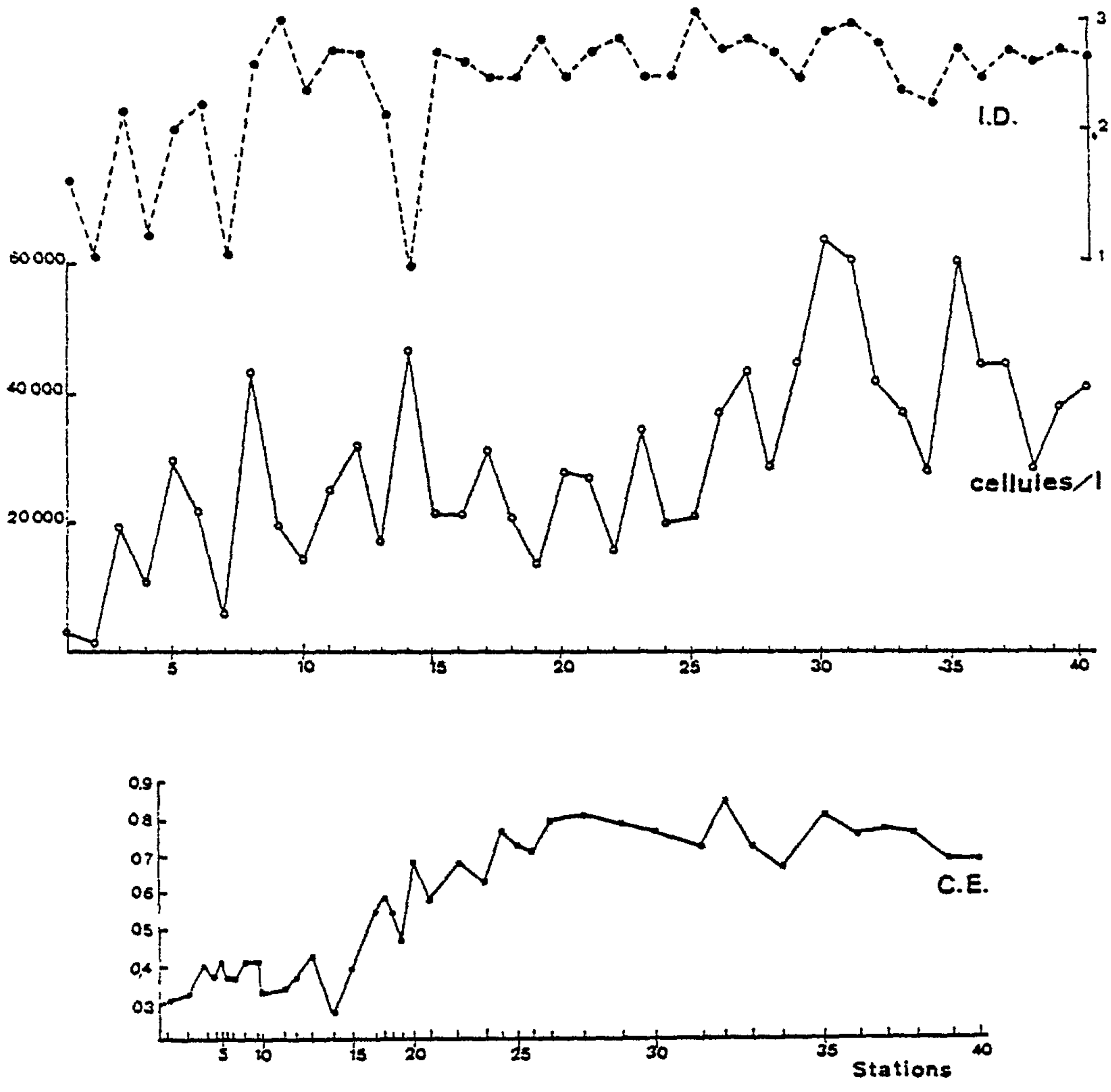


Fig. 5. Evolution de l'indice de diversité, de l'effectif total des populations phytoplanctoniques et de la charge énérgétique en fonction des stations de prélèvement (CORTIOU II)

Research Centre: Institute of Oceanographic and Fisheries Research
GR-16604 Hellinikon
Greece

Principal Investigator: C. BOGDANOS

Period of Reporting: April 1977 to March 1980

INTRODUCTION

The Institute of Oceanographic and Fisheries Research (I.O.F.R.) has conducted several oceanographic projects in the past in certain sea areas of Greece, i.e. Pagasitikos, Thermaikos gulfs. These gulfs were sampled for a year and a half, every three months; technical reports were submitted to the Ministry of Public Works for the final purpose of plans for constructing central sewage systems discharging into these gulfs. The Pagasitikos gulf study includes six samplings taken every three months from August 1975 to December 1976. This area is generally in good condition except the upper part of it where the city of Volos is located with a primitive sewage system. A new outfall is going to discharge the effluents of this city into a clean part of the gulf. We hope to be able to study this gulf again intensively, i.e. after the function of this new outfall, in order to assess the over-all impact of pollutants on healthy macrozoobenthic communities. On the other hand, taking into account the background information (already obtained from the six cruises), we will study the rate of change in benthic populations due to the progressing pollution impact throughout the future years.

The importance of these studies for fishery research and activities is quite obvious. The fisheries section of I.O.F.R. has been working for years on fish population dynamics (benthic and pelagic) of the Greek seas. Many trawlings have taken place in the Saronikos gulf, some of them in our area of investigation. Benthic fish usually prey upon certain polychaetes; in fish samples, from the clean section of our investigation area, stomach contents of the species Pagellus erythrinus and Mullus barbatus were mainly composed of undigested parts of Glycerids and Paralacydonia paradoxa (Ioakimidou, personal communication).

METHODOLOGICAL CONSIDERATIONS

Area:

A rather large part of Saronikos Bay was sampled, as shown in Fig. 1, in order to obtain information on benthic communities from both the sub-area in the vicinity of the existing sewage outfall and that of the possible new location for the future, centralized, waste waters disposal of Athens.

Communities:

Soft bottom communities of macrobenthos were investigated.

Pollutants:

The area is polluted by the untreated domestic effluents of the metropolitan district of Athens through a main sewer, discharging at the coast of Keratsini (near Piraeus port). A small but unknown amount of industrial effluents is discharged through the same sewer. The total amount of effluents is reaching the rate of 350,000-400,000 cubic metres per day (Zarkanellas and Bogdanos, 1977). The waters around Keratsini are also polluted thermally by means of the existing huge thermoelectric power plant in the coastal area. There is also a fertilizer factory at the entrance of the main port of Piraeus. Other pollutant sources are: the oil spillages caused by tankers anchored in, or passing through the straits between Salamis island and Attiki, plus shipyard and other activities along both banks of the straits. A considerable amount of industrial effluent enters the area of investigation through the straits from Elefsis Bay in the north.

Elefsis Bay is really suffocating from industrial effluents originating in 29 various industrial plants, located along the northern coast of Attiki; these industries include: shipyards, refineries, steel, electrochemicals, canneries, textiles, glass, cement, wine making, olive mills, powder works, resin factories, etc. Elefsis Bay is the most polluted area in Greece and its benthos (in the deeper parts) is devoid of life throughout the year. This is also attributed to the physical condition of water masses in this bay. Hopkins (1974) suggested that a strong stratification is formed during the summer preventing vertical mixing of the layers. The point is that a few decades ago Elefsis Bay benthos was very healthy as shown by remnants in the top sediment layers such as tellinids, turitellids and corals of the genus Cladocora (Zarkanellas and Bogdanos, 1977), the presence of a coral dominated population being an indication of a calm, transparent and well oxygenated overlying sea-water. Also Elefsis Bay was one of the best summer resort areas in Greece, especially before World War II.

METHODOLOGY

The stations, as shown in Fig. 1, were sampled by a 0.18 m^2 Van Veen grab, operated from various fishing vessels. Samples were sieved through a pair of sieves, 1.0 and 0.5 mm mesh, preserved in 5% formalin and stained by Rose Bengal in order to facilitate sorting procedure.

Undisturbed sediment samples were taken for successive granulometric and carbon content analyses. H_2S content was measured at sea in sediments (colorimetrically by Hach-kit-HS-7) and dissolved oxygen in sea-water (Winkler).

In the I.O.F.R. laboratory, benthic samples were sorted into major taxonomic groups, preserved in 75% ethanol, successively identified and species group abundances as well as biomass (D.W.) determined.

Biological parameters were then calculated, i.e. diversity, using Margalef-Gleason and Shannon-Weaver diversity indexes and affinity index using Sanders' method. The Shannon-Weaver index was chosen as the most suitable, being practically independent of sample size (Stirn 1975). Stirn also suggests that the communities most suitable for diversity studies seem to be those in homogeneous soft bottoms which are free from intertidal or estuarine influences.

Sanders' affinity index is the percentage value of affinity between all possible pairs of stations. We first estimated the percentage proportion of each species per station and then added the smaller of the two percentages for those species present in both stations. For example: if the sample of station A contains 15% of species a, 25% of species b, 60% of species c and the sample of station B, 24% species a, 0% of species b, 76% of species c, the affinity index between the stations A and B should be 15% + 60% = 75%. As we see, the common species between stations A and B are only two (a and c), for species a, the smaller value is 15% and for c, 60%, and by adding these we obtain Sanders' affinity index for this pair of stations.

RESULTS AND THEIR INTERPRETATION

According to values of diversity, affinity, presence of certain pollution indicators, values of physical, chemical and geological parameters in the bottom, sea-water and sediment and also according to the type of pollution, i.e. domestic, industrial etc., we determined the following biotopes:

- Biotope heavily polluted mainly from domestic effluents through the sewage outfall. Completely degradated community, polychaetes the only group present, the values of H' (Shannon-Weaver diversity index) are very low, representative station is D and the dominant organism is the worm *Capitella capitata* (huge number of individuals), followed by *Scolelepis fuliginosa*.

- Biotope heavily polluted mainly from industrial effluents (fertilizers). Seriously degradated community, the values of H' are low, representative station is A_1 and the dominant organism is the polychaete *Scolelepis fugilinosa* (very high number of individuals).

- Biotope polluted by various pollutants, mainly domestic and oil residues. Community is rather rich in species, number of individuals and overfed (well-grown) individuals, the values of H' are high, representative stations are B, C, E and the dominant organisms are the polychaetes *Hyalinoecia brementi*, *Glycera convoluta*, *Lumbrioconereis latreilli* and the bivalve *Corbula gibba*.

- Biotope unpolluted with rather fine (sandy silt to mud) sediment. Community normally intergraded, the values of H' are intermediate, representative stations are B_1, B_2, B_4, B_5, B_6, B_7, B_8, B_9, the dominant organisms are the polychaetes *Tharyx dorsobranchialis*, *Tauberia gracilis* and the bivalve *Thiasira flexuosa*.

- Biotope unpolluted with rather coarse (silty sand) sediment. Community normally intergraded, the values of H' are very high, representative station is A_2, the dominant organism being the polychaete *Paralacydonia paradoxa*. This distribution is also assessed from affinity index values schematically indicated in Fig. 2. The biotope a) corresponds to values 0.2-2.3 between D and the rest of the stations, except A_1 the one most resembling D (polluted). The biotope b) corresponds to values 7.7-28.8 between station A_1 and the rest of them; the rather high value of 28.8 corresponds to the also polluted D. The biotope c) corresponds to values 37.4-52.8 between the representative stations B, C, E. The biotope d) corresponds to values 39.4-81.7 between the representative stations B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, these values being concentrated in a well-defined triangle formed by the diagonal of the rectangular and vertical lines starting from the points between B and B_1 on the horizontal side, and the point between B_9 and C on the vertical side of the rectangular. The biotope e) corresponds to values 0.6-38 between station A_2 and the rest.

- Hydrogen sulphide, H_2S, testing in sediment showed: over 5 ppm in heavily polluted stations A_1, D; 2-5 ppm in polluted stations B, C, E, and less that 0.5 ppm in the rest of the stations in clean areas. Organic carbon content was very high at station D (about 5%), very low at station A_1 (about 0.5%) and at the rest of the stations it ranged from 0.5 to 1.5%. Grain size analyses revealed that: station D is characterized by sandy silt covered by a thick sludge layer from organic precipitated matter; stations B, C, E by coarse sandy silt mixed with a lot of petroleum residues; stations B_1, B_2, B_3, by fine sandy silt; stations B_4, B_5, B_6, B_7, B_8, B_9, by mud, and finally, station A_2 by silty sand. These findings seem to agree with those of Schwartz-Tziavos (1975) "Sedimentary provinces of the Saronikos gulf system".

The effects of pollutants and especially those caused by domestic effluents on benthos have already been studied by many scientists in the world, e.g. Henrikson (1969), Blegvad (1932), Bellan et Bellan-Santini (1972), Gognetti (1975), Tulkki (1968) and many others. Most of these workers have suggested distinct zones of bottom areas at increasing distances from the polluting source (by means of pollution degree).

Diversity, abundance, biomass and species composition (pollution indicators) are the main descriptive characteristics of benthic assemblages and the measure of response to pollution impact.

Typical pollution indicators, i.e. _Capitella capitata_, _Scolelepis fuliginosa_, characterize our polluted stations and a gradual recovery in benthic degraded communities takes place with increasing distance from the sewage outfall. Two different clean biotopes are encountered based, mainly on grain size of the sediment differentiation.

Coarse sediment at station A_2 indicates considerable movement of bottom water (Sanders 1958) that may result in well-oxygenated bottom water masses and more diversified microhabitats.

ACKNOWLEDGEMENTS

The author is expressing his thanks to the following personnel for their various contributions which made possible this publication.

a. To Miss A. Niotaki, technician of our laboratory for sorting, typing and drawing.

b. To Mr. G. Souras, Captain of the Institute for his valuable help on board during field work.

c. To Mr. E. Hatzigeorgiou, technician of Chemical Laboratory of I.O.F.R., for help during field work and also for dissolved oxygen - organic carbon determinations.

d. To Mrs. M. Phillipidou and Mr. A. Diapoulis, Marine biologists of I.O.F.R. for their help during field work.

REFERENCES

BELAN, G. et BELAN-SANTINI, D. (1972). Influence de la pollution sur les peuplements marins de la region de Marseille, in M. Ruive (Ed.). Marine pollution and sea life, p.p. 396-401, Fishing news (Books) Ltd., London 369-401.

BLEGVAD, H. (1932). Investigations of the bottom fauna at outfalls of drains in the Sound, Rep. Danish Biol. Sta 32, 1.

COGNETTI, G. (1972). Distribution of Polychaeta in polluted waters, Rev. Intern. Ocean. Medic, 25 pp. 23-33.

HENRIKSON, R. (1969). Influence of pollution on the fauna of the Sound (Oresund), Oikos 20 pp. 507-523.

HOPKINS, T.S. (1974). A discussion of marine pollution problems in the Saronikos gulf as disclosed by current research S.S.P. Tech. Rep. 3 I.O.K.A.E., 37 pp.

MARGALEF, R. (1968). Perspectives in ecological theory, Univ. Chicago Press, Chicago.

SANDERS, L.H. (1958). Benthic study in Buzzards bay 1. Animal sediment relationships Limn. and Ocean. III (3) pp. 245-258.

SCHWARZ, L.M., TZIAVOS, C. (1975). Sedimentary provinces of the Saronic gulf system, Nature Vol. 257, pp 573-575.

STIRN, J. (1972). Ecological consequences of marine pollution. Rev. Intern. Oceanogr. Medic. Vol. 24. pp. 13-46.

STIRN, J. et al. (1975). Selected biological methods for assessment of marine pollution, Proc. 2nd Int. con. San Remo 17-21 Dec. 73. Pergamon Press, pp. 307-327.

TENORE, R.K. (1972). Macrobenthos of the Pamlico river estuary North Carolina, Ecol. monogr, 42(1) pp. 41-69.

TURKKI, P. (1968). Effect of pollution on the benthos off Gothenburg, Helgoländer wiss, Meeresunters, Vol. 17. pp. 209-215.

ZARKANELLAS, A., BOGDANOS, C. (1977). Benthic studies of a polluted area in the upper Saronicos gulf, Thalassographica, Vol. 1. No. 2. pp. 155-177.

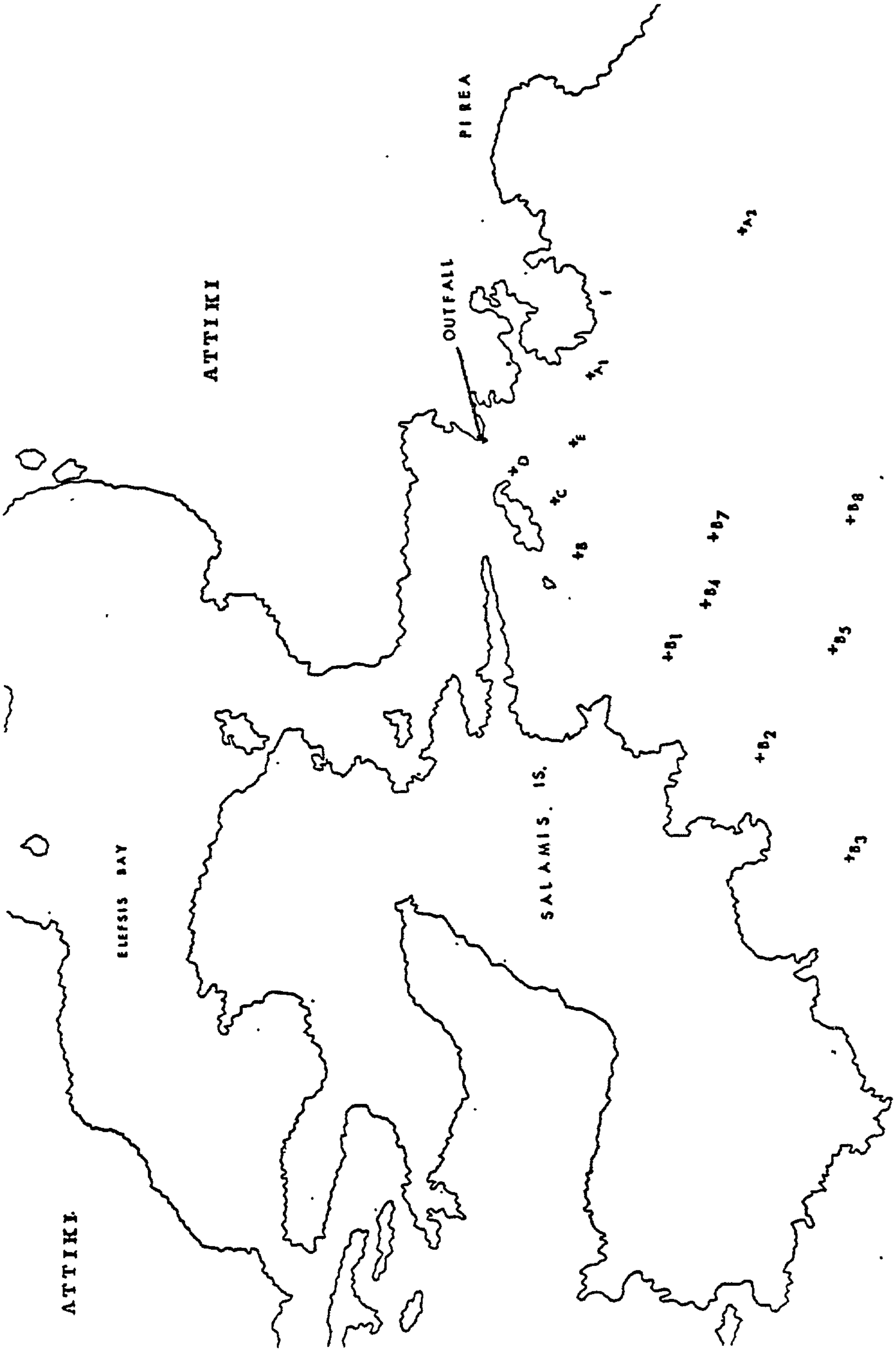
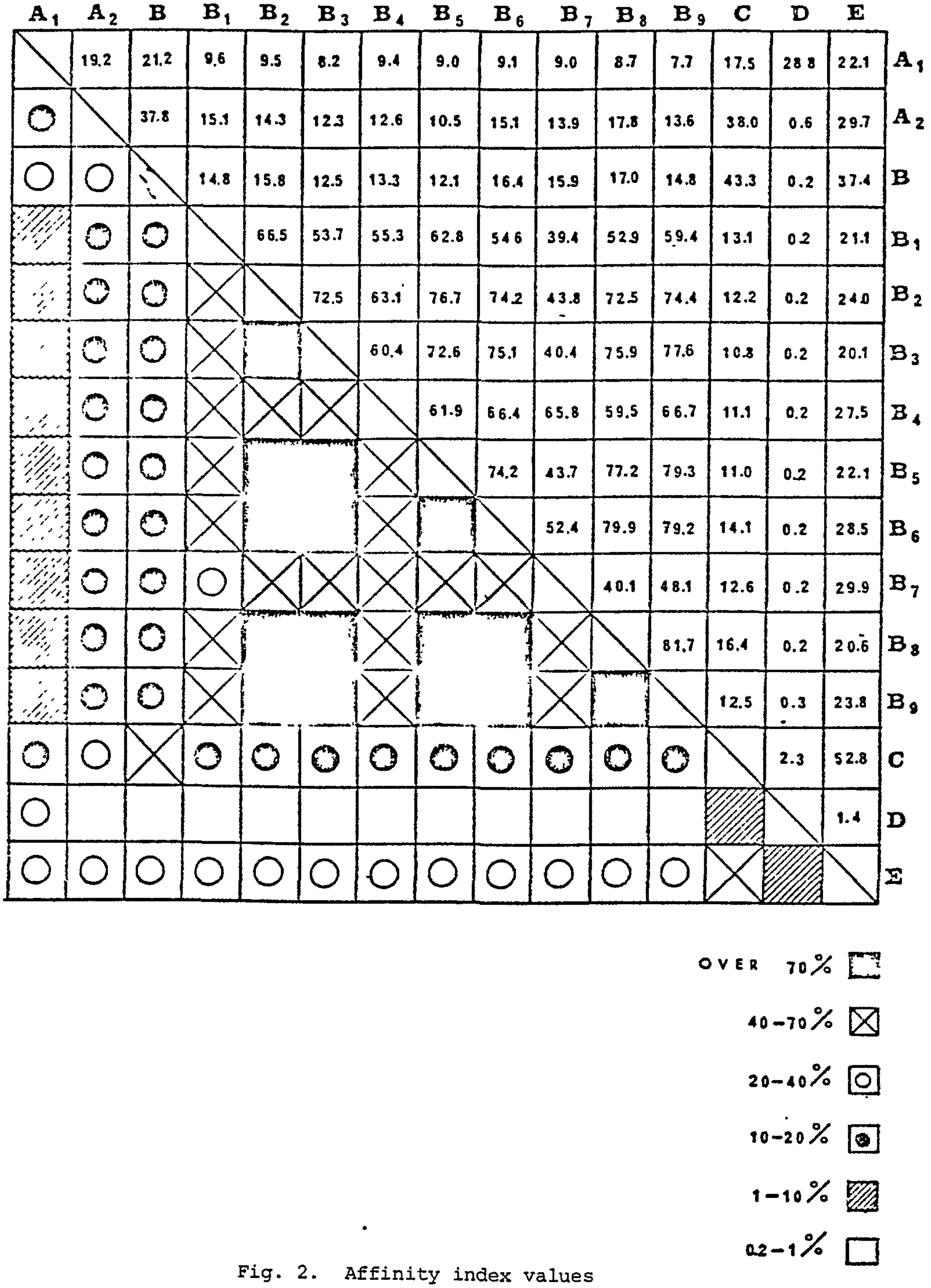


Fig. 1. Sampling stations

CRUISE NOV. 78

TRELLIS DIAGRAM AFFINITY INDEX (after SANDERS)



	A_1	A_2	B	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	C	D	E
A_1		19.2	21.2	9.6	9.5	8.2	9.4	9.0	9.1	9.0	8.7	7.7	17.5	28.8	22.1
A_2			37.8	15.1	14.3	12.3	12.6	10.5	15.1	13.9	17.8	13.6	38.0	0.6	29.7
B				14.8	15.8	12.5	13.3	12.1	16.4	15.9	17.0	14.8	43.3	0.2	37.4
B_1					66.5	53.7	55.3	62.8	54.6	39.4	52.9	59.4	13.1	0.2	21.1
B_2						72.5	63.1	76.7	74.2	43.8	72.5	74.4	12.2	0.2	24.0
B_3							60.4	72.6	75.1	40.4	75.9	77.6	10.8	0.2	20.1
B_4								61.9	66.4	65.8	59.5	66.7	11.1	0.2	27.5
B_5									74.2	43.7	77.2	79.3	11.0	0.2	22.1
B_6										52.4	79.9	79.2	14.1	0.2	28.5
B_7											40.1	48.1	12.6	0.2	29.9
B_8												81.7	16.4	0.2	20.6
B_9													12.5	0.3	23.8
C														2.3	52.8
D															1.4
E															

Fig. 2. Affinity index values

Research Centre: Laboratory of Zoology
Faculty of Sciences
University of Thessaloniki
THESSALONIKI
Greece

Principal Investigator: M.E. KATTOULAS

Period of Reporting: November 1978 to March 1980

INTRODUCTION

The Laboratory was not previously involved in research activities relevant to MED POL, and these investigations started after signature of the agreement. It is believed that the results of this research will prove highly useful to the fisheries of the regions investigated. It will also contribute to the estimation of the degree and extent of pollution, and it will assist in determining better the proper measures to be taken for the restriction of pollution.

METHODOLOGICAL CONSIDERATIONS

Areas:

The Gulfs of Thermaikos, Strymonikos and Kavala were investigated. The general topography, pollution sources and distribution of sampling transects and positions of the stations are shown in Figs. 1-3, 5 and 8. The topography of recent sediments is presented in Figs. 4, 6 and 7.

Communities:

Fine sand community with Mactra substruncata: Located in all three gulfs under examination at depths between 3 m and 25 m. The sediment was usually sand, well calibrated with a median particle diameter of 110 um to 270 um. Although a large number of species has not yet been identified, it is obvious that the dominant species are: Mactra subtruncata, Ophiura texturata, Aliodis gibba, Diogenes pugilator and Venus galina. Some other species in relatively great abundance are the following: Cyclonassa sp., Natica sp., Nephthys hombergii, Anapagurus sp., Ophiura albida, Molgula sp., Mactra stultorum, Nassa incrassata and Notamastus latericeus.

Community of coarse sands and fine pebbles with Brachiostoma lanceolatum: Located in the Thermaikos and Strymonikos Gulfs at depths between 2 and 12 m. The sediment in this community is made of particles with a median diameter of 400 μm to 2,450 μm. Of the species identified up to now, the following seem to be dominant: Venus ovata, Ebalia deshayesi, Aspidosiphon mulleri, Ophiura texturata and Brachiostoma lanceolatum. Other species with a relatively great abundance are: Upogebia tipica, Cardium papillosum, Parthenope massena, Diogenes pugilator, Dosinia exoleta, Pitar rudis, Ophiorthrix fragili and Spatangus purpureus.

Community of silty bottoms with Amphiura filiformis: Located in all the three gulfs under examination, at depths between 25 m and 95 m. The silty substrate had a median particle diameter smaller than 90 um. Of the species identified up to now, the dominant ones seem to be the following: Sternaspis scutata, Amphiura chiajei, Labidoplax digitata, Amphiura filiformis, Lumbrinereis impatiens, Anapagurus laevis and Notamastus latericeus. Other species in relatively great abundance are: Nephthys hombergii, Trachythyone elongata, Trachythyone tergestina, Turritella communis, Macropipus pusillus, Pagurus cuanensis, Processa caniculata, Goneplax rhomboides, Ebalia granulosa, Aspidosiphon mulleri and Glycera vouxii.

Pollutants:

There are three major categories of pollutants: domestic sewage, industrial effluents and river discharges.

In the Gulf of Thessaloniki, effluents flow from a great number of industries (e.g. refineries) and artisanal factories (e.g. tanneries) that are situated on the west side of the city of Thessaloniki; such effluents being discharged into the northern end of the gulf. Domestic sewage is mainly discharged into the northern part of the gulf, with a smaller portion discharged into the eastern part. The river discharge flows into the gulf by the system of the river Axios-Loudias-Aliakmonas. In Strymonikos Gulf there is only the discharge of Strymonas river, flowing into the northern side of the gulf.

In the Gulf of Kavala there are industrial effluents originating from an artificial fertilizer industry, situated on the north coast of the gulf. In addition, domestic sewage from the city of Kavala is discharged in the harbour in front of the city.

METHODOLOGY

In all three gulfs, qualitative sampling was made once by a Charcot dredge in order to locate the existing communities. These sampling sites are indicated on the maps attached as numbers in circles. Transects were also laid out: 5 in the Gulf of Thessaloniki, 2 in the Strymonikos Gulf and 2 in the Gulf of Kavala, and at certain points double quantitative samples by a Van Veen sampler were taken in autumn, winter, spring and summer from 1976 to 1979. For the sorting of the fauna, a sieve of 500 um mesh size, was used. The fauna was preserved in a 10% formol solution. During the sampling, a number of *in situ* measurements were taken regarding the following physical and chemical parameters:

- depth;
- temperature (of sediment and water);
- salinity (of surface and bottom water layers);
- oxygen content (of surface and bottom water layers);
- water conductivity;
- pH of water;
- H_2S content in water.

The following measures were made on water and sediment samples in the laboratory:

- organic carbon in water and sediments;
- oil content in water;
- H_2S in sediments;
- HCO_3 content in sediments;
- SO_4 content in water and sediments;
- SO_3 content in water and sediments;
- chlorinity of water.

DISCUSSION OF RESULTS

Since, at present, benthic sample results are not yet fully worked out, only the following preliminary results can be reported.

Gulf of Thessaloniki:

Sediment analysis has been made for all the sediment samples and the sedimentological map was constructed as shown in Fig. 4.

A first estimation of the benthic fauna of the gulf revealed, in our opinion, the division of the gulf into four regions, with different degrees of pollution. These regions are given in Fig. 5. The first region is the one marked in black, situated in the northern part of the gulf, around the central outfall of the industrial effluents. In this area, which was characterized as "azoic", the macro and meiofauna, at least, are completely absent. The values of the annual fluctuations of some of the parameters measured are the following: sediment temperature from 10°C to 27°C; oxygen content of the water from 3 ppm to 5 ppm; pH from 7.1 to 9.6; S from 36.5 to 38.8; organic carbon of the water, near the bottom, from 30 mgC/l to 73 mgC/l.

The second area is the one marked by the crossed lines. In this area, which can be characterized as "polluted", the presence of a very restricted number of species that belong almost exclusively to polychaetes, was observed. Dominant species with very high densities were, in order of density, the following: Notomastus latericeus, Capitella capitata and Audouinia tentaculata. The annual fluctuation of some of the measured parameters gave the following values: sediment temperature from 10°C to 25°C; oxygen content of the water from 2.5 ppm to 7.2 ppm; pH from 7.4 to 8.3; S from 33.8 to 27.6; organic carbon of the water, near the bottom, from 65.1 mgC/l to 90.58C/l.

The third area is the one marked by horizontal lines. In this region characterized as "subnormal", the communities examined seem to have been subjected to a disturbance to a greater or lesser degree. The dominant taxon are the polychaetes; second, but with remarkable differences, the molluscs.

The fourth area is the remaining part of the gulf, in which the fauna does not seem to have been affected by pollution. The composition of communities shows fluctuations within apparently normal limits.

Strymonikos Gulf:

From the sediment analysis that was made for all the sediment samples from this gulf, a map was drawn (Fig. 6) where their distribution can be seen. In the area of the gulf no disturbance has been observed on the composition of the communities in relation to any pollution effect. There was no remarkable deviation in the values of the physicochemical parameters.

Gulf of Kavala:

The sediment distribution in this gulf is given in Fig. 7. The pollution seems to have influenced three regions. There is an "azoic" area, a "polluted" area and a larger "subnormal" area (shown in Fig. 8). The communities of the remaining part of the gulf seem to be unaffected. In the azoic area, which is situated near an artificial fertilizers industry, the annual fluctuation of the parameters measured has the following values: sediment temperature from 11°C to 26°C; oxygen content of the water from 3.2 ppm to 7 ppm; pH from 6.9 to 8.8; S from 37.2 to 39.1; organic carbon of the water, near the bottom, from 7.1 mgC/l to 27.18 mgC/l.

In the polluted area, which includes the harbour region, the faunal diversity is more restricted. There is a small number of polychaete species, with the following order of dominance: *Lumbrinereis impatiens*, *Paraonis gracilis*, *Notomastus latericeus*, *Capitella capitata* and *Prionospio malmgreni*. The annual fluctuation of the parameters in this region gave the following values: sediment temperature from 12°C to 26.5°C; oxygen content of the water from 3.6 ppm to 6.2 ppm; pH from 7.1 to 8.6; S from 32.6 to 38.1; organic carbon of the water, near the bottom, from 25.3 mgC/l to 50.1 mgC/l.

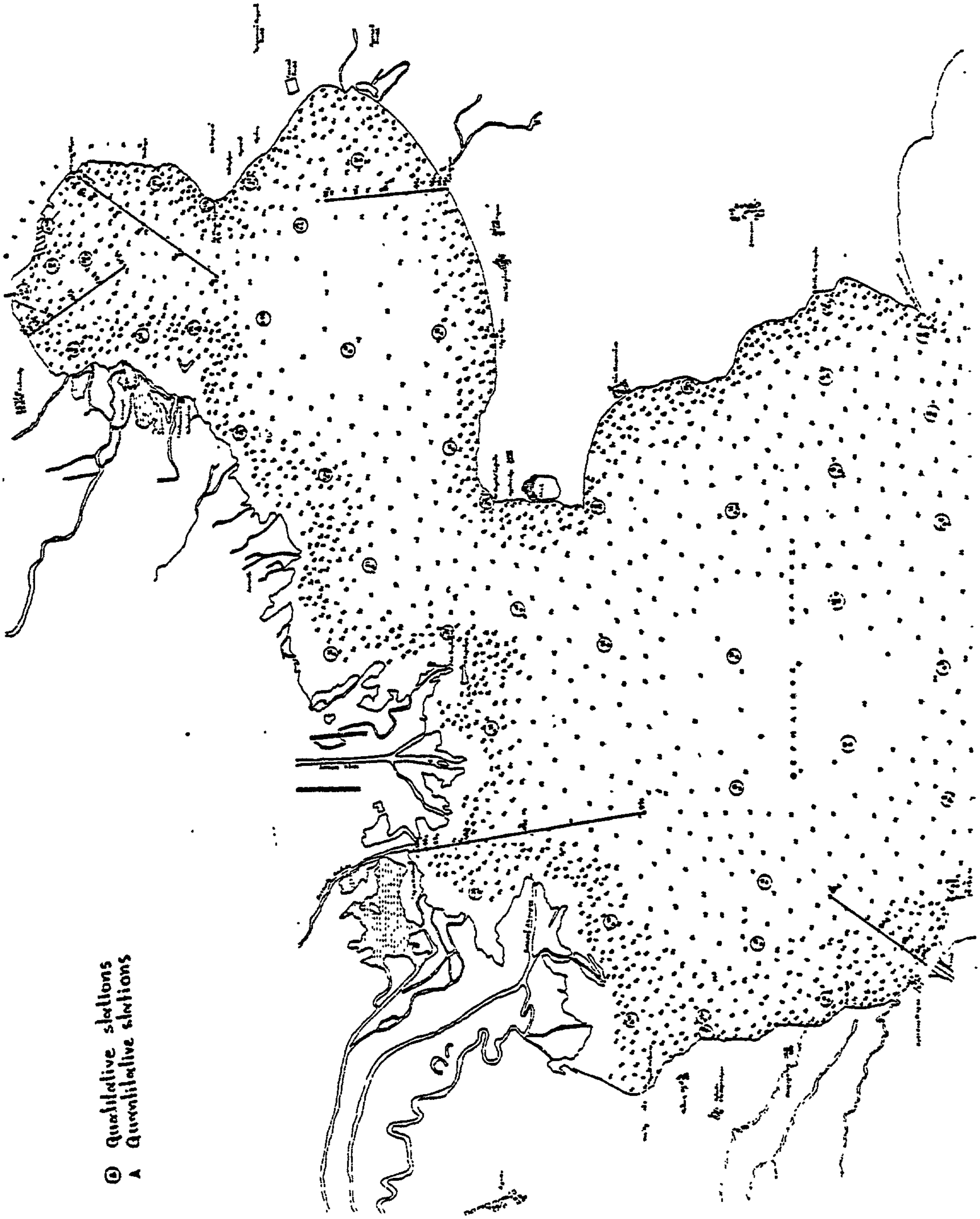


Fig. 1. Thermaikos gulf (gulf of Thessaloniki)

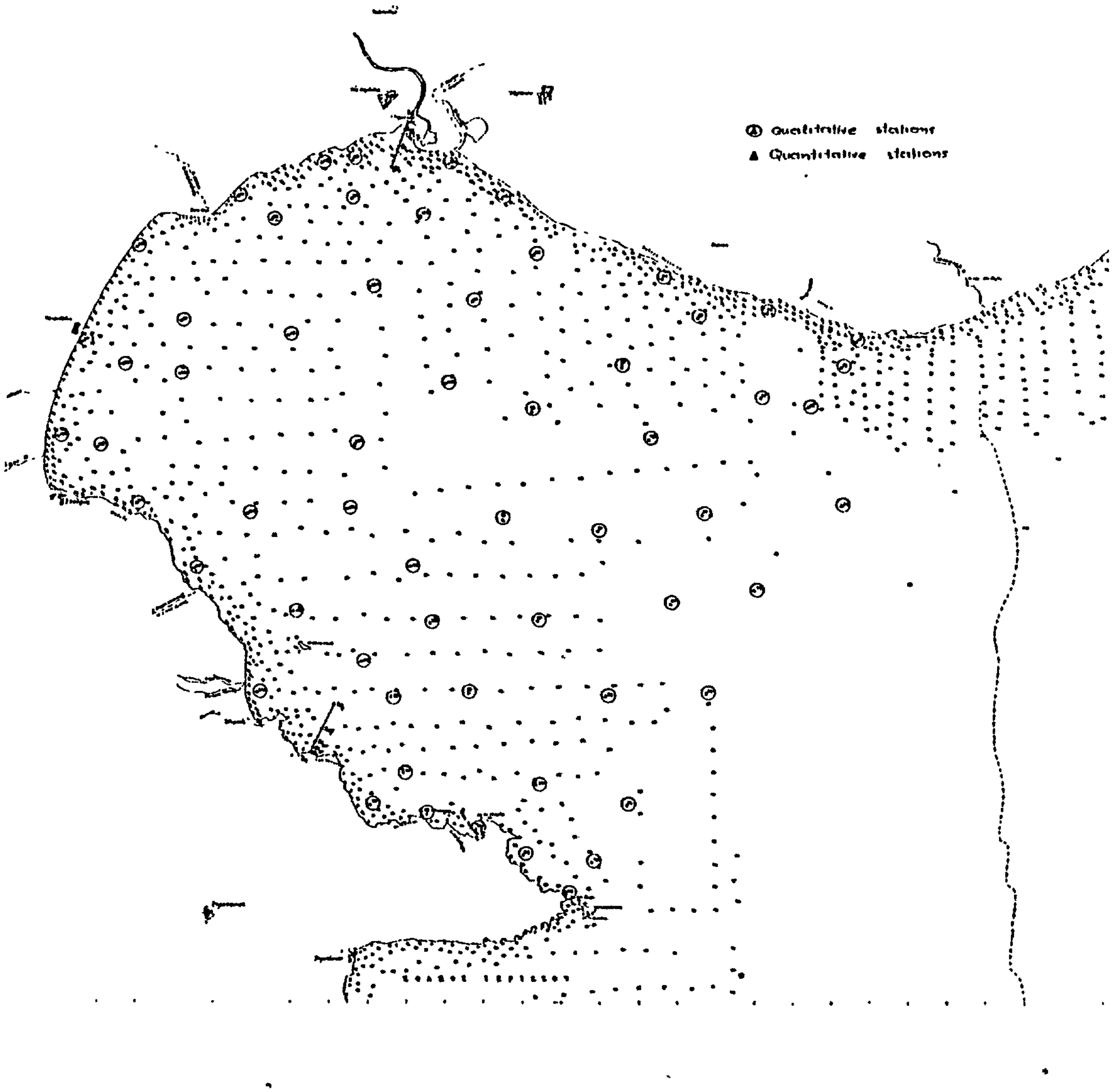


Fig. 2. Strymonikos gulf

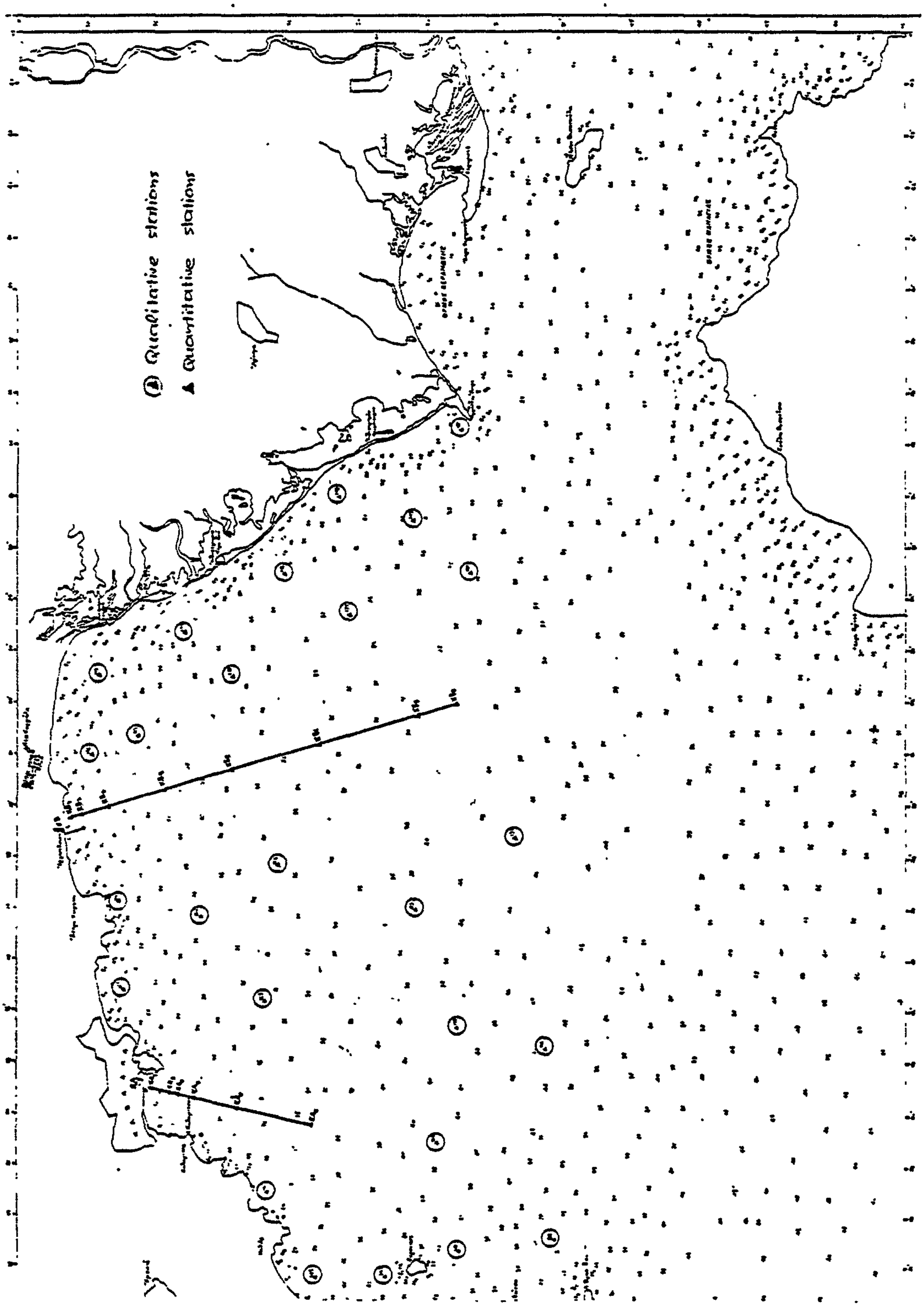


Fig. 3. Gulf of Kavála

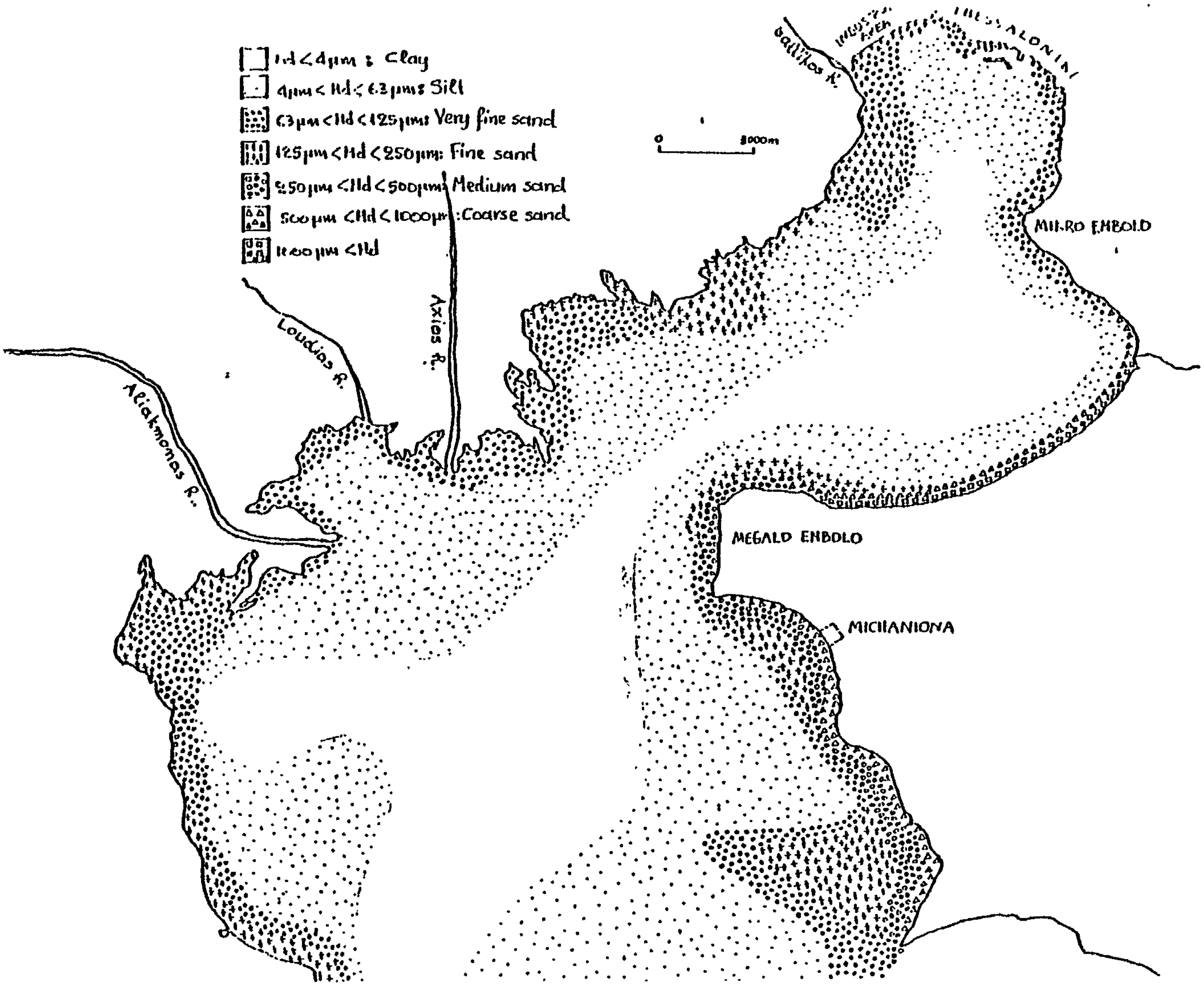


Fig. 4. Thermaikos gulf. Sediment distribution

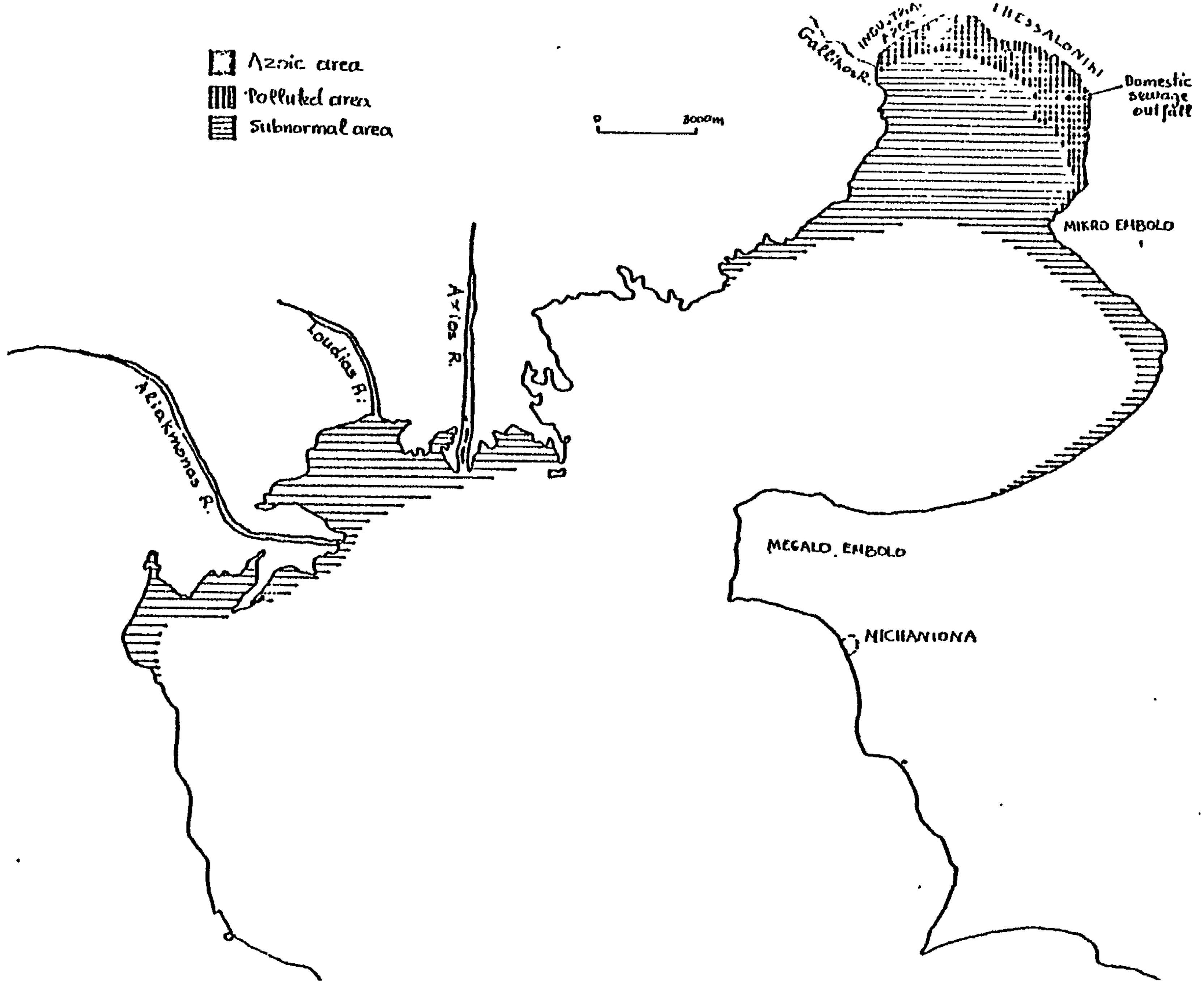


Fig. 5. Thermaikos gulf. Areas of pollution

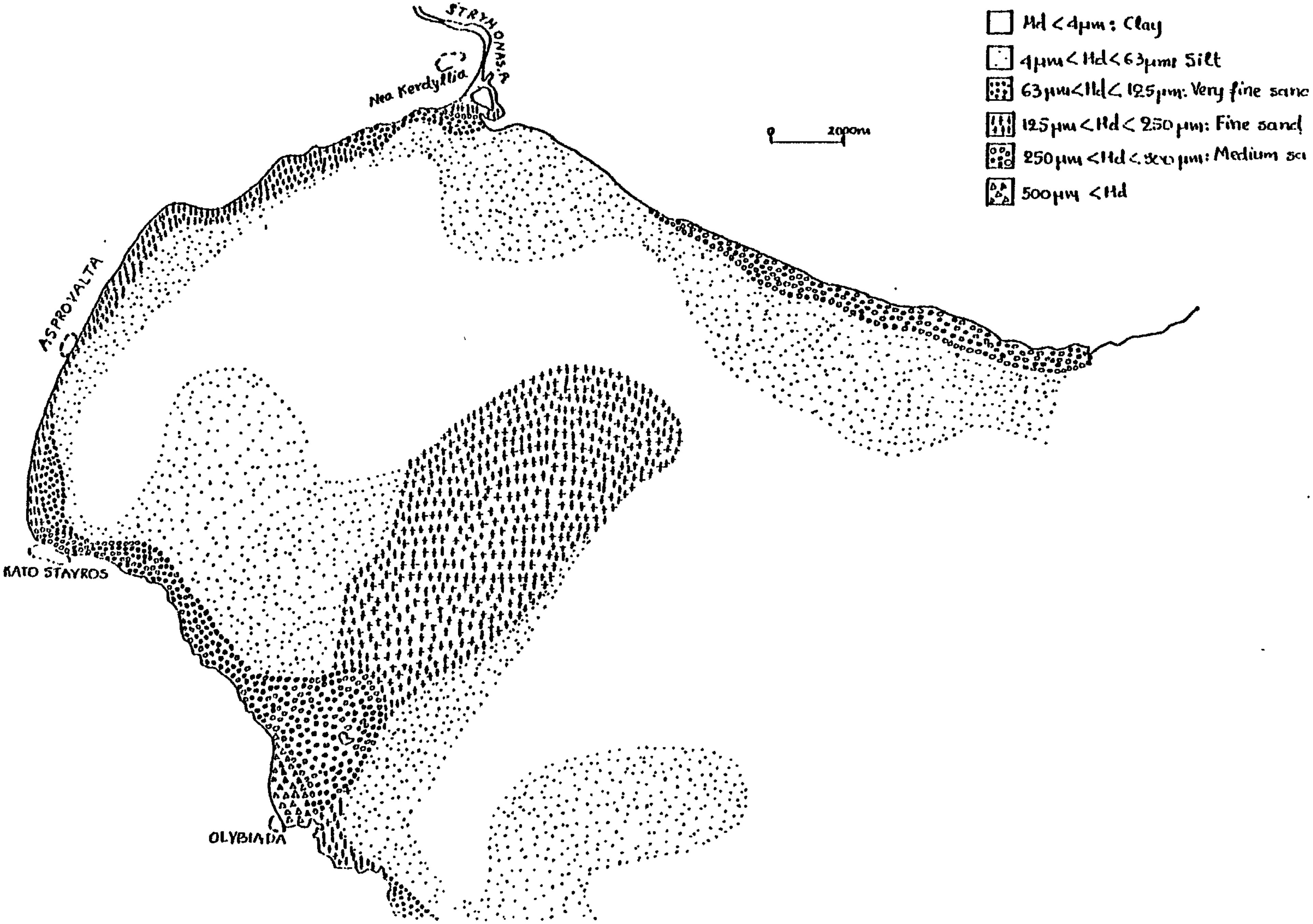


Fig. 6. Strymonikos gulf. Sediment distribution

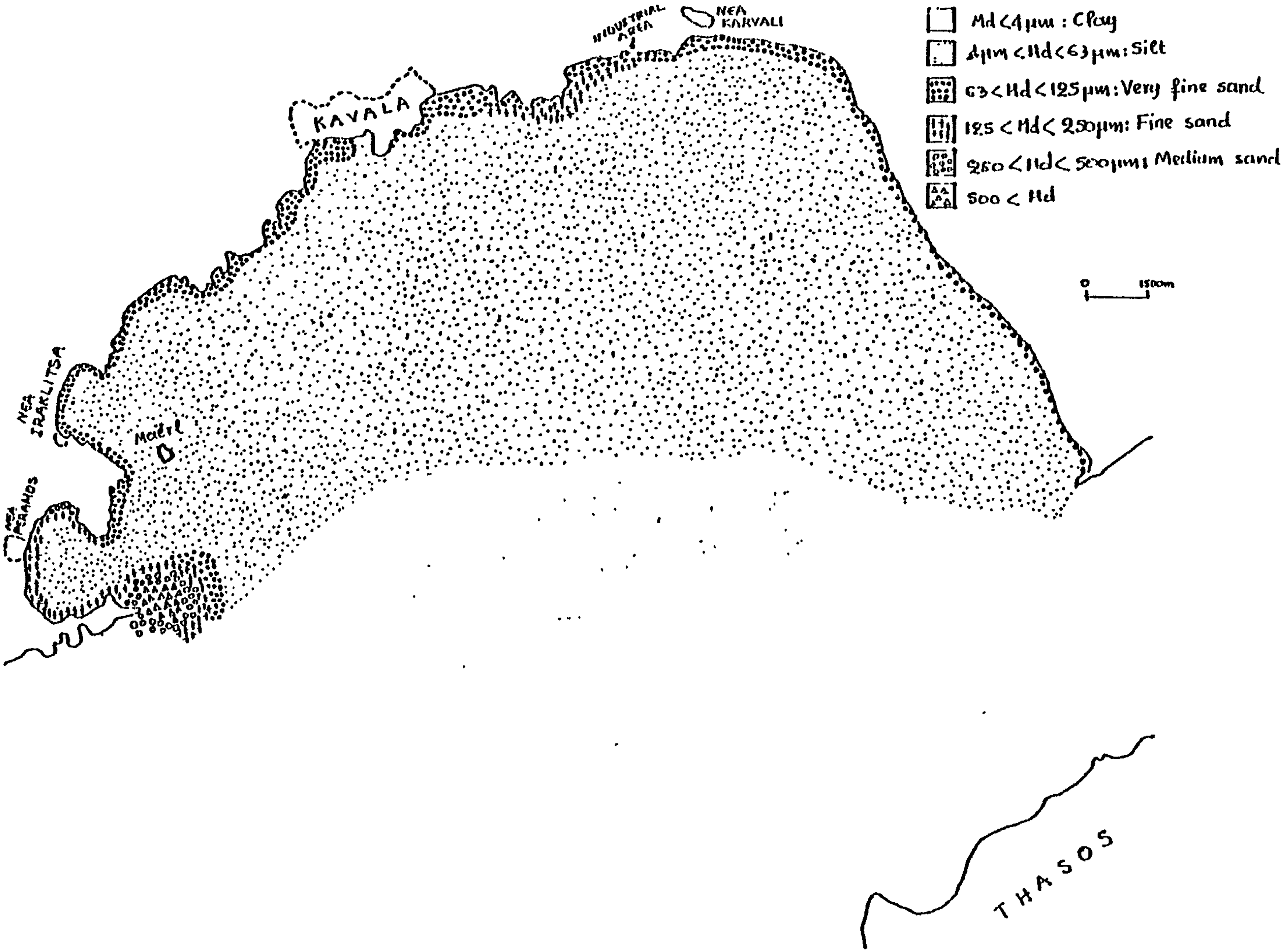


Fig. 7. Gulf of Kavala. Sediment distribution

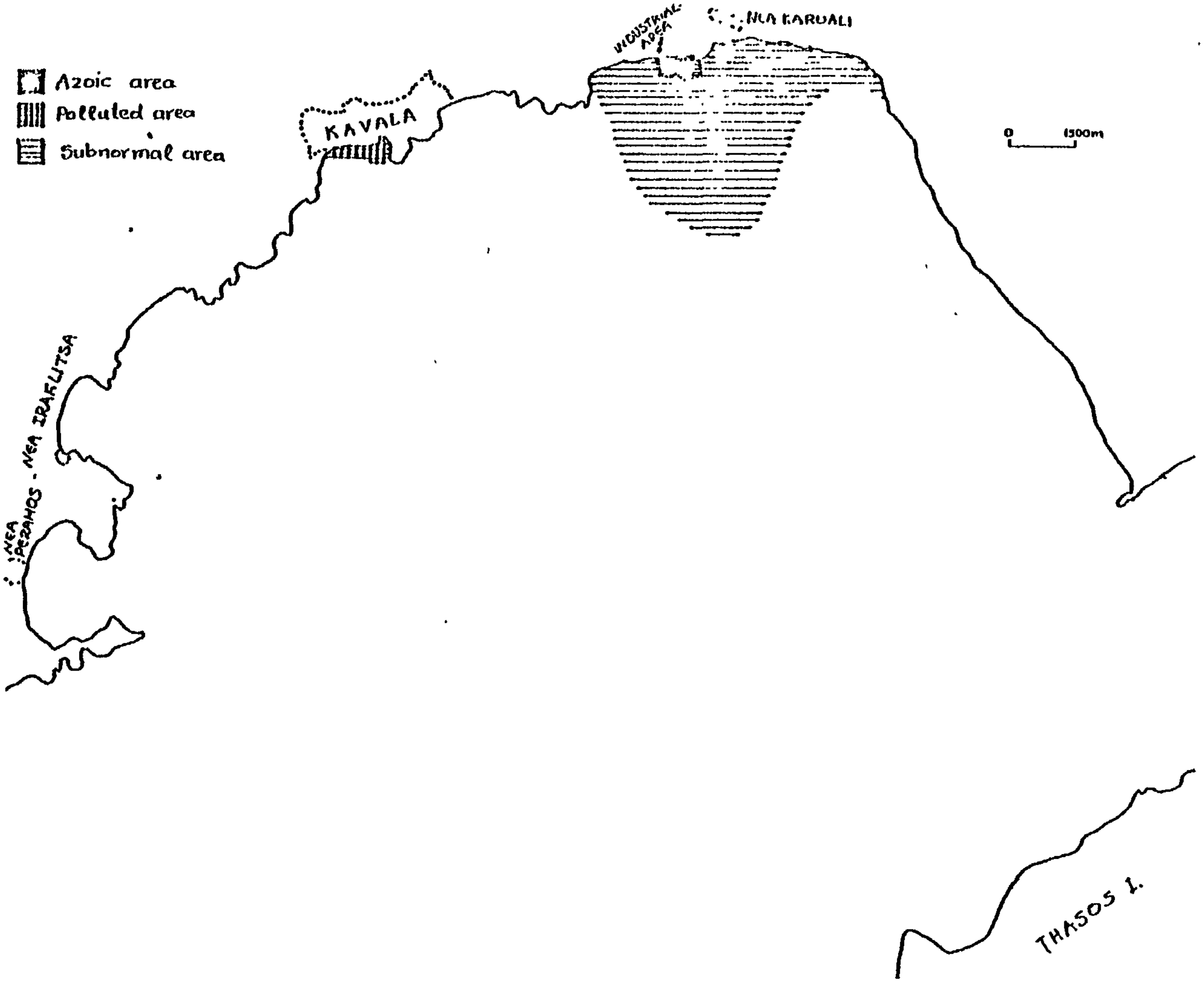


Fig. 8. Gulf of Kavala. Areas of pollution

Research Centre: Institute of Oceanography and Fisheries Research
ATHENS
Greece

Principal Investigator: C. E. VAMVAKAS

The final report has not been received. Following instructions given by the Principal Investigator, the previous report published in Summary Reports on the Scientific Results of MED POL (UNEP/IG.18/INF.3, February 8, 1980, Part 2, pages 334-337) can be used.

Research Centre: Zoological Laboratory and Museum
University of Athens
ATHENS
Greece

Principal Investigator: C.E. VAMVAKAS

INTRODUCTION

The effects of different kinds of pollutants (domestic sewage, industrial effluents, thermal pollution, etc.) on the structure and development of fouling communities is being studied on submerged panels.

AREA(s) STUDIED

Six experimental sites have been selected for this study. One was in Piraeus harbour and five in the area near Lavrion harbour, southeast of the Attica peninsula, in depths from 1 to 10 m. Besides general pollution, heated effluents from an energy plant, mining dust and phosphorus from a match factory are influencing the sites near Lavrion harbour.

MATERIAL AND METHODS

The biofouling panels were made of polyvinyl chloride, asbestos and wood. They were regularly changed by scuba divers every month, and during summertime, every fortnight. Series of panels were also submerged for a longer period (see tables I and II).

The environmental parameters measured each month were: temperature, salinity, dissolved oxygen, transparency, phosphates, nitrites, nitrates, ammonia, silicates, pH and suspended matter.

Standard methods were used to determine physical and chemical parameters of the water. Testing panels were manipulated by divers.

RESULTS AND THEIR INTERPRETATION

The study of the following community examined on approximately 157 panels has shown some differences between different sites, especially compared to Piraeus harbour. Systematic identification of the organisms has been undertaken in the samples taken from the panels in Piraeus while constituents of the community on the panels placed in the 5 sites in the Lavrion area were partly identified, the others being kept for further identification. The whole panel has been preserved for biomass measurements.

Twenty-nine species of fouling and boring organisms have been identified on the panels in Piraeus harbour. The most important and common species found was in the barnacle Balanus amphitrite. Other common species were among the serpulids, e.g. Serpula vermicularis, Hydroides norvegica and Spirorbis sp., and bryozoans, e.g. Bugula stolonifera, B. neritina, Watersipora subovoidea and Cryptosula pallasiana

The interpretation of the biological data was carried out in conjunction with the study of chemical parameters. So far, the fouling communities in Lavrion harbour have proved to be rather poor in comparison with those in Piraeus. The most common groups in the Lavrion area were bryozoans and polychaetes (Serpulids). A complete list of the species found in Piraeus harbour is given in tables I and II. The maximum settlement and growth of organisms was observed during the summer months, and particularly in July.

CONCLUSIONS

A preliminary comparison between Piraeus harbour and the sites in the Lavrion area has shown that, in spite of evident pollution, the fouling community in Pireaus (mainly domestic wastes) is richer in species abundance and diversity than the one in Lavrion (higher percentage of industrial discharge). Temperature and related parameters seem to play the dominant role in the settlement and growth of fouling organisms while other factors like turbidity are less important.

TABLE I

List of species found in > 1 month submersion PVC panels

	Π-2	Π-3	Π-4	Π-5	Π-6	Π-8	Π-10	Π-12
Balanus amphitrite	+	+	+	+	+	+	+	+
Balanus eburneus		+	+	+	+	+	+	+
Balanus tintinnabulum		+	+	+	+	+	+	+
Balanus perforatus				+	+	+	+	+
Tubularia sp.	+							
Obelia geniculata	+							
Bugula stolonifera	+	+	+	+	+	+	+	+
Bugula neritina	+	+	+	+	+	+	+	+
Zoobotryon verticillatum			+	+	+			
Bowerbankia imbricata			+	+				
Bowerbankia gracilis		+	+	+	+			
Watersipora subovoidea	+		+	+	+	+		
Cryptosula pallasiana	+	+	+	+	+	+		+
Schizoporella unicornis					+			
Serpula vermicularis	+	+	+	+	+	+	+	+
Hydroides norvegica	+	+	+	+	+	+	+	+
Spirorbis sp.	+	+	+	+	+	+	+	+
Botryllus schlosseri	+	+	+	+	+	+	+	+
Botrylloides leachi			+	+	+	+	+	+
Ascidia virginea					+	+	+	+
Styela partita				+	+	+	+	+
Phallusia mammillata				+	+	+	+	+
Ostrea edulis					+	+		
Mytilus edulis			+			+	+	+
Sycon raphanus					+	+	+	+
Miscelaneous		+	+	+	+	+	+	+

Π-2, Π-3,... : Panel submerged for 2, 3, ... months.

TABLE II

List of species found in > 1 month submersion asbestos-wood panels

	AP-JL	AP-NO	AU-NO	AP-MR	DE-MR
Balanus amphitrite	+*	+*	+*	+*	+*
Balanus eburneus	+*	+*	+*	+*	
Balanus tintinnabulum	+*	+*	+	+*	
Balanus perforatus		*		+*	
Bugula stolonifera	+*	+*	+*	+*	
Bugula neritina	+*	+*	+*	+*	+
Watersipora subovoidea			*	+	
Cryptosula pallasiana	+	+	*	+*	+*
Schizoporella unicornis			*		
Serpula vermicularis	+*	+*	+*	+*	+*
Hydroides norvegica	+*	+*	+*	+*	+*
Spirorbis pagesteceri	+*	+*	+*	+*	+*
Pomatostegus polytrema					*
Pomatoceros triqueter					+
Botryllus schlosseri		*	+*	+*	+*
Botrylloides leacki	+*	+	+*	+*	+*
Ascidia virginea	+	+*	*	+*	*
Styela partita	+*	+*	+	+*	
Phallusia mammillata	+	+*		+*	
Ostrea edulis		*			
Mytilus edulis	+*	+		+	
Sycon raphanus		*	+	+*	
Miscelanous	+*	+*	+	+*	

+ asbestos

* wood

Research centre: Department of Biological Oceanography and Hydrobiology
Faculty of Science
Bornova-Izmir
Turkey

Principal investigator: A. KOCATAS

Period of reporting: May 1977 to March 1980

INTRODUCTION

More than 650,000 people live around the Bay of Izmir. Their daily domestic wastes flow directly into the sea via many sewers and small streams without any treatment. In addition, the bay and the docks of Izmir are busy commercial centres. For this reason, the pollution as specifically caused by domestic sewage, increases in the bay rapidly and induces negative effects on the environment and biota.

The benthic fauna of the bay has already been investigated. Decapods were studied by Kocatas (1971) and polychaetes by Ergen (1976).

The benthic communities of soft substrata were examined by Geldiay and Kocatas (1972) whereas those of hard substrata were investigated by Kocatas (1978a). In addition, the physico-chemical characteristics of the polluted inner bay waters and the effects on the benthic forms were investigated by Kocatas (1978b) while the distribution of benthic forms affected by pollution were reported by Geldiay, Ergen and Kocatas (1978).

METHODOLOGICAL CONSIDERATIONS

Area studied:

The Bay of Izmir, situated on the western coast of Anatolia, may be topographically divided into an inner (harbour area) and an outer bay, (figure 1). The inner part is linked to the outer bay by a narrow channel and resembles a lagoon. The outer bay, with a number of small and some larger islands, is open to the Aegean Sea through a rather wide entrance. For the purpose of these investigations the inner bay was chosen and 10 sampling stations selected as representing typical pollution conditions. Stations 1, 2 and 3 are located in the most polluted eastern end of the bay near the Altinyol coast; Stations 4 and 5 are located between Alsancak and Karsiyaka; Station 6 is in front of the Balikhane (Fishermen's warehouse); Stations 7 and 8 are in the opening to the Göztepe Bay; Station 9 is located in the waters near Karsiyaka Bostanli where only few sewers discharge domestic sewage, and Station 10 is in the vicinity of the lighthouse in the open waters of Yenikale which are relatively clean.

Communities:

Benthic communities of littoral mud were investigated.

Pollutants:

Domestic sewage and industrial effluents.

METHODOLOGY

Research began in May 1977 and continued for two years. Physico-chemical parameters were measured monthly and benthic sampling was performed once at specific stations in the inner bay.

The following physico-chemical parameters were measured: salinity and temperature (by a portable temperature-salinity bridge); transparency (Secchi-disc); seston (gravimetrically on Millipore HA 0.45 u filters dried at 60°C); oxygen (by Winkler method); pH (electrometrically); nitrates and phosphate (colorimetrically).

Benthic sampling was performed with the orange peel grab delivering 4.5 litres of sediment per sample. Two samples per station were taken and the composite sample of 9 litres sediment sieved through a 2 mm mesh.

DISCUSSION OF RESULTS

Environmental conditions:

- Temperature: Seasonal range of surface temperature was between 9° - 27.5° C. There were no significant differences observed between stations.

- Transparency: The variability of this physical characteristic is highly oependent on the investigation stations which reflect the varying effects of pollution as well as seasonal changes. For example, the seasonal changes for Station 1 are between 54 cm and 265 cm while those for Station 10 are between 200 and 400 cm.

  Although in general the inner bay waters are more turbid in the spring and summer months, changes in transparency can also be observed during the course of one day. Average changes related to the stations are important. Transparency has been found to increase from the inner to the outer regions. For example, while it has been determined at Station 1 to be 130 cm it is 307 cm at Station 10.

- Seston: The amount of seston shows important variations depending on season. Seasonal variations range between 4 mg/l and 100 mg/l. In general, the quantity of seston in the winter and spring months is greater than the amount in the summer and autumn months due to the addition of soil drainage waters to the domestic waste flow. When the stations are compared for average seston values, a decrease is noted from the inner to the outer bay. For example, the value for Station 1 is 39 mg/l while the value for Station 10 is 25.2 mg/l.

- Salinity: The surface salinity of bay waters has been observed to change seasonally between 30 and 40.08 percent. These variations are dependent on surface temperature and precipitation reaching tne maximum value in the summer. A small increase has been observed for the average values of the stations from the inner to the outer regions.

- Oxygen: The quantity of dissolved oxygen in surface water shows important seasonal changes. These changes have been observed to be between 0.70 mg/l and 8.90 mg/l.

Seasonal changes have been observed to occur due to the introduction of organic material into the bay and to the activity of phytoplankton populations. There is an increase from the inner to the outer areas according to the average station values. For example, the average value for station 1 is 4.18 mg/l and the value for station 10 is 5.55 mg/l.

- pH: The waters in the bay are slightly basic and this value varies between 6.9 and 8.6 in relation to the seasons. When the average pH values of the stations are compared, it seems that the mean is around 7.7.

- Nitrate: Concentrations of this nutrient changes seasonally between 3.0 and 32.0 µgat/l in the waters of the bay; when compared, the average values for the stations did not show a major difference.

- Phosphate: Phosphate concentrations vary seasonally in the bay between 0.05 and 1.90 µgat/l. A linear decrease of average values from the inner to the outer areas has been observed.

Effects on communities:

Benthic sampling at the 10 stations led to the determination of 15,653 individuals belonging to 112 species (tables I and II). In the major group are polychaetes with 52 species, but the total number of individuals is greater for molluscs although represented by only 21 species. The reason for this is that the population of Arca (Scapharca) amygdalum which appeared in the bay several years ago shows an increasing and large distribution. Among 9119 molluscs found, 5735 individuals belong to this species.

Table I : The taxonomical distribution of species and individuals

Taxonomical group	Number of species	Percentage of species	Number indiv.	Percentage of indiv.
Polychaeta	52	46.42%	5179	33.09%
Crustacea	25	23.21%	1231	7.86%
Mollusca	21	18.84%	9118	57.93%
Algae+Angiospermae	4	3.57%	-	-
Echinodermata	4	4.57%	113	0.72%
Ascidiacea	2	1.78%	-	-
Nemertini	2	1.78%	7	-
Plathelminthes	1	0.99%	2	-
Cephalochordata	1	0.99%	3	-
Total	112		15.653	

The distribution of the number of species of the Polychaeta, Mollusca and Crustacea which present 88.47 per cent of total biota (91 species) shows that the numbers of mollusc and polychaete species increase from the inner towards the outer bay; the increase in crustacean species number is not as regular.

In contrast, the numbers of Mollusca and Polychaeta individuals vary greatly between stations. These fluctuations are due to the nature of the substrate at the stations where one or few species may largely increase their abundance. For example, the dominant species at Station 6 which has a black mud substratum are Scolelepis fuliginosa (Polychaeta) and Arca amygdalum (Mollusca). When the stations are compared as to total richness of fauna, a regular increase in the number of species is seen from the polluted to the clean zones. While only 9 species were found at Station 1, 77 species were collected at Station 10.

This effect of pollution on the richness of fauna may be clearly observed by comparing the diversity indices found for the stations: an index of 1.18 for Station 1 located in polluted waters, and a diversity index of 10.00 for Station 10 in relatively clean waters. It is clear, especially when Stations 2, 4, 5, 8 and 10, which are located on the same line, are looked at, that the richness of fauna increases from polluted to clean waters.

Zones of pollution: The degree of pollution in a polluted region can be described in terms of zones by comparing the species numbers of benthic fauna and the types of substratum. This kind of zonal system was first suggested by Reish (1955, 1959, 1972) for the Los Angeles-Long Beach harbour. In this region, five zones were distinguished (very polluted bottom, polluted bottom, semi-healthy bottom I, semi-healthy bottom II and healthy bottom) on the basis of macrobenthic populations and environmental conditions. Bellan (1967), working in the Bay of Marseille, divided the polluted region into four zones (zone of maximal pollution, polluted zone, subnormal zone and zone of pure waters) according to the characteristic number of species. Following these two researchers, many workers have investigated other polluted regions. Among them, Leppakoski (1975), revised all of the work done until then and showed that the polluted area could be described by five zones (very polluted bottom, polluted bottom, semi-polluted bottom, semi-healthy bottom and healthy bottom). In general, all three authors have found that: (a) macrofauna cannot be found on the very polluted bottom; (b) only 3 to 5 species, with Capitella capitata as the dominant one, can be found on the polluted bottom; (c) the number of species on the semi-polluted bottom changes with respect to the locality; and (d) the number of species on the semi-healthy and healthy bottoms is related to conditions of the biotope.

During our investigations on the macrobenthic forms in the Bay of Izmir, we have observed the presence of the following five zones:

- Very polluted bottom: Since 1979 no macrobenthic species have been found in this region which encompasses areas in the harbour, the vicinity of Station 3, and the mouth of Halkapinar stream.

- Polluted bottom: This zone, which surrounds the vicinities of Stations 1 and 2 has Capitella capitata as the characteristic organism and the number of all species is 5 to 6.

- Semi-polluted bottom: This zone is located around the vicinities of Stations 4, 5, 6, 7 and 8 with the number of species between 16 to 28 with respect to these stations, while the characteristic species is Corbula gibba.

- Semi-healthy bottom: This zone is found in the vicinity of Stations 9 and 10 and the number of species has been determined to be about 70.

In conclusion, it can be stated that, at present, the very polluted bottoms in the Bay of Izmir occupy a rather limited area, the polluted bottom has a longer extension and the semi-polluted bottoms cover a large region of the inner bay.

The continuous flow of untreated sewage from domestic and commercial sources into the lagoon-like inner bay will transform this region into an azoic zone in the very near future. The consequences of this event are great for the marine life in this area as well as for the population of Izmir.

PUBLICATIONS AND REFERENCES

BELLAN, G. (1967). Pollution et peuplement benthiques sur substrat meuble dans la région de Marseille - Revue int. Océanogr. méd., 6-7, 53-87.

ERGEN, Z. (1976). Investigations on the taxonomy and ecology of Polychaeta from Izmir Bay and its adjacent areas. Scient. Rep. Fac. Sci. Ege Univ. 209 (135), 1-73.

GELDIAY, R., KOCATAS, A. (1972). Note préliminaire sur les peuplements benthiques du Golfe d'Izmir-Scient. Monogr. Fac. Sci. Ege Univ. 12, 1-34.

GELDIAY, R., KOCATAS, A., ERGEN, Z. (1975). Izmir Korfezinin Genel Hidrografi uzerinde ilk gorusler. TBTAK V. Bilim Kongresi, Ankara, 315-327.

GELDIAY, R. ERGEN, Z., KOCATAS, A. (1978). Some effects of pollution on the benthic communities of the soft substrate in the Bay of Izmir (Turkey). Rapp. P.V. Réun. CIESM. (Sous presse).

KOCATAS, A. (1971). Investigations on the taxonomy and ecology of crabs. "Bachyura" from Izmir Bay and its adjacent areas. Scient. Rep. Fac. Sci. Ege Univ. 121 (76), 1-77.

KOCATAS, A. (1978a). Distribution et évolution des peuplements benthiques du Golfe d'Izmir soumis à des multiples pollutions. IV^{es} Journées Etud. Pollutions. Antalya, CIESM. 417-421.

KOCATAS, A. (1978b). Contribution à l'étude des peuplements des horizons supérieurs de substrat rocheux du Golfe d'Izmir (Turquie). Scient. Monogr. Fac. Sci. Ege Univ. 12, 1-93.

LEPPAKOSKI, E. (1975). Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackishwater environment. Atc. Acad. Abo. B. 35 (2), 1-90.

MARGALEF, R. (1958). Temporal succession and spatial heterogeneity in phytoplankton. - In: Buzzati-Traverso, A.A.(ed.), Perspectives in marine biology, 323-349. Los Angeles.

PERES, J.-M. (ed.) (1976). La pollution des eaux marines. Gauthier-Villars, Paris, 227 pp.

REISH, D.J. (1955). The relation of polychaetous annelids to harbour pollution. Publ. Hlth. Rep. 70, 1168-1174.

REISH, D.J. (1959). An ecological study of pollution in Los Angeles-Long Beach Harbours, California. - Occ. Rap. Allan Hancock Fdn. 22, 1-119.

REISH, D.J. (1972). The use of marine invertebrates as indicators of varying degrees of marine pollution. - In: Ruivo. M.(ed.), Marine Pollution and Sea Life: 203-207. London.

Table II. The distribution of species and individuals of the stations for each group

Taxonomical Group	STATIONS 1		2		3		4		5		6		7		8		9		10	
	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in	N.sp	N.in
Algae+ Angiosp.	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	4	-	3	-
Plat helminthes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	4
Nemertea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	1	2
Polychaeta	7	797	11	592	6	24	16	164	10	41	14	1217	15	92	16	65	31	1499	38	524
Mollusca	2	48	2	193	1	1	4	1138	3	180	5	1789	5	377	7	772	10	3281	16	1284
Crustacea	-	-	-	-	1	1	-	-	1	2	8	132	2	17	-	-	15	1050	14	120
Echinodermata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	2	1
Ascidiacea	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	9	-	1	-
Cephalochordata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Total	9	845	13	785	8	26	20	1302	16	223	28	3138	23	486	26	841	72	5832	77	1935

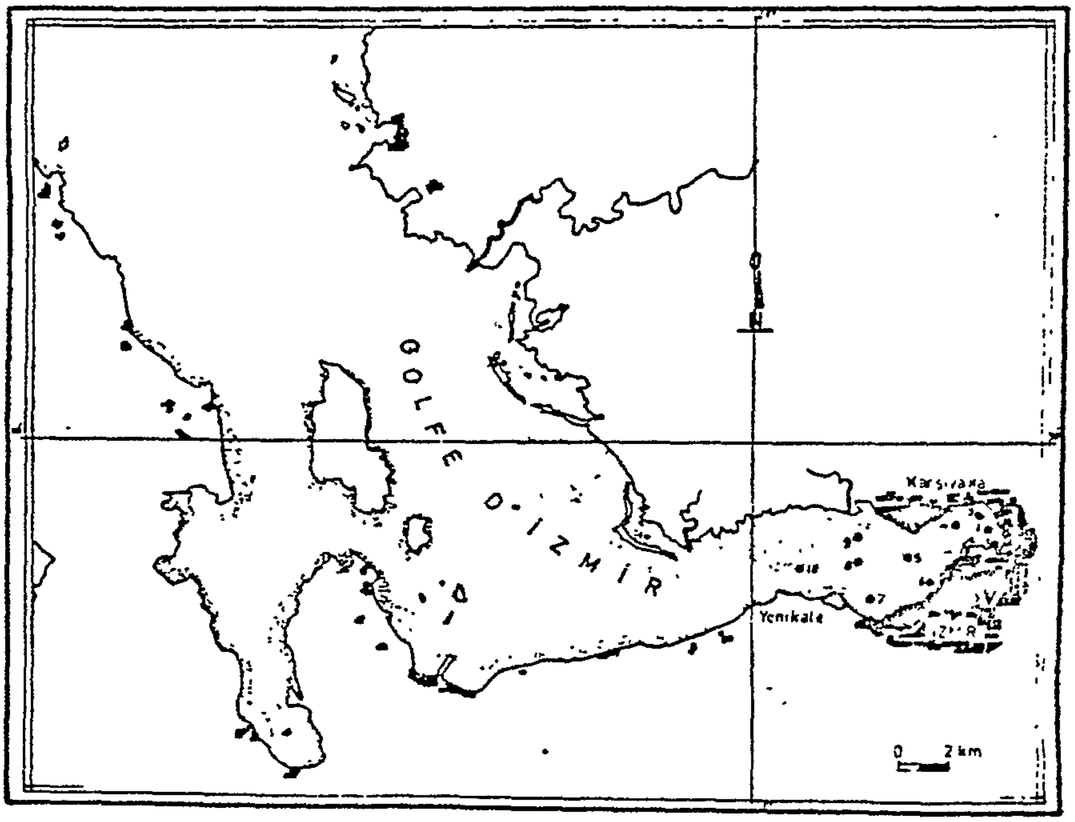


Fig. 1. Bay of Izmir

Research Centre: Biological Institute
DUBROVNIK
Yugoslavia

Principal Investigator: A. BENOVIC

Period of reporting January 1976 to February 1980

INTRODUCTION

Before the start of the MED POL research programme in 1976, a number of zooplankton investigations along the Yugoslav coast and in off-shore waters of the Adriatic Sea had begun. This research served as a baseline study for the MED V pilot project which was undertaken in the Dubrovnik area. During the 1973-1976 period, 14 cruises were undertaken (seasonally) covering 71 stations in coastal and off-shore waters from the northern Adriatic to the Strait of Otranto. The results from this investigation will be published soon. During this investigation the adequate parameters and methodology for the MED POL pilot project were chosen.

METHODOLOGICAL CONSIDERATIONS

Area studied:

According to the agreement signed with FAO(GFCM) it was anticipated that zooplankton would be collected at 4 stations. However, due to the plans for considerable urbanization of the area of Rijeka Dubrovacka and the plans for sewage disposal in the estuary, the area of investigation was enlarged, as well as the frequency of sampling so as to be able to assess the plans for the site of waste disposal.

The entire area (figure 1) is characterized by freshwater inflow (stations 1, 2, 3), harbour pollution and domestic wastes (station 4), and inflow of deep southern Adriatic water (stations 5 - 8). The station "Petka" is at the location where municipal waste discharges are planned to start soon, and which was adopted as the best choice according to the results obtained.

Communities:

The total zooplankton community under observation is divided into two categories: microzooplankton and net-zooplankton. Under the microzooplankton category, special attention is paid to the group of tintinnid species because of their sensitivity to environmental changes, and under net-zooplankton the group of copepods has been selected as the most numerous net-zooplankton species.

Pollutants:

Pollution in the area of investigation is of domestic and harbour type, and there are no data about direct measurement of any specific pollutant.

METHODOLOGY

The following examination was performed:

- qualitative and quantitative analyses of microzooplankton including tintinnids to the species level and other taxonomic groups, i.e. nonloricate ciliates, naupli, small copepods, other metazoans, etc.;

- qualitative analysis of the net-zooplankton including copepods to the species level and other zooplankton groups as summary data for each one; and

- quantitative analysis of the net-zooplankton including determination of dry weight, ash weight, total number of individuals, organic content, carbon content and caloric value.

Sampling procedure:

Microzooplankton was collected using a Van Dorn bottle of 5 l. volume at 3 levels. Samples were fixed by 2.5 per cent neutralized form-aldehyde.

Net-zooplankton was collected by plankton net 113 cm diameter, with mesh netting of 0.25 mm, either in vertical tows from bottom to surface or in oblique tows of 10 to 15 min. Nets were mounted by G.M. MFG. No. 24 flowmeters. Samples were preserved by 2.5 per cent neutralized formaldehyde.

Analysis of the sample:

After precipitation, microzooplankton was counted and values expressed as number of individuals per m^3. Sub-samples for qualitative analysis of the net-zooplankton were used and the values were standardized to No/m^3.

Net-zooplankton biomass was gravimetrically determined by dry weight (60°C), ash weight, organic content (800°C, Lovegrove, 1966), carbon and caloric content (Wiebe, et al., 1975; Plat, et al., 1969).

Qualitative classifications include tintinnids and copepods (to the species level) and other groups.

RESULTS

162 samples of microzooplankton and 96 samples of net-zooplankton were collected at stations indicated in figure 1. Sampling was performed in June, August, December 1977, March and June 1978, August and December 1979, and February 1980.

June 1977:

Favella ehrembergi as the most abundant tintinnid species was found only at station 1 and surface layers of station 4 to a maximum of 7.200 ind./m^3. The greatest abundance of nauplii were in surface samples from stations 1 (71.600 ind/m^3), 4 (20.000 ind/m^3) and 5 (71.600 ind/m^3), while their numbers at stations 5 - 8 were from 4.000 - 14.000 ind/m^3. The values of copepodites vary from 600 - 12.000 ind/m^3 and their abundance was greater within the inner part of the area (stations 1 - 4). Of the small copepods only *Oithona*, *Oncala* and *Acartia* (400 - 3.800 ind/m^3) were found.

Other metazoans were present in numbers of 200 - 17.800 ind/m^3 with appendicularians as the most numerous. At inner area stations (1-4) the dry weight and ash weight values of net-zooplankton increase; the maxima occurred at station 4 (21.65 mg/m^3 dry w., 10.60 mg/m^3 ash w.). A greater amount of inorganic content resulted from the presence of inorganic detritus within the harbour, and caloric content of samples was only 2222 cal/g DW. In Rijeka Dubrovacka (stations 1-3) caloric content is higher because organic detritus is present. At station 8, higher values of dry weight, ash weight as well as total number of individuals were found as a result of the mixed inflow of offshore waters with waters from the inner part of the area. All the values at other stations (5-7) were in normal ranges for the season and the area of sampling.

The qualitative composition of net-zooplankton shows an alternation of typical Adriatic coastal species (e.g. Euterpina acutifrons, Centropages kroyeri, Muggiaea kochi, Sagitta setosa, Kowalevskia tenuis, Obelia spp.) with wider horizontal distribution species (e.g. Ctenocalanus vanus, Centropages typicus). Percentage relationships show a greater proportion of copepods at outer area stations, while in Rijeka Dubrovacka cladocerans and appendicularians were more abundant.

August 1977:

Among the microzooplankton samples the most numerous tintinnid species were Favella ehrembergii found mostly at stations 1-3, in numbers up to 12.000 ind/m^3. Nonloricate ciliates were more abundant at the same stations (up to 11.000 ind/m^3). The most abundant microzooplankton organisms were nauplii. Their number at inner area stations were from 28.000 - 152.000 ind/m^3, decreasing in the deeper layers, except at station 4 where values decreased in the upper layers. Copepodites were also abundant at inner area stations (5.800 - 28.400 ind/m^3); in the other groups only juvenile appendicularians and polychaete larvae were present in considerable numbers. Small copepods, Oncaea, Oithona, Temora and Euterpina were found in low numbers within the entire area. Maximum biomass values of net-zooplankton were found at station 8, and minimum values at station 1.

Higher inorganic content was determined in the outer part of the area, and caloric and organic values were higher at stations 1-3. The net-zooplankton qualitative analyses distinguish species which are either more abundant or only found at stations 1-3 (e.g. Centropages kroyeri), and the species of wider horizontal distribution (e.g. Centropages typicus) which were present in higher numbers in the outer part of the area. Within the other net-zooplankton groups only cladocerans appear in considerable numbers.

December 1977:

Very few individuals were present in microzooplankton samples, especially in the inner part of the area. Of the tintinnid species mainly Rhabdonella spiralis, an autumn high-salinity species, was present. Nauplii dominated, while other groups and adult copepods were present in very low numbers. The number of microzooplankters at stations 1-4 increase towards deeper layers, and in the outer part of the area their numbers decrease in the same way. Both maximum and minimum net-zooplankton dry weight values were present in the Rijeka Dubrovacka (stations 1, 3). The greatest number of individuals was found in the harbour of Cruz (station 4), but due to the presence of inorganic detritus at some stations there were lower values of organic and caloric content. Copepods dominated, especially at stations in the outer area. Detailed qualitative analyses show a strong influence of the offshore waters on the inner part of the area, since even at station 1 net-zooplankton species of wider horizontal distribution such as Copilia mediterranea, Lensia subtilis, Sagitta inflata, Sagitta minima and Fritilaria borealis were identified.

March 1978:

Among the microzooplankton, mostly non-loricate ciliates were in the inner part of the area in numbers up to 24.000 ind/m^3. A low number of tintinnids was found except at station 4 where the species Stenosemella nivalis was present in higher numbers. Nauplii were most abundant, especially in surface layers of the inner area stations, while at outer stations their highest numbers were found at a depth of 20 m. Copepodites followed the distribution of nauplii in numbers of 800 - 5.300 ind/m^3. Other groups of microzooplankton, including small copepods, were present in very low numbers. The dry weight maximum of net-zooplankton was determined at station 8, and the minimum at station 5. The caloric values of the samples were rather high because of the greater number of copepods. The domination of copepods within the entire area is due to the abundance of only two species, Acartia clausi and Paracalanus parvus. The first is more abundant at inner area stations, and the second in the outer part of the area. From other net-zooplankton groups only appendicularians (Oikopleura dioica) were abundant.

June 1978:

Within the microzooplankton samples, tintinnids were again present in higher numbers. The species Tintinnopsis radix was found at all the stations in average numbers of 2.400 ind/m^3, while Tintinnopsis levigata dominated the surface layers of stations 4 and 8 in numbers up to 36.000 ind/m^3. Nauplii were present in lower numbers at inner area stations and their maximum was found in the surface sample at station 8. Values for other groups and small adult copepods were very low. The net-zooplankton biomass value was very high at station 2 (more than 7.0 mg/m^3 DW), and a minimum was found at station 7. Organic and caloric content values were lower at stations 1, 5 and 7, either because of the presence of inorganic detritus, or because of the higher proportion of low-caloric plankton organisms. Qualitative differences were also found between the inner area (Acartia clausi, Podon spp.) and outer part of the area where the population was more diverse. At all the stations copepods dominated but other net-zooplankton groups such as Podon spp., Muggiaea kochi, Oikopleura spp. were also well represented.

August 1979:

Among the microzooplankton samples the most numerous tintinnid species were Codonellopsis schabi found at station 1 in the surface layer (66.400 ind/m^3) and at station 3 in the middle layer, maximum value 124.000 ind/m^3. At some stations (1,3) and layers the tintinnid species Stenosemella ventricosa were also found in rather significant quantities (12.000 - 24.000 ind/m^3). Nonloricate ciliates were more abundant at the outer part of the area (stations 4,8), decreasing toward deeper layers. Nauplii were the most abundant microzooplankters (metazoans) and their maximum was noted at station 1 in the surface layer. Their numbers were from 10.400 - 116.800 ind/m^3 decreasing in deeper layers and the outer part of the area. Copepodites were also abundant at inner area stations (800 - 26.000 ind/m^3), small copepods were confinded to Oncaea and Oithona, and in the other groups only juvenile appendicularia, bivalves, echinoderms and polychaete larvae were present in considerable numbers. Among the net-zooplankton, copepod species dominated across the entire area, and the most abundant at all the stations was the species Acartia clausi (78-323 ind/m^3). The minimum number of copepods was determined in the harbour of Gruz (station 4). The net-zooplankton qualitative analyses determined certain species (e.g. A. clausi, O. helgolandica, O. nana, I. clavipes, P. denudatus) as being more abundant, or only found at inner area stations, and the species P. nanus, C. furcatus, O. plumifera, Corycaeus spp., as preferring the outer part of the area which is under the influence of the offshore waters. Within other net-zooplankton groups only cladocerans appeared in considerable numbers. Doliolids were found only at outer area stations.

December 1979:

Due to the winter conditions few microzooplankters were present across the entire area. Of the tintinnid species, Tintinnopsis radix and Stenosemella nivalis were present only at station 4 (1.600 - 5.600 ind/m^3). The maximum number of nonloricate ciliates were found in the surface layer of station 3. Nauplii dominated at all the stations, especially in deeper layers at station 1 (17.600 ind/m^3) and in middle layers of all the other stations (8.000 - 12.000 ind/m^3). Other microzooplankton groups were present in very low numbers, increasing towards deeper layers. Among the net-zooplankton species, copepods were the most abundant with a maximum number at station 4 (Gruz Harbour). Other net-zooplankton groups were present in very low numbers distributed equally across the entire area.

February - March 1980:

Among the microzooplankton, 3 species of tintinnids were found in very low numbers, except at station 1 (5 m) where the species Tintinnopsis beroidea and at station 3 (surface) where the species Tintinnopsis campanula were present in higher numbers. Nonloricate ciliates dominated at the inner area stations in surface layers (2.400 - 200.000 ind/m^3). Numbers of nonloricate ciliates decreased towards the outer part of the area and deeper layers. A considerable number of radiolarian Sticholonche zanclea were found in deeper layers of all the stations. The numbers of nauplii found at all the stations (1.000 - 58.000 ind/m^3) increased towards the deeper layers, except at station 5 where their number decreased in the same way. Copepodites followed the distribution of nauplii in numbers of 800 - 11.200 ind/m^3. Small copepods and other groups were present in greater numbers only in deeper layers at station 4 (2.800 - 4.000 ind/m^3).

Within the net-zooplankton samples copepods were again present in higher numbers. The most abundant species Acartia clausi was found in numbers of 42 -541 ind/m^3 with a maximum at station 4. Greater diversity, especially at station 5, as well as a greater number of individuals, was noted at the outer area stations where the impact of fresh water influx was weakened due to mixing with the deep southern Adriatic waters. Among other net-zooplankton groups only appendicularians at outer area stations were found in considerable numbers.

DISCUSSION OF RESULTS

In analysing the microzooplankton samples, tintinnids are classified to the species level because of the hypothesis that some species are more abundant in the areas enriched by organic compounds. Favella ehrembergii in June and August 1977, Stenosemella nivalis in March 1978, Tintinnopsis levigata in June 1978, Codonellopsis schabi and Stenosemella ventricosa in August 1979, Tintinnopsis radix and Stenosemella nivalis in December 1979, and Tintinnopsis beroidea and Tintinnopsis campanula in March 1980 were found at stations 1, 2, 3 and 4 where organic compounds were present either from river influx or harbour pollution.

In December 1977 the most numerous tintinnid, especially in deeper layers, was Rhabdonella spiralis because of the strong influence of open southern Adriatic waters on the area. Nauplii were the most abundant microzooplankton group and their distribution corresponded to that of tintinnids, while the abundance of other metazoan groups were not significant enough to draw any conclusions.

A comparison of the microzooplankton community of the Drubrovnik area with other coastal areas of the Adriatic Sea (Krsinic, 1977) shows insignificant differences of appearance, abundance or species diversities at the outer Dubrovnik area stations and other non-polluted areas. The inner area stations are under the constant influx of fresh water and organic compounds which cause differences in species composition and their abundance from the other areas of the Adriatic coastal waters. Higher values of net-zooplankton biomass were obtained previously at inner area stations and at station 8 because of the mixed influence of nearshore and offshore waters. Higher values of dry weight occasionally do not correspond to the total number of individuals and organic and caloric contents, primarily because of the presence of organic or inorganic detritus from fresh water influx or harbour pollution.

All the results suggest that the river mouth is a separated sub-area with a rather strong surface outflow and deeper water inflow to the bay. The harbour of Gruz is full of inorganic detritus (June 1977) while the outer part of the investigated area is strongly influenced by the deeper waters of the southern Adriatic. The qualitative composition of net-zooplankton mostly coincides with the zooplankton diversity of other non-polluted coastal areas of the southern Adriatic (Hure 1969, 1973; Benovic 1977 and Gamulin 1979). This suggests a designation of the investigated area as a presumably clean and undisturbed ecosystem. The permanent appearance of some species in the inner part of the area as well as the greater quantity of microzooplankton in deeper layers (December 1977, 1979) point to the significance of the inflow of deeper non-polluted waters. During the warm seasons this influence is rather small within the inner part of the area, mainly because of very low inflow.

PUBLICATIONS

BENOVIC, A., GAMULIN, T., HURE, J., KRSINIC, F. and SKARAMUCA, B. (1978). Zooplankton communities of the NW Adriatic inshore waters near Dubrovnik. IV^{es} Journées Etud. Pollutions, pp. 391-398, Antalya, CIESM.

REFERENCES

BENOVIC, A. (1977). Biomasa mreznog planktona Jadranskog mora s posebnim osvrtom na neka podrucja istocne obale, Disertacija, Sveuciliste u Zagrebu.

HURE, J. (1969). Kvantitativne karakteristike kopepodske faune obalnih voda sjevernog i juznog Jadrana. Thalassia Jug., 5. 121-125.

HURE, J. (1973). Hidrografske i produkcione prilike u Malostonskom zaljevu. Acta Adriat., 15 (2) pp. 60.

GAMULIN, T. (1979). Zooplankton istocne obale Jadranskog mora. Acta Biologica, Prirodoslovna istrazivanja, 43, 177-270.

KRSINIC, F. (1977). Kvalitatina i kvantitativna istrazivanja tintinida uz istocnu obalu Jadranskog mora, Disertacija, Sveuciliste u Zagrebu.

LOVEGROVE, T. (1966). The determination of the dry weight of plankton and the effect of various factors on the values obtained. In: Some contemporary studies in Mar. Sci., Ed. H. Barnes, London, pp. 429-67.

PLATT, T., BRAWN, V.N. and IRWIN, B. (1969). Caloric and carbon equivalents of zooplankton biomass. J. Fish. Res. Bd. Canada, 26, 2345-9.

WIEBE, P., BOYD, S and COX, J.L. (1975). Relationships between zooplankton displacement volume, wet weight and dry weight and carbon. Fish.Bull., 73, 777-86.

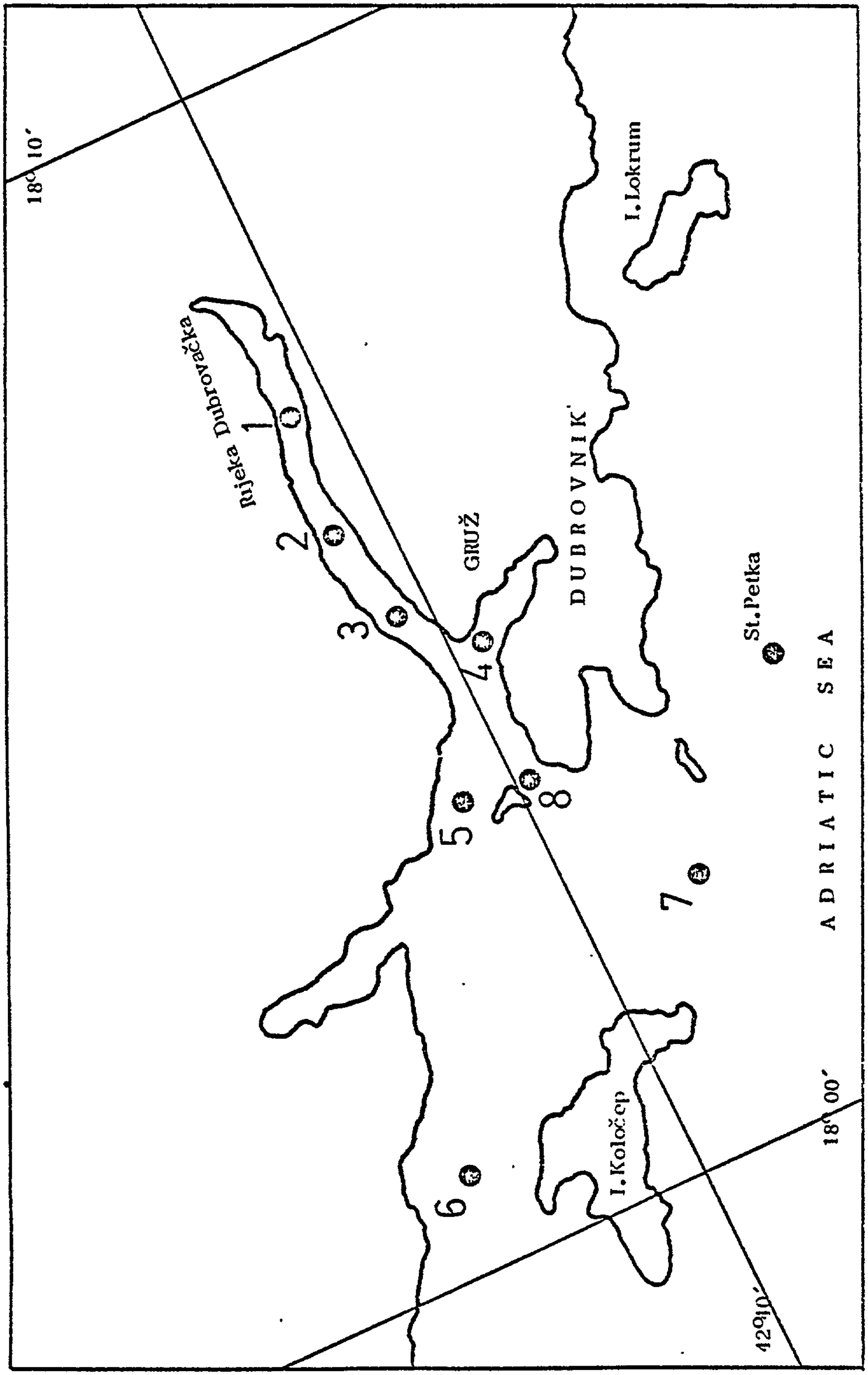


Fig. 1. Location of stations

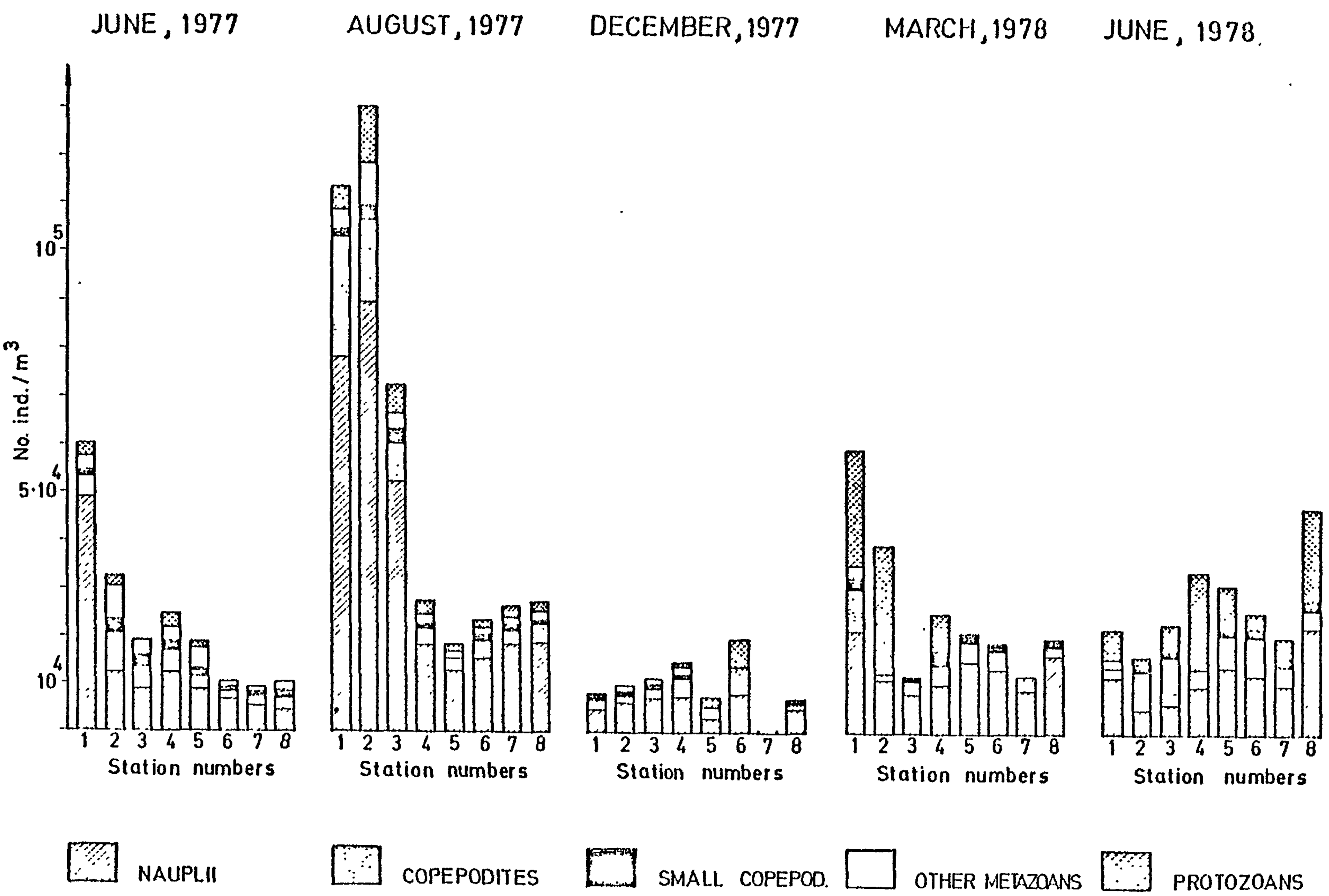


Fig. 2. Average numbers of different microzooplankton groups per m^3

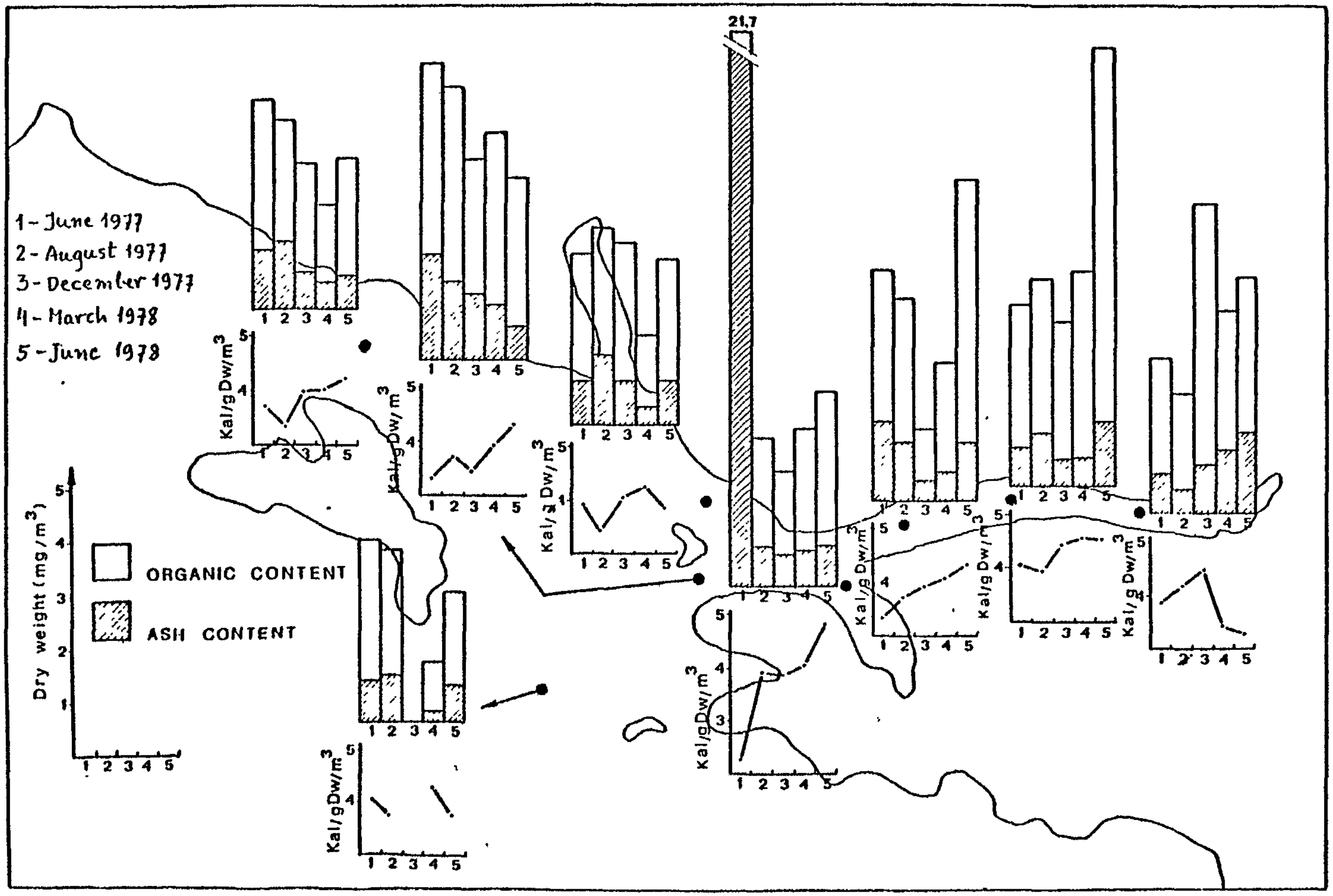


Fig. 3. Net-zooplankton gravimetric biomass values

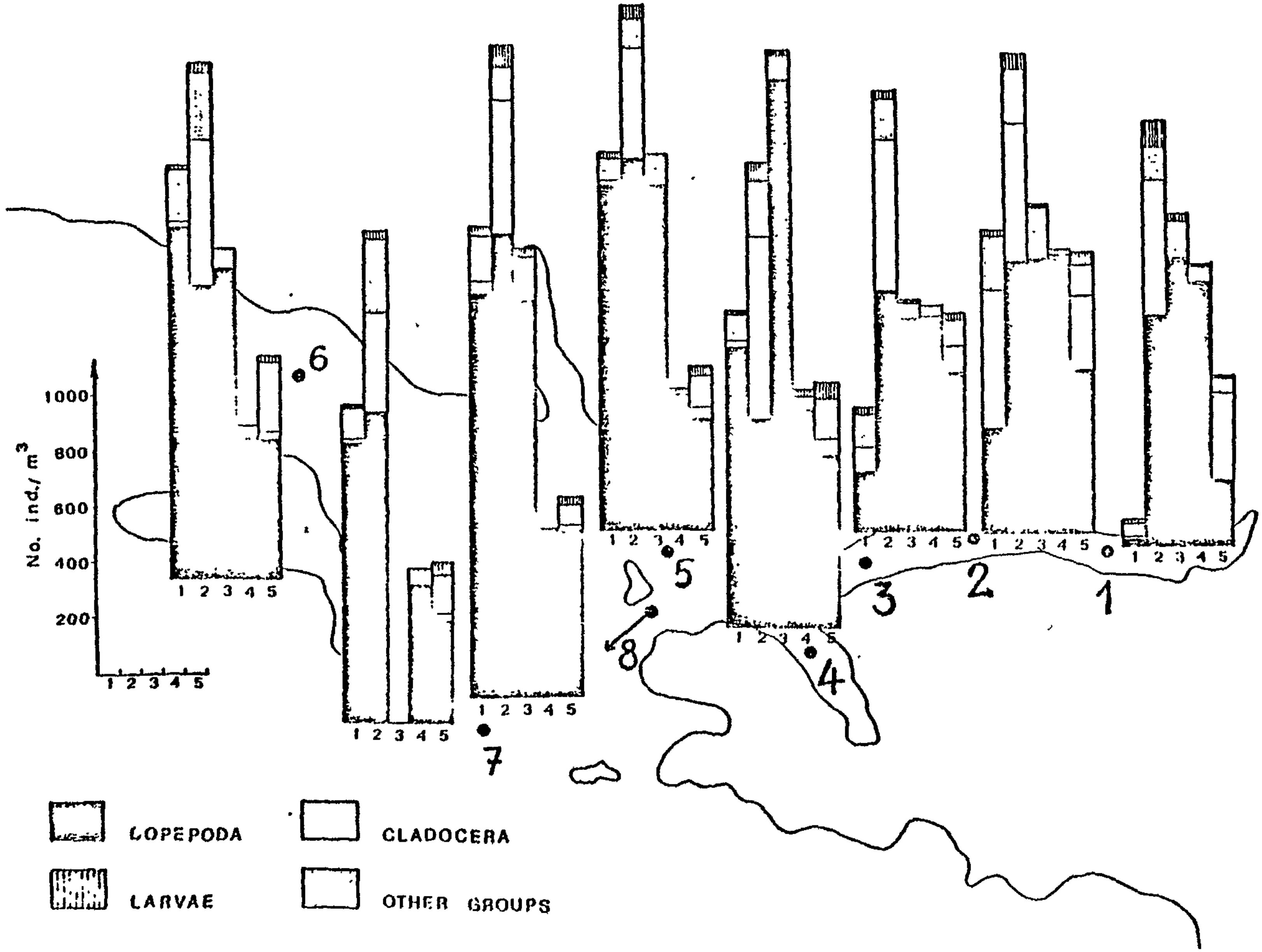


Fig. 4. Total numbers of different groups of net-zooplankton per m3

Research centre: Institute of Oceanography and Fisheries
SPLIT
Yugoslavia

Principal investigator: T. PUCHER-PETKOVIC

Period of reporting March 1977 to September 1979

INTRODUCTION

Some investigations of the Central Adriatic region, included in MED V, were carried out earlier in order to study the seasonal and long-term fluctuations of phytoplankton and zooplankton biomass, the primary production, ichthyoplankton, connected with the study of sea currents, hydrographic and climatic factors. This allowed us to make an assessment of the yearly organic production on different trophic levels (phytoplankton, zooplankton, fish) and to make short-time predictions of the fish catch in the Adriatic. The investigations carried out along the eastern Adriatic coast, connected with the study of pollution problems, particularly near the urban and industrial centres, are of more recent date, but also began before 1977.

METHODOLOGICAL CONSIDERATIONS

Areas studied:

The investigations were carried out in the eastern coastal waters of the Adriatic Sea, mainly in its central part. The plankton community, including some abiotic factors (phytoplankton, zooplankton, bacteria, fish larvae, physical and chemical parameters, heavy metals) was investigated at 3 stations of a transversal profile in the Central Adriatic (figure 1).

The benthic communities were surveyed along the eastern coast of the Adriatic, i.e. in its northern and central part. The areas surveyed are shown in figure 2.

Communities:

Complex pelagic and benthic, on hard and soft bottom, were investigated.

Pollutants:

- Bay of Rijeka (North Adriatic):

  Domestic sewage and industrial effluents originating from the towns of Rijeka, Urinj and Bakar.

  Industrial effluents: petrochemistry, oil refinery, shipyard, mechanical engineering.

- Region of Sibenik:

  Domestic sewage: Town of Sibenik

  Industrial effluents: The Sibenik region is a centre for metal refining (ferroalloys) and the aluminium industry.

River discharge: River Krka

- Region of Split:

  Domestic sewage: Town of Split.

  Industrial effluents: The region of Split is a centre for the cement and asbestos industry, shipbuilding, chemical industry (plastics, dyes, food manufacture), ironworks, mechanical engineering.

  Agriculture run-off: fertile Kastela field, forest of Marjan.

  River discharge: River Jadro.

- Reference areas: e.g. Stoncica (Vis).

METHODOLOGY

Phytoplankton: Numerical abundance (No. of cells/l). Samples taken at standard depths: 0, (5), 10, 20, 30, 50, 75, 100 m, depending on the depth of the station, preservation with 2.5 per cent formol. Material sedimented and counted on the inverted Utermöhl microscope. Biomass (mg chlorophyll a/m^3). Determinations of chlorophyll a and pheopigments by fluorometry. Primary production (mg C m^3/day). Carbon 14 technique in situ.

Zooplankton: Samples taken by Hensen plankton net (No. 3) from bottom to surface. Quantitative-qualitative composition of preserved zooplankton and dominant Copepod group by counting (No/haul). Biomass determination of the total zooplankton by standard method (mg/m^3 dry weight).

Phytobenthos: Field observations: Scuba diving, photography, underwater television. Sampling by Petersen grab and trawl. Determination of characteristic and dominant species.

Zoobenthos: The same methods as for phytobenthos.

Bacteria: Sampling at standard levels (as for phytoplankton). Total bacterial number ultrafiltration by membrane filters. Heterotrophs by plate counting technique.

Fish larval stages: Samples taken by vertical hauls by Helgoland net. Preservation of samples by 2 per cent formol. Samples analysed as a whole, all fish plankton stages separated (No/haul).

Environmental measurements: (hydrographic parameters, currents, nutrients, oxygen, pH and alkalinity) were performed by standard oceanographic methods. Trace metals (Zn, Cd, Pb and Cu) were measured by anodic stripping voltametry.

RESULTS

Pelagic communities:

(a) Bay of Kastela (Split)

The densities of phytoplankton, occurring in different seasons in this region, are presented in table I.

The phytoplankton densities in this region are relatively high, their mean values (0-35 m) varying from 152 x 10^3 to 1,091 x 10^3 cells/l in 1977, from 295 x 10^3 to 970 x 10^3 in 1978 and from 87 x 10^3 to 4,431 x 10^3 cells/l in 1979. Annual mean values of phytoplankton are 654 x 10^3 cells/l in 1977, 614 x 10^3 cells/l in 1978 and 1,663 x 10^3 cells/l in 1979.

In general, the phytoplankton is concentrated in the upper 10 m. This is in agreement with the results of measurements of primary production and the vertical distribution of phytoplankton pigments.

Quantitatively, diatoms are the most important phytoplankton group. In the period of investigations their relative abundance fluctuated from 52 to 98 per cent except in September 1979, when it was only 18 per cent. The investigations of different phytoplankton size fractions in photosynthetic activity, density and biomass, carried out in the upper euphotic layer (0.10 m) showed that nanoplankton is more significant than microplankton, making up 68 per cent of annual production, 67 per cent of density and 58 per cent of biomass.

Diatoms are mainly prevalent in the nanoplankton size fraction of the Kastela Bay phytoplankton. Common spring-summer maximum of phytoplankton was found to be the result of the intensive photosynthetic activity of nanoplankton. In the autumn maximum, however, the role of microplankton is more significant (Pucher-Petkovic and Homen, 1977, 1979).

According to our earlier productivity estimations, the Kastela Bay counts among the regions of the highest productivity in the Adriatic with an annual production of about 150 gC/m^2, i.e. of an average assimilation of phytoplankton of 430 mgC/m^2/day. This may be easily understood as the result of the direct influence of the adjacent mainland. In addition to the vertical convection by which the upper sea layers are supplied with nutrients, the run-off from the River Jadro, affecting the properties of the Bay, is of considerable significance. Kastela Bay is surrounded on the one side by the fertile Kastela field, and on the other by the Marjan forest. In addition, town discharge waters are of groving importance for the enrichment of the Kastela Bay. Since 1968 some changes have been noted in the dynamics of phytoplankton and in the structure of diatom population. They may be connected with the eutrophication of the Bay. In other words, the phytoplankton density, observed from 1962 on, has shown an increasing trend. The ranges of density fluctuations, however, have been considerably reduced. Thus, instead of the summer stagnation, even an additional phytoplankton summer maximum has been observed on several occasions. The occurrence of some diatom species not known earlier in this area has been recorded. It is held that the Kastela Bay is now in the initial stage of eutrophication characterized by the mass bloom of diatom species: Skeletonema costatum, Nitzschia seriata, Leptocylindrus danicus, which affects the total phytoplankton. All the above mentioned phenomena are, for the time being, positive as far as the increase in production of the basin is concerned.

Table I : Numerical abundance of phytoplankton in the Kastela Bay (Number of cells/l).

Depth/m	1977			
	III	VI	IX	XII
0	1 345 680	1 475 460	1 976 520	193 200
5	1 176 840	925 680	-	115 080
10	878 640	474 600	1 212 960	231 840
20	204 120	68 880	1 070 160	94 080
35	147 000	100 440	105 840	125 160
Depth/m	**1978**			
	III	VI	IX	XII
0	528 360	1 485 960	932 400	280 560
5	-	990 360	-	462 840
10	608 160	530 880	2 182 320	405 720
20	467 000	272 160	568 680	153 720
35	361 000	216 720	197 400	172 200
Depth/m	**1979**			
	III	VI	IX	XII
0	4 687 200	735 840	37 380	
5	6 168 960	776 160	-	
10	5 193 720	141 120	44 520	
20	1 676 640	236 880	40 320	
35	-	466 200	226 800	

Zooplankton shows some differences in standing crops and in faunistic composition but the results should be compared with the previous data to conclude whether these are natural fluctuations or changes influenced by the intensive human activity along the coast, e.g. the following fluctuations of biomass (mg DW/haul) were observed:

1977				1978			
III	VI	IX	XII	III	VII	VIII	XII
84	104	180	46	52	211	218	77

During three years of investigations (1977-1979), special attention has been paid to copepods, quantitatively the most important group of zooplankton. The most recent data on the frequency of occurrence, the fluctuation in qualitative and quantitative composition, and on the index of copepod diversity, are given. In the Kastela Bay a total of 36 species and 3 genera were found. According to the frequency of occurrence, the most frequent species (in 75-100 per cent samples) were: Centropages typicus, Acartia clausi, Ctenocalanus vanus, Temora stylifera, Centropages kroyeri and Paracalanus parvus. All of them are neritic, eurythermal and euryhaline species, well adapted to changeable environmental conditions. Thus, they belong to the first group of copepods which occurred permanently. The second group comprises species which occurred over a larger part of the year, such as: Calanus tenuicornis, Nannocalanus minor, Corycaeus typicus, etc. The third group comprises rarely occurring species: Neocalanus gracilis, Ischnocalanus plumulosus, Mecynocera clausi, Sapphirina nigromaculata, etc. They were found from time to time as isolated specimens.

During the year, the number of species varied with seasons from 10 to 20, with a maximum in the colder part of the year.

The seasonal fluctuations of the number of copepods were also examined. Three maxima were found: the first in spring, the second in summer, and the third in late autumn.

The most frequently occurring species were at the same time the dominant ones. They made up 70-80 per cent of the total number of copepods. The global diversity index (using the formula by Margalef, 1951) was 6,5. Specific ichthyoplanktologic studies were also made.

Density, distribution and annual fluctuations of bacterioplankton were studied with special reference to the active heterotrophs. The rate of reproduction of heterotrophs and specimens of released zooplankters were analysed. Mean monthly values of heterotroph density in the Kastela Bay are given in table II. In this Bay the annual means of density are 4 to 7 times greater than those from the open Central Adriatic.

Table II : Mean density of heterotrophs (colonies/ml)

Kastela Bay					
Year	March	July	September	December	Mean value
1977	431.1	93.2	282.5	472.5	321.3
1978	490.0	533.0	1 625.0	1 710.0	1 087.0
1979	578.2	186.7	487.2	-	417.3

Reference areas:

The waters which are far from any significant pollution sources, such as station Pelegrin in the vicinity of Hvar Island and station Stoncica near the Island of Vis were studied; the same information as shown above for the Bay of Kastela was obtained. Due to limitations of space, only a comparison of results obtained for polluted and clean environments is made.

Phytoplankton densities are given in table III in order to illustrate comparisons.

Table III : Numerical abundance of phytoplankton at Stoncica (Vis)
(Number of cells/l)

Depth/m	1977			
	March	June	September	December
0	48 300	81 480	-	193 200
10	61 320	81 480	314 160	403 200
20	33 180	55 020	85 680	543 480
30	46 620	-	145 320	205 800
50	30 660	801 360	218 400	142 800
75	42 840	179 760	175 560	121 800
100	17 220	262 920	175 560	129 360

Depth/m	1978			
	March	July	August	December
0	110 880	231 840	170 520	183 960
10	155 400	138 600	142 800	178 920
20	98 280	141 120	205 800	110 040
30	94 920	99 120	630 840	127 680
50	147 000	527 520	262 080	93 240
75	152 880	473 760	506 520	197 400
100	155 400	76 420	121 800	-

Depth/m	1979		
	March	June	September
0	171 360	190 680	30 450
10	212 520	161 280	49 140
20	357 840	148 680	19 740
30	386 400	192 360	32 340
50	289 800	150 360	13 860
75	235 200	175 520	42 840
100	194 880	260 400	53 760

For the same purpose, mean densities of heterotrophic bacteria (No. colonies/ml) are given as follows:

Station Stoncica (Island Vis)					
Year	March	July	September	December	Mean value
1977	71.2	64.1	87.5	64.7	71.8
1978	104.5	99.4	298.8	106.8	152.3
1979	104.4	57.5	67.0	-	76.3

If compared with results for the Bay of Kastela this table shows that annual mean values of density of heterotroph bacteria at this station are considerably lower than those of the coastal area.

Benthic communities:

The investigations of the influence of pollution on the changes in the composition and distribution of benthic communities (biocoenoses), which started in 1977, were continued and expanded in terms of time and space in 1978 and 1979.

The composition of characteristic benthic biocoenoses was studied in all four seasons at a total of 30 transects in the coastal, channel, insular and open, northern and central Adriatic (figure 2). Some conclusive observations are given below.

DISCUSSION OF RESULTS

Considering the Bay of Kastela as an environment with a variety of man-made influences, there are a number of ecosystem modifications to be mentioned. Phytoplankton density has been increasing from 1968 on and is showing one order of magnitude higher values than previously; accordingly very high primary productivity is observed (average 430 mg C/m^2/day). Summer stagnation of phytoplankton has not been observed any longer. Therefore, the seasonal ranges of fluctuations of phytoplankton are considerably reduced. It is held that the conditions for the development of phytoplankton are favourable in summer, as well. This is the result of the influence of urban pollution which, in the summer period, is increased to a considerable extent. The occurrence of some diatoms, not earlier found, or found in modest quantities in this area, has been recorded. These are the species that are characteristic of eutrophic waters. Mass bloom of *Nitzschia seriata*, *Leptocylindrus danicus* and *Skeletonema costatum*, which affect the total phytoplankton, is typical of the first stage of eutrophication. According to our findings, Kastela Bay is now in the first stage of eutrophication.

The occurrence of three maxima (instead of two) in the oscillations of copepod numbers throughout the year is supposed to be a consequence of the eutrophication in the coastal area. This phenomenon might be due to the increased quantity of phytoplankton (the main copepod food) all year round. The situation is entirely different in reference, pollution-free area (Station

Stoncica). Primary production on an average is 150 mg C/m^2/day and the density of phytoplankton here is about five times lower than in the Kastela Bay. A very high proportion of the presence of coccolithophorids typifies the phytoplankton structure at Stoncica. This group of organisms, which is used as an indicator of the presence of Mediterranean water in the Adriatic, was present in very high percentages in these years. This is in agreement with the above-mentioned conclusion on the increased influence of the Mediterranean water in these years.

The qualitative composition and density of copepods indicate the common ecological situation in this region and similar regions of temperate zones in the Mediterranean.

As far as the extent and intensity of changes in the composition of benthic biocoenoses, caused by the adverse effects of sea pollution, are concerned, it may be concluded for the major part of the open, insular, channel and partly even coastal regions of the investigated areas that they are in a natural condition. However, benthic biocoenoses in the vicinity of larger urban centres and industrial complexes in the coastal belt, particularly in the coastal parts of the Rijeka Bay, Sibenik and Kastela Bays, as well as the shores of the town of Split, which are under the continuous influence of polluted surface waters, have suffered considerable changes in their floristic and faunistic compositions. These changes are manifested through the reduction in the species diversity, elimination of some characteristic and dominant species, abundant development of some characteristic nitrophyle species and forming of degradational nitrophyle facies. These changes were recorded from the biocoenoses of the supralittoral, mediolittoral and the upper part of the infralittoral (biocoenoses of the supralittoral rocks, biocoenoses of the upper and lower mediolittoral rocks, and upper parts of the abundant biocoenosis ofphotophilic algae, as well as biocoenosis of beds of Posidonia oceanica). No adverse effects of pollution were recorded from the biocoenoses of the circalittoral zone since their characteristic compositions were completely preserved and unaltered.

PUBLICATIONS AND REFERENCES

PUCHER-PETKOVIC, T. and HOMEN, B. (1977). Etudes saisonnières du phytoplancton de tailles différentes dans l'Adriatique moyenne. Rapp. Comm. int. Mer Médit., 24(10):93-94.

PUCHER-PETKOVIC, T. and HOMEN, B. (1979). Etudes saisonnières de la photosynthèse, densité et biomasse du nanoplancton et du microplancton dans la Baie de Kastela (Adriatique moyenne). Acta. Adriat., 19(7):47-60.

PUCHER-PETKOVIC, T. and MARASOVIC, I. (1979). Projekti zastite mora u uzoj regiji Splita. Utjecaj eutrofikacije na fitoplankton Kastelanskog zaljeva. Druga konferencija o zastiti Jadrana. Zbornik referata, 2:263-269.

PUCHER-PETKOVIC, T. and MARASOVIC, I. (1979a). Evolution de quelques populations diatomiques dans une aire soumise à l'eutrophication (Adriatique Centrale), Rapp. Comm. int. Mer Médit., 25/26 (8):89-90.

PUCHER-PETKOVIC, T. (1979). Dugorocna opazanja fitoplanktona i primarne proizvodnje u srednjem Jadranu. Nova Thalassia, 3:267-282.

PUCHER-PETKOVIC, T. and MARASOVIC, I. Développement des populations phytoplanctoniques caractéristiques pour un milieu eutrophisé (Baie de Kaštela, Adriatique centrale). Acta Adriat.

REGNER, D. (1977). The oscillations of copepods number in the Kastela Bay (Central Adriatic) in relation to some ecological factors. Rapp. Comm. int. Mer Médit., 24 (10):165-166.

REGNER, D. (1977a). Investigations of copepods in the coastal areas of Split and Sibenik. Acta Adriat. 17 (12):1-19.

REGNER, D. (1978). Istrazivanja bioloske komponente mora splitske regije s aspekta ocuvanja covjekove okoline. Savjetovanje o zastiti i unapredjenje covjekove okoline - opcine Omis, Sinj, Split i Trogir. Split, 1978.

REGNER, D. (1979). The influence of eutrophication on the copepods in the coastal area of Split (Central Adriatic). Rapp. Comm. int. Mer Médit. 25/26 (8):101-102.

REGNER, D. (1979a). Odnos izmedju dominantnih fitoplanktonskih i zooplanktonskih grupa u Kastelanskom zaljevu. Nova Thalassia, 3: 257-266.

VUCETIC, T. (1977). Les investigations écologiques à long terme du zooplankton et leurs applications aux problemes de la pollution. Rapp. Comm. int. Mer Médit., 24 (10):109-111.

VUKADIN, I. (1978). Utjecaj grada Splita na kemijski sastav mora. Savjetovanje o zastiti i unapredjenju covjekove okoline - opcine Omis, Sinj, Split i Trogir, Split, 1978.

VUKADIN, I. (1979). Kemijska svojstva mora u podrucju splitske regije s osvrtom na zagadjenje. Druga konferencija o zastiti Jadrana. Zbornik referata, 2:279-283.

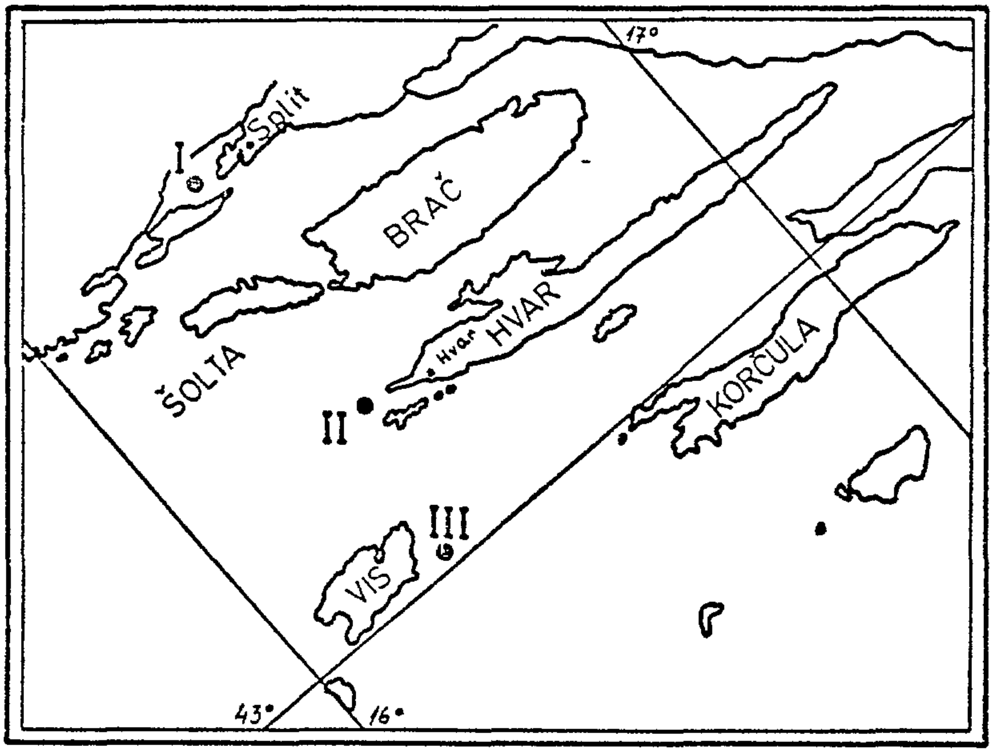


Fig. 1. Investigated central Adriatic region

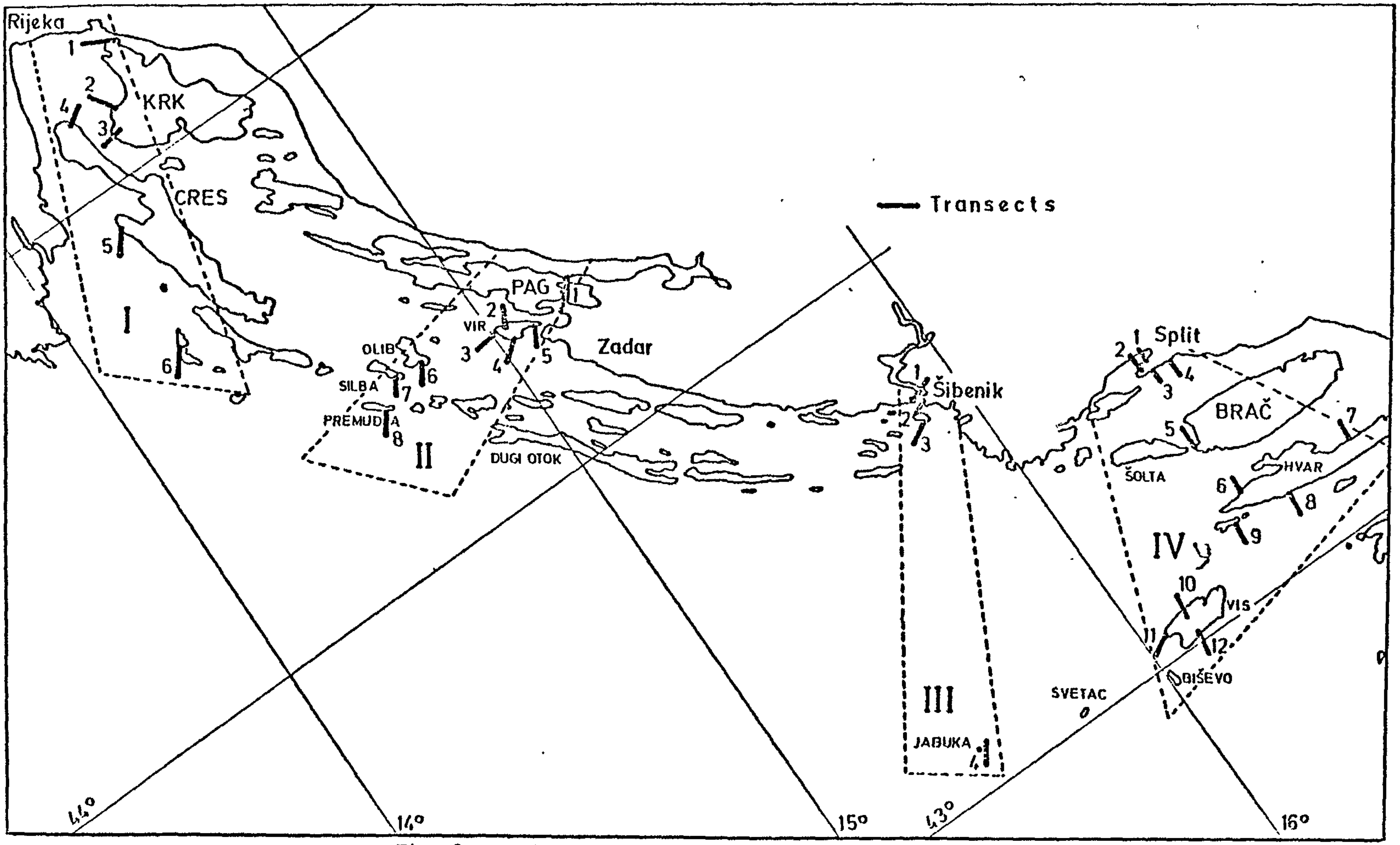


Fig. 2. Regions of benthic communities investigations

Research Centre: Marine Biological Station
Institute of Biology of
the University "E. Kardelj"
Ljubljana
PORTOROZ
Yugoslavia

Principal Investigator: J. STIRN

Period of Reporting: July 1976 to March 1980

INTRODUCTION

Since 1964 our research team has been actively involved in research on effects of pollution (particularly of biodegradable effluents) upon marine ecosystems and communities and in environmental consultancy for a large number of systems for waste disposal into the marine environment. Bearing these experiences in mind, the following considerations were taken into account when preparing the programme of work for this project.

There is a relatively important and growing body of scientific information available from some regions of the Mediterranean on modifications of coastal marine ecosystems and their communities as induced by, for example, sewage-born pollutants. For obvious reasons the relevant papers deal in the majority of cases with modifications which occur post factum, i.e. late after the pollution stress begins and without information on previous conditions of the actual polluted environment. Such information usually originates only from longer and detailed ecological investigations of the area or of a rather large portion of a coastal ecosystem. It seems superfluous to say that without such information there is a rather limited chance for a significant distinction to be made between fluctuating natural conditions and pollution stress. Therefore it appears that a real understanding of ecological processes, as developed by pollution stresses, would be almost impossible without substantially improved knowledge. In accordance with the aims mentioned above, we decided to contribute to the improvement of relevant knowledge with a long-term research programme whose main objectives are interdisciplinary investigations of experimentally polluted natural ecosystems.

METHODOLOGICAL CONSIDERATIONS

Area:

The experimental field was selected within the area of the Gulf of Trieste - the most northerly and the shallowest part of the northern Adriatic, where the impacts of pollution are so significant that the area can be considered as one of the most endangered parts of the Mediterranean Sea.

Partly for technical and partly for ecological reasons the experimental system, as described below, was installed in the Lagoon of Strunjan, a typical coastal formation of the north-western Adriatic shelf and quite comparable to similar ecosystems elsewhere in the Mediterranean.

Community:

The Lagoon of Strunjan, i.e. the area of our experimental field, presents a specific and relatively independent lagoonary ecosystem inhabited by only one community which is characterized by rich vegetation comprising the sea-grasses Cymodocea nodosa and Zosterella noltii.

Besides the main component of the prairies there are a few minor facies, such as a narrow mediolittoral belt of cladophoran vegetation and insular habitats of vegetation-free muddy bottom, completing this rather diverse and productive community. The vegetation and all faunistic components of the Lagoon of Strunjan were studied quite intensively and long before the start of experiments reported here (from 1971 on), and up to now over 200 species have been recorded. Since floro-faunistic investigations were performed quantitatively, respecting seasonal dynamics and being accompanied by environmental measurements, the experimental fields were set up within a scientifically well-known ecologic entity. For information on the natural environmental conditions and community of the Lagoon of Strunjan, see Avcin et al., 1973 and 1974.

Pollutants:

Purely domestic sewage; composition is given below.

METHODOLOGY

Experimental field and procedure:

For the purpose of our experimental investigations we selected within the Lagoon two equal surfaces (63 m^2 each) of undisturbed community which were separated from the surrounding environment by solid walls, made of natural sandstone, avoiding concrete and other possibly toxic or inhibitory materials. The exchange of water between experimental basins and the main lagoon was provided by a pipe whose average flux is approximately proportional with the rate of exchange between the main lagoon and the outer coastal sea (see Fig. 1, symbol U). In order to facilitate samplings without disturbing the experimental environments, the basins were equipped with movable sampling bridges (Fig. 1, symbol M), and the rope-made trellises (1 m^2 mesh) for convenient mapping of the vegetation and other macrobiota. One experimental basin served as an undisturbed blank supposed to keep approximately the same ecosystem conditions as exist naturally in the main lagoon. Although there were some quite obvious consequences of an isolation-induced "self-contamination", the function of the blank basin was quite satisfactory. The second experimental basin was used for pollution experiments and was therefore equipped with the discharge outlet and a flowmeter (Fig. 1, symbols IZ and V) receiving primary settled sewage by a pipeline from a 5 m^3 polyester tank (Fig. 1, symbol C and R). Sewage was transported once a week in a "minitanker" by the sea-route from the sewerage system of the city of Piran.

Knowing approximately the sewage charges which are inducing quite heavy hypereutrophication and temporary anaerobioses in the Bay of Koper, conditions that were studied extensively by our previous investigations, we estimated the proportional doses needed for artificially induced similar consequences in the experimental basin.

During the first phase of the experiment we empirically checked various daily charges against the eutrophication response and we determined the 300 l of primary settled sewage daily (about 1.5 population equivalent) as an adequate charge. Starting in July 1976, the experimental lagoon then received regularly 300 l of sewage per day during the following two years.

The pollutant used for the experiment was typical municipal sewage originating from the population of 4,000 inhabitants of the city of Piran without any industrial or other non-biodegradable wastes. It was untreated centrally, but quite an efficient primary settlement was achieved in the storage tank. Unfortunately there were, particularly in the summer period, quite rapid biological processes active in the storage tank, transforming the composition of our stock-sewage during the residence week into variable types of pollutants with outbreaks of sulphur-bacteria or algal blooms. In spite of such undesirable deviations the average composition of the daily charge was as follows (in g per 300 l sewage):

Phosphorus - particulate P (6.8); organic (P (8.0); PO_4 (1.1)

Silicium - 1.3

Nitrogen -organic (3.4); NH_4 (2.3); NO_2 (0.02); NO_3 (0.7)

Particulate Carbon - 2.6

BOD - 170 mg/l

After 2 years of uninterrupted artificial pollution, the experiment was discontinued in July 1978, and the basin has remained undisturbed for two years (until 1980) in order to investigate the process of restoration.

Environmental measurements:

A rather large spectrum of environmental parameters was measured during the whole duration of the experiments in both experimental basins, and a reduced number of them in the main lagoon and the adjacent coastal waters for comparative purposes. The major chemical compositions of pollutants used for the experiments were analysed regularly too. Some data were collected also for the local rain-water. The frequencies of sampling and measurements were adapted according to needs and technical possibilities. The parameters of crucial importance were monitored while the long series of measurements were performed twice a month, but continuously during 24 - 26 hour cycles.

The following parameters were measured regularly:

Meteorological conditions, tides and water exchange, radiant energy, light penetration, turbidity and extinction, temperature, salinity and density, pH - alkalinity - CO_2 system (electrometrically) - CO_2 and its forms (gasometrically), oxygen and BOD, H_2S and Eh, total seston, particulate carbon, particulate phosphorus, nutrients: total P, organic P, PO_4, organic N, NH_3, NO_2, NO_3, SiO_2 and detergents as MBAS.

Investigations of communities:

(a) Primary productivity level: At the sampling locations mentioned above, and with regular weekly frequency, the following data were collected for atoxically sampled and living samples:

- phytoplankton density;

- species composition of phytoplankton community; and

- biomass as measured by chlorophylls a,b,c.

For technical reasons, the measurements of functional productivity, i.e. carbon fixation, were not possible; however the rough estimations as described from the data of diel oxygen metabolism are available. For the same reason (enzymes not properly supplied) the programmed ATP measurements were also not performed.

Benthic vegetation was studied by regular mapping of the coverage species structure, and standing crops of benthic macrophyte (algae and sea-grasses) communities. Preliminary research on species composition and density of smaller algae (diatoms, cyanophyts) in the film which covered the sediment substrata, was performed.

(b) Secondary and tertiary productivity level: Zooplankton was sampled at regular bimonthly frequencies, always during a 24 h cycle by the filtration of 50 l water samples through a mesh of 12 microns. Standing crop as total and ash-free dry weight, total abundance and species compositions were determined for all samples obtained.

Zoobenthic communities were studied with specific approaches for macro and meiofauna. The macrofauna was sampled bimonthly by a newly developed large-size (270 cm^2) corer which collects quantitatively and without disturbance of the sediment core as well as overlying water column with nektonic organisms.

The nektonic phase can easily be separated from the benthic fraction immediately after the samples have been obtained. The meiofauna was sampled at approximately the same frequencies, using simple tube corers of 25 mm diameter. All collected samples were processed by quantitative screening and flotation techniques up to the smallest size 0.5 mm for macrofauna and 67 microns for meiofauna. The following data were analysed for all benthic (and nektonic) samples:

- total biomass, by major taxonomic groups, and by some dominant species, expressed as total dry weight, ash-free organic matter;

- density of organisms as above;

- species composition of total community with exact identifications of all species, except for some groups of meiofauna (Harpacticoida, Nematoda).

- structural analyses of community using modern models for diversity, similarity, etc.

In order to obtain additional environmental information essential for benthic studies, i.e. the conditions of the sedimentary substrata, sediments were analysed for granulometry, mineralogical components, redox conditions, and content of carbon, phosphorus, nitrogen, iron and manganese.

(c) Bacteriological investigations: Using multiple and plate-counts techniques the population of aerobic heterotrophic micro-organisms were studied in the water and sediments of the experimental lagoons in comparison with the adjacent natural marine environment at the same observational frequencies applied for the environmental measurements.

In parallel, faecal coliforms in the experimental lagoons and pollutants in the adjacent environment were investigated, using membrane-filtration techniques and selective media as recommended by WHO/UNEP project MED POL VII.

(d) Investigations on metals and pesticides and PCB accumulations: In order to trace the pathways and biogeochemical accumulations of potentially toxic or ecologically important metals (Hg, Se, Cd, Pb, Zn, Ni, Cr, Cu, Co, Sb, Fe, Mn), and residues (DDT, aldrin-dieldrin, lindane, PCB) introduced into the experimental ecosystem by discharged sewage, during the experiment samples of water, sediments, and all dominant species of the community were collected for further analyses which are now already close to completion. Analytical methods used are those applied to FAO/UNEP Projects MED POL II and III, and some specific ones, generally AAS, NAA, and GCH. Results are reported within the projects MED POL II and III.

DISCUSSION OF RESULTS

Modifications of the physical environment:

As mentioned previously, the "polluted" basin received once a day at low tide a portion of 300 l of primarily treated sewage.

Consequently, during the retention period of a maximum of 6 hours daily, there were obvious but rather slight modifications, such as decreased salinity, increased turbidity, fluctuating oxygen and CO_2 conditions, etc. There were always remarkable daily increases in nutrients, particularly of ammonia (4-11 ug at/l) and phosphates (0.5 - 5.2 µg at/l, while the budget modifications for nitrites, nitrates and silicates in the "polluted" basin were rather insignificant as compared with the conditions in the "clean" basin. Due to the metabolic and sedimentary uptake and to flushing effects, all the loads mentioned were usually compensated to the level of natural conditions (as observed in the "clean" basin) within 6 - 12 h. In conclusion, it can be stated that the primary effects of daily discharges of sewage were rather insignificant if compared with long-term environmental modifications which were induced by secondary effects, i.e. by increased primary productivity and decomposition of biomass produced.

Consequently there was an extremely high and diurnally sharply-fluctuating oxygenation in the "polluted" basin during vegetation - rich seasons (10 - 15 ml/l of O_2) and very low during prevailing decomposition seasons (0 - 4 ml/l of O_2) with total anoxias occasionally appearing with H_2S evolution up to concentrations of 80 ug at S. There were significant and definite modifications of sediment structure involved in the texture, oxygenation and increased content of nitrogen and phosphorus in sediments, while, unexpectedly, the carbon content in sediments did not show significant modifications.

Modifications of community:

Although modifications of the physical environment as induced by sewage discharges into the "polluted" basin were relatively quite modest, they are the principal cause of the significant and seasonally even drastic modifications of the community, its structure, productivity and over-all metabolism. (It should be noted, however, that the isolation of the experimental basis from the main lagoon also induced some ecosystem modifications as was clearly visible from conditions in the "clean" basin).

Phytobenthos:

At the beginning of the experiment in summer 1976 the "clean" basin was mainly inhabited by sea-grasses interspersed with some bunches of Laurencia obtusa and Cystoseira barbata. Cymodocea nodosa and Zosterella noltii were the main inhabitants also in the "polluted" basin, though its central portion was occupied by some clusters of Ulva rigida and Entermorpha compressa. During the winter of 1977 the vegetation period of Ulva rigida began. While in the "clean" basin it reached its normal spring peak and co-existed with well-developed Laurencia obtusa, Cystoseira barbata and Gigartina acicularis, the "polluted" one, provided with a high amount of nutrients, was literally filled up with these nitrophylic algae; the standing crop reached 0.5 kg/m^2 DW. At the end of the spring and in summer Ulva terminated its vegetation period. Sea-grasses and some macrophytic algae (Cladophora battersi, Laurencia obtusa, Cladophora echinus, Cystoseira barbata, Polysiphonia tenerrima) developed according to their normal seasonal dynamics after the decay of Ulva only in the "clean" basin. During the maximum decomposition period of organic matter produced chiefly by the population of Ulva rigida, the polluted ecosystem became temporarily anaerobic. The entire vegetation decayed and the bare sediment covered with Cyanophyta and Bacteria was left behind. As the experiment proceeded, Ulva rigida and Enteromorpha compressa developed again, as well as a few clusters of Cymodocea nodosa, but they soon degenerated.

Phytoplankton:

The main phytoplanktonic groups observed were diatoms, dinoflagellates and "microflagellates", the last two being relatively more numerous in the "polluted" ecosystem. Extirpation of some species of the genera Chaetoceros, Rhizosolenia, Syracosphaera, Rhabdosphaera, Dictyocha, which are normally common phytoplankton elements in coastal waters ana which are registered in the clean lagoon as well, was observed. Contrary to our expectations, phytoplankton biomass and abundance in the "polluted" lagoon dropped: the range of phytoplankton density was 0.8 -50 x 10^5 cells/l and chlorophyll a + c biomass from limit of detection to 9.7 µg/l, while in the "clean" one the values were higher (biomass a + c from 0.42 µg/l to 31.37 µg/l).

Zooplankton:

The taxonomic structure of zooplankton also showed modifications; for instance, some species which were present in the clean control lagoon, were not recorded in the experimentally polluted ecosystem, such as: Sarsia gemmifera, Ctenocalanus vanus, Clytemnestra sp., Sapphirina sp., Corycaeus sp., Cikopleura longicauda and Oikopleura fusiformis. Generally, zooplankton in the "polluted" basin became more monotonous, and a surprising decrease in both biomass and abundancy occurred.

However the species Penillia avirostris, Acartia clausi and Oithona sp., known as highly tolerant species anyway, were somehow more abundant in the experimentally polluted ecosystem. The zooplankton standing crop in the "polluted" basin was in the range of 16 - 434 mg/m^3 (dry weight), and 89 - 1033 mg/m^3 in the "clean" one. (High values in both cases are partly due to the content of the detritic matter which cannot be technically separated from true zooplankton).

Heterotrophic bacteria:

In the water, a significant difference between bacterial density in the "polluted" basin (max. 247,500/ml) and the "clean" one (max. 16,700/ml) was found. There was also an apparent difference between sampling counts soon after sewage discharge and the repeated sampling after 24 h, showing an intensive disappearance of bacteria from the "polluted" basin while in the "clean" one the bacterial populations were stable. In the sediments of the "polluted" basin there was no increase in bacterial populations during the colder seasons, but a very remarkable one during the summer period.

Zoobenthos:

Normal lagoonal macrofauna is typically associated with sea-grasses and it is represented mainly by Mollusca, Mysidacea, Amphipoda, Decapoda and Isopoda, while the sediment is primarily populated by some mullusca, Polychaeta and the shrimp Upogebia litoralis. The macrobenthic community was modified under the stress of experimental pollution quite significantly too, yet the total biomass and abundance of a few super-tolerant organisms were increased. The following macrofaunistic elements significantly increased their populations: the polychaetes Neantes succinea, Scolelepis fuliginosa and Capitella capitata, the shrimp Upogebia litoralis and some species of amphipods which were among the most abundant of all the organisms - up to 3,000 specimens per 1 m^2. Due to the reduction of species in the community, and to the increased abundance of some particular organisms described above, the over-all diversity obviously dropped to the level which is characteristic of stress-communities. The mean value of the Shanon-Weaver diversity index for the benthic community of the experimentally polluted basin was $H_s = 1.25$; in the "clean" basin it was 1.65 and in the undisturbed natural lagoon H_s was 1.82.

The main groups of meiofauna in both basins were Nematoda, Harpacticoida, Polychaeta, Oligochaeta and Ostracoda while Kinorhyncha, Turbellaria, Cumacea, and others were only accessory or accidental, these being found in the polluted ecosystem only at the beginning of the experiment. As previously mentioned, temporary anoxic conditions were observed in the polluted lagoon which consequently caused a mass mortality of meiofauna. The only groups that suffered relatively little in the polluted ecosystem, were nematodes and some harpacticoid copepods. The average biomass (as dry weight) obtained in the polluted lagoon was 15.7 mg/10 cm^2 and the mean abundance 1066 specimens/10 cm^2, while in the clean control lagoon they were much higher: 21.3 mg/10 cm^2 and 2,979 specimens/10 cm^2.

PUBLICATIONS

AVCIN, A. *et al.*, 1973. Aquatic Ecosystems in the Bay of Strunjan. Sci. Rep. mar. Biol. Stat. Portoroz, 3 : 1-47 (Slov., Engl. Abstr.).

AVCIN, A. *et al.*, 1974. Comparison of benthic communities in the clean Bay of Strunjan and polluted Bay of Koper. Biol. vest., 22 : 171 - 208 (Slov., Engl. Abstr.).

FANUKO, N., 1980. Phytoplankton of experimentally polluted lagoons (Croat. Eng.Abstr.). M. Sc. Thesy : 85 p.

MALEJ, A. *et al.*, 1978. Modifications of an experimentally polluted ecosystem in the Lagoon of Strunjan. Proc. 4. Journ. Etud. Poll. CIESM, Antalya : 423-429.

STIRN, J. *et al.*, 1979. Results of pollution experiments in the Lagoon of Strunjan. Report to Res. Comm. of S.R. Slovemija: 127 p.

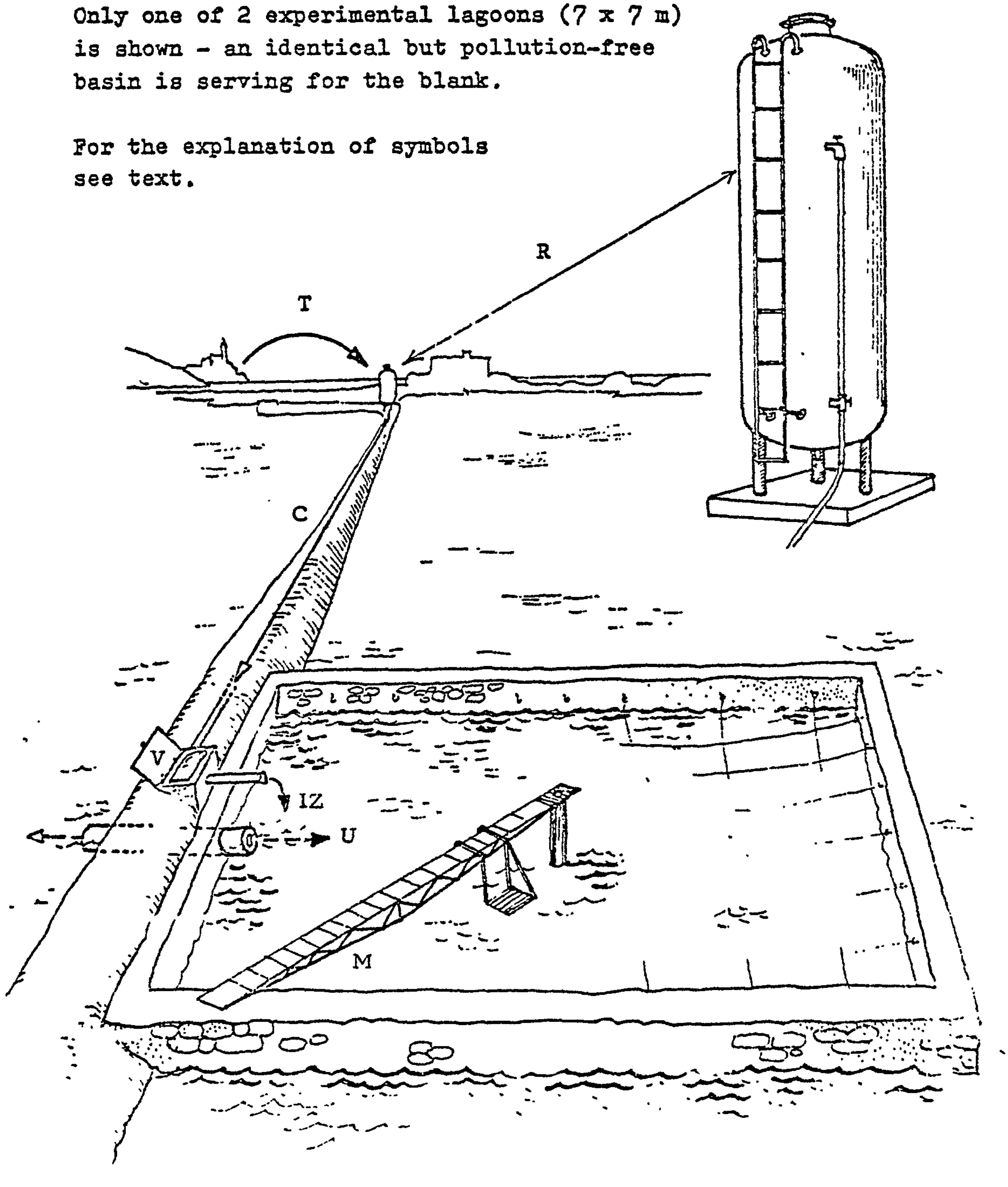
VRISER, B., 1979. Meiofauna of experimentally polluted lagoons. M. Sc. Thesia : 89 p. (Slov. Eng. Abstr.).

Fig. 1.

SCHEMATIC PRESENTATION OF INSTALLATIONS MADE FOR ARTIFICIAL POLLUTION OF EXPERIMENTAL LAGOONARY ECOSYSTEM IN STRUNJAN, YUGOSLAVIA

Only one of 2 experimental lagoons (7 x 7 m) is shown - an identical but pollution-free basin is serving for the blank.

For the explanation of symbols see text.



Research Centre: "R. Boskovic" Institute
Centre for Marine Research
ROVINJ
Yugoslavia

Principal Investigator: D. ZAVODNIK

Period of Reporting: June 1976 to March 1980

INTRODUCTION

Primary productivity of phytoplankton and relevant physical and chemical parameters have been monitored in the northern Adriatic since 1963. Baseline studies on benthic marine communities in coastal waters in this area have been carried out since 1960. Since 1972, the pollution-stressed Bay of Rijeka has been specially studied.

METHODOLOGICAL CONSIDERATIONS

AREA(S) STUDIED (Fig. 1).

The research was done in two areas:

(a) in the offshore and coastal waters west of the Istrian peninsula, which is largely influenced by the discharges from the Po river and by sewage from numerous tourist centres and resorts on the mainland. Ten permanent stations are situated in the vicinity of Rovinj and along the transect Rovinj-Punta della Maestra (mouth of the Po river); and

(b) in the landlocked Rijeka Bay, where one of the largest industrial and municipal conglomerates in the Adriatic Sea is located. The localities investigated were situated near Rijeka city, in the vicinity of the newly constructed oil terminal and petrochemical complex, and in the open waters of the Bay (total of 5 offshore and 22 coastal stations).

Communities:

Due to the multidisciplinary approach of the research, the results of the complex investigations in the offshore waters of the shallow northern Adriatic are given in their integral form in the section "Discussion of Results".

In other areas, the following four benthic communities were specially studied:

(a) The biocoenosis of supralittoral rocks has been studied in Rijeka Bay and in the surroundings of Rovinj: In both areas, its characteristic populations are those of Chthamalus depressus, Littorina neritoides, Ligia italica, epilitic Cyanophyta and a few species of lichens. In the lower horizon of the supralittoral zone, the barnacle Chthamalus stellatus is dominant (the populations can exceed 10,000 specimens $m/^2$), which is usually accompanied by Rivularia. Near Rovinj, in the coastal incisures, the sciaphile Catenella repens association is developed.

(b) The biocoenosis of midlittoral rocks: In the midlittoral zones, in both areas investigated (Rijeka and Rovinj), the rocks are occupied by typical

Mediterranean communities of which the characteristic species in the upper horizon are Chthamalus stellatus and Patella Lusitanica, and in the lower horizon Lithophyllum lenormandi, Monodonta turbinata, several species of Gibulla and Patella, Mytilaster minimus and Mytilus galloprovincialis, Actinia equina and others. In Rijeka Bay, at non-polluted and exposed sites, a belt of Lithophyllum tortuosum can be found. Near Rovinj, common organisms in the midlittoral zone are also Middendorfia caprearum, Barleeia rubra, Crassostrea gigas and the endemic seaweed Fucus virsoides. In this area, from 1977 on, an extension of Mytilus galloprovincialis, Crassostrea gigas and Balanus perforatus populations were noted at many sites. The reason for this phenomenon cannot yet be explained.

(c) The community of Cymodocea nodosa: This eelgrass is fairly tolerant to various environmental variations. Therefore, it is growing on the sediments which vary from pure coarse sands to silty sands, and is distributed in the relatively clear waters as well as in waters which are affected by slight organic pollution. The seasonal dynamics of standing crop, production and chemical composition were monitored in Faborsa cove, near Rovinj, during a period of one and a half years. It was found that all these parameters are closely related to environmental conditions. The maximum production rate measured in situ was 77.2 $mgC/m^2/h$. Comparative measuring of production of Cymodocea in Rijeka Bay and at Rovinj indicated that the production capability of plants in both areas is very similar when calculated by unit of plant weight. The maximum values of standing crop were measured in the summer period (nearly 1,300 g $(WW)/m^2$, the roots share being about 50%).

(d) The biocoenosis of coastal terrigenous ooze: In Rijeka Bay, the silty sediment is distributed in its deepest area, i.e. usually below the 30-50 m depth. This is the habitat of the biocoenosis of coastal terrigenous ooze, in which the most characteristic species are: Turritella communis, Cultrensis adriaticus, Nephthys hystricis, Marphysa kinbergi, Jaxea nocturna, Synapta digitata and Brissopsis lyrifera. The biomass usually amounts to about 40 g $(WW)/m^2$. It was found that, according to faunal composition, the central part of the Bay differs somewhat from the northern part (near the mainland) and the southern (insular) area. It should be added that, in the south-eastern and central part of Rijeka Bay the Norwegian lobster Nephrops norvegicus is fished.

Additional information on this biocoenosis is given in the section "Discussion of Results".

Pollutants:

The following pollution sources and pollutants were considered:

- complex pollution originating from municipal sewage and industrial effluents;
- waterborne pollution-excess of nutrients;
- oil, tar;
- solid waste.

METHODOLOGY

The samples of sea-water for chemical analyses were taken by Nansen and Van Dorn water bottles; the latter were also used for sampling of phytoplankton. For quantitative sampling of fauna on deep oozy bottoms, the Van Veen grab (0.1 m^2) was used. Shallow-water bottom communities were studied directly by divers, who also provided the biological material for field and laboratory experiments.

Temperature was measured by Richter and Wiese reversing thermometers which were mounted on Nansen water bottles.

Salinity was determined by modified Knudsen-Mohr titration after Strickland and Parsons (1968).

Dissolved oxygen values were obtained by the modified Winkler's titration method, according to Strickland and Parsons (1968).

pH was measured directly by the Beckmann pH meter.

Total alkalinity was determined by the method of Anderson and Robinson, as described by Strickland and Parsons (1968).

Reactive phosphate was determined by the method of Murphy and Riley (1962).

Nitrites were determined by the method of Wood et al., as described by Strickland and Parsons (1968).

Ammonia was determined by the method of Solorzano (1969), which was modified according to Degobbis (1973).

Reactive silicate was determined by the method of Mullin and Riley (1955) as modified by Strickland and Parsons (1968).

Chlorophyll-a was measured fluorimetrically. 500 ccm of water was filtered through Whatman GF/C, the pigments were extracted in 90% acetone, and the extinction of clear solution was measured.

Photosynthetic activity was calculated by the method of white and dark bottles, which were exposed in controlled laboratory or in situ conditions for 1-3 hours. Photosynthetic activity of phytoplankton was determined by radio-carbon method according to Steeman-Nielsen using $Na_2{}^{14}CO_3$. The photosynthetic activity of eel grasses and seaweeds was calculated through oxygen production measured by the Winkler's method.

Counting of phytoplankton cells was done using the Utermöhl method. The samples were fixated in Lugol's solution and sedimented in Opton's chambers.

Counting of benthic animals: In littoral communities this was carried out visually using wire squares 20 x 20 cm and expressed according to Braun-Blanquet (1923). From sediment samples the animals were extracted by sieving through 2 mm sieves, preserved in neutralized formol 4% or alcohol 60%, and elaborated using Reichert or Zeiss optical equipment.

Biomass measurements of macrofauna and flora were performed using Mettler balances, according to techniques accepted by CIESM, s/commission, benthos (1965).

DISCUSSION OF RESULTS

Offshore waters of the northern Adriatic and eutrophication phenomena:

Phytoplankton:

The northern Adriatic, especially its western part is one of the most productive regions of the Mediterranean, primarily due to the eutrophication influences of Italian rivers, in particular the Po.

During 1977 and until March 1980, 20 cruises at 5-8 stations were conducted. Basic hydrographical parameters, light penetration scattering, nutrients, cell densities and composition of the phytoplankton community, chlorophyll-a concentrations, and ^{14}C primary production were monitored. Investigations showed that, from April to September 1977, in the entire area the surface layer salinity (about 10 m depth) was unusually low. The freshwater influences were especially expressed in June 1977. At that time, the standing-crop of phytoplankton was high and, in the eastern part, reached levels (up to 13 ug chlorophyll-a/l) never previously observed during 20 years of continuous investigation. The phytoplankton cell densities were relatively high (up to 2×10^5 cell/l) due to the bloom of a still unidentified species, which was not observed previously. The level of organic production was accompanied by an unusual decrease in dissolved oxygen in the bottom water layers, which reached the minimum value in September (13%). It is noteworthy that, in the low oxygen layers, high nutrient concentrations were observed: nitrate to 10 ug-at/l, phosphate to 0.9 ug-at/l and silicate to 33 ug-at/l. Concurrently, pH values were unusually high near the surface and very low in the bottom layer. Later in 1977, the increased vertical mixing, a reduction in eastern advection, and the strengthening of southern currents along the Italian coast, created more "normal" conditions. Accompanied by the decrease of organic production, chemical and biological relationships in the eastern part of the northern Adriatic were re-established in December and investigated parameters fell again within normal ranges.

During June 1978 similar conditions did not develop in the eastern part of the area. However, the highest dissolved oxygen concentrations (190%) and pH values (about 8.8) ever reported for the surface waters off the Po delta indicate the extremely high rates of organic production at this time. The usual distribution of all parameters was observed for the west of the northern Adriatic in 1978 with the normal seasonal bloom at the beginning of November.

A similar situation was observed in 1979. At the beginning of April, strong phytoplankton bloom was located in the western part of the northern Adriatic (Stations 9, 10, 11) with corresponding increments in all measured parameters. During the July cruise the usual summer bloom near the Po was not observed. The values of all parameters were in the normal range for the area as well as for all the other cruises in 1979.

In 1980 one cruise was conducted (in March) and spring bloom was observed in the whole area. Corresponding increments in oxygen saturation and pH were also observed.

At present, it could be stated from the results obtained that the influence of the Po river in the eutrophication processes is strong. In special circumstances, as in 1977, its influence can reach the Yugoslav coast, causing problems for benthic organisms as well as for tourist activities because of visual changes of the sea-water quality.

Benthic communities:

Along the transect between Rovinj and the mouth of the river Po (stations 6-9), in the offshore waters of the northern Adriatic, three types of benthic communities have been surveyed: the biocoenosis of coastal detritic bottom (station 6), the biocoenosis of detritic bottom mixed with ooze (stations 7, 8), and the biocoenosis of coastal terrigenous ooze (station 9).

The coastal detritic bottom consists of sand and coarse particles of organic origin (calcareous algae, debris of shells and tests, colonial sessile animals). The silty fractions are purely represented; this is an indication of the fair near-the-bottom dynamics of water masses. The community is characterized by numerous species of various ecological origin, above all bivalves, polychaetes and echinoderms. The most common are Corbula gibba, Cultrensis adriaticus, Pitaria rude, Spiophanes kroyeri, Myriochele heeri, Thelepus cincinnatus, Owenia fusiformis, Astropecten irregularis pentacanthus, Ophiothrix quinquemaculata, Ophiura grubei and, of the tunicates, the synascidian Distoma adriaticum. The most numerous population is that of Corbula gibba (on an average 144 specimens/m^2). The mean biomass is about 95.5 g/m^2 (WW).

The biocoenosis of detritic bottom mixed with ooze occupies the central part of the shallow northern Adriatic. In the sandy sediment, the amount of silty fractions is susceptible to local variations, and in the area investigated it is increasing westwards. In correlation to the bottom quality, the amount of pelophilic elements at the western station (8) indicates a transition to the community which is characteristic of silty sediment. In the area investigated, the most common species in this biocoenosis are: Virgularia mirabilis, Turritella communis, Corbula gibba, Nephthys hystricis, Eunice vittata, Notomastus latericeus, Owenia fusiformis, Terrebellides stroemi, Spiophanes kroyeri and Aspidosiphon kovalevskii. An average biomass of about 170 g (WW) per square metre was calculated.

The biocoenosis of coastal terrigenous ooze was identified at station 9. The sediment consists mainly of silty fractions, while the amount of skeletal debris is very low. Besides the polychaetes, the most characteristic species is Virgularia mirabilis, which belongs to the stock of exclusives to this community. The most common organism is, however, the sipunculan Aspidosiphon kovalevskii of which, on average, 161 specimens were counted per square metre.

The species composition in the communities studied corresponds to that of other parts of the northern Adriatic. To check eventual effects of the inflowing waters of the river Po on bottom life, some auxiliary stations were preliminarily surveyed (stations 3, 4, 10, 11, 12, 13). No important variations in species composition were found regarding the communities described above. It is, however, interesting that the quantities of Aspidosiphon kovalevskii had increased at the time of sampling at stations near the inflow area of the river Po, thus reaching 500 specimens of this sipunculan per square metre. Further research is needed to find the reason for specific distribution of this species in the shallow northern Adriatic. During the period of investigation, several quantitative variations in sampling areas were noted. Unfortunately, at stations surveyed, the seasonal dynamics of the communities could not be checked. Nevertheless, we suppose that these variations reflect the spatial distribution of benthic populations in station areas. A comparison with previous data (Vatova, 1949) indicates a recent mass mortality of Turritella communis in the entire westward area of the shallow northern Adriatic. For example, at station 10, among 1,602 dead shells/m^2, only 4 Turritella were alive. A lot of loose shells are usually occupied by sipunculans (Phascolion strombi and, mostly, Aspidosiphon kovalevskii); the occupation rate can even be 30%. It seems, however, that the mortality of Turritella is not correlated to environmental conditions caused by phytoplankton blooms in the area, such as low oxygen pressure. Consequently, the benthic organisms in the area are probably adapted to the specific environmental conditions of the aquatorium. On the other hand, in the conditions of stratification, the possible unfavourable effects of pollution and/or eutrophication are limited to surface and intermediary levels of the water body and therefore can have a minor influence on benthic populations.

Effects of pollution on benthic communities:

(a) The biocoenosis of supralittoral rocks: It was found that supralittoral rocks are affected by polluted water only sporadically, i.e. at the time of stormy weather. Therefore, at many sites in the area investigated, the supralittoral rocks are speckled by tar and oil deposits, especially in the vicinity of Rijeka and its petroleum refineries. By rule, tainting is fatal to the organisms thus contaminated; only rarely, however, was the mortality of barnacles covered by thin tar deposit noted. In January 1977, an oil spill of about 500 t occurred offshore in the Rovinj area; luckily, this spill tainted only a few localities on the coast. Therefore, littoral communities were not affected, but a great mortality of cormorants was noted. Near Rovinj, due to constant deposition of fats and amino-acids from effluents to the 'Mirna' fish cannery, the communities in the midlittoral and supralittoral zones have been completely destroyed.

(b) The biocoenosis of midlittoral rocks: The structures and distribution patterns of several facies of this biocoenosis indicate that the effects of complex pollution take place above all in the vicinity of large urban and industrial complexes. Therefore, the nitrophile seaweed associations based on Ulva and Enteromorpha are distributed in a nearly continuous belt along the entire northern and north-western coast of Rijeka Bay. In the surroundings of Rovinj, the nitrophile midlittoral associations are distributed in the vicinity of the town, on the shore and around the sewage outlets of numerous hotels, camps and similar tourist places. For the time being, the south and south-western parts of Rijeka Bay seem to be unaffected by the complex municipal and industrial pollution. In the region of Rovinj, the areas of Limski kanal, outer islets of the archipelago, and the area south of the Polari tourist campus, are relatively clear.

(c) The community of Cymodocea nodosa: The eelgrass Cymodocea nodosa is tolerating unfavourable effects of complex pollution much better than most seaweed species, especially Cystoseiras. Therefore, the importance of eelgrass meadows as the source of organic detritus in pollution-stressed areas can be considerable. In Rijeka Bay, however, the Cymodocea meadows are distributed only in its eastern part, and they are almost completely absent in other parts of the Bay. In consulting previous literature (Vouk, 1915; Benacchio, 1938), the regression, or even the disappearance, of eelgrass populations is reported along the western coast of Rijeka Bay and in the Bay of Bakar (Zavodnik et al., 1978). In the Rovinj area, the meadows of *Cymodocea nodosa* have also disappeared at many localities, and only the population in Faborsa cove kept its structure and the area occupied. It is supposed that the disappearance of *Cymodocea nodosa* in the Bay of Bakar is caused by pollution (oil, siltation). To our regret, the problem of the general reduction of *Cymodocea* populations in other parts of the investigated areas could not be explained by present research.

(d) The biocoenosis of coastal terrigenous zone: Near Rijeka harbour, and in the vicinity of several tourist resorts, here and there heaps of crude wastes and a lot of charcoal can be found on muddy bottoms; so far, however, no significant effects of these wastes on endopelic infauna can be established. Also, it seems that, below the 30-40 m depth, the communities are not affected by complex urban/industrial pollution, even in the immediate vicinity of the town of Rijeka. This phenomenon is, in all probability, related to specific hydrodynamic conditions in the area, especially to surface and mid-water currents.

CONCLUSIONS

In the offshore waters of the northern Adriatic, during the period of investigations (1976-1980), several extraordinarily high phytoplankton blooms occurred which were accompanied by an extreme deficiency of oxygen, high pH and high nutrient content in sea-water.

At some localities in the coastal waters of West Istria, further reduction of eelgrass communities and large-scale changes in midlittoral populations were noted.

In Rijeka Bay, no modifications in faunal composition of oozy bottoms occurred, which could be related to complex pollution of the area.

PUBLICATIONS

DEGOBBIS, D., POJED, I. and SMODLAKA, N., 1979. Non-seasonal phytoplankton bloom in the Northern Adriatic (abstract). Nova Thalassia, 3 (Suppl.):321 p.

DEGOBBIS, D. *et al.*, 1979. Increased eutrophication of the northern Adriatic Sea. Mar. Poll. Bull., 10(10):298-301.

ZAVODNIK, D., 1977. Benthic communities in the Adriatic Sea: reflects of pollution. Thalassia Jugosl., 13(3/4):423-32.

ZAVODNIK, D., 1979. Stanje priobalnih zivotnih zajednica morskog dna u sjevernom Jadranu (The state of coastal benthic communities in the northern Adriatic). Zbornik II Konf. o zastiti Jadrana, 2:429-34.

ZAVODNIK, D., 1979a. Utjecaj otpadnih voda na biocenoze morskog dan (The effects of sewage on benthic biocoenoses). Zbornik III konf. SITH o tehnoloskom razvoju SR Hrvatske, 2(3.8):1-13

ZAVODNIK, N. and ZAVODNIK, D. 1979. The benthos of Rijeka Bay - subject to stress of pollution. Comm. int. Explor. sci. Mer Médit., IVes Journées Etud. Pollutions, Antalya, pp. 405-10.

ZAVODNIK, N. and ZAVODNIK, D. 1979, Zivotne zajednice morskog dna u slozenim uvjetima zagadjivanja Rijeckog zaljeva (Benthic communities in complex conditions of pollution in Rijeka Bay). Zbornik II konf. o zastiti Jadrana, 2:415-21.

ZAVODNIK, D. *et al.*, More Poluotoka Istre (The sea of the Istrian peninsula). Izd. Jugosl. Akad. znan. umjet. (In press).

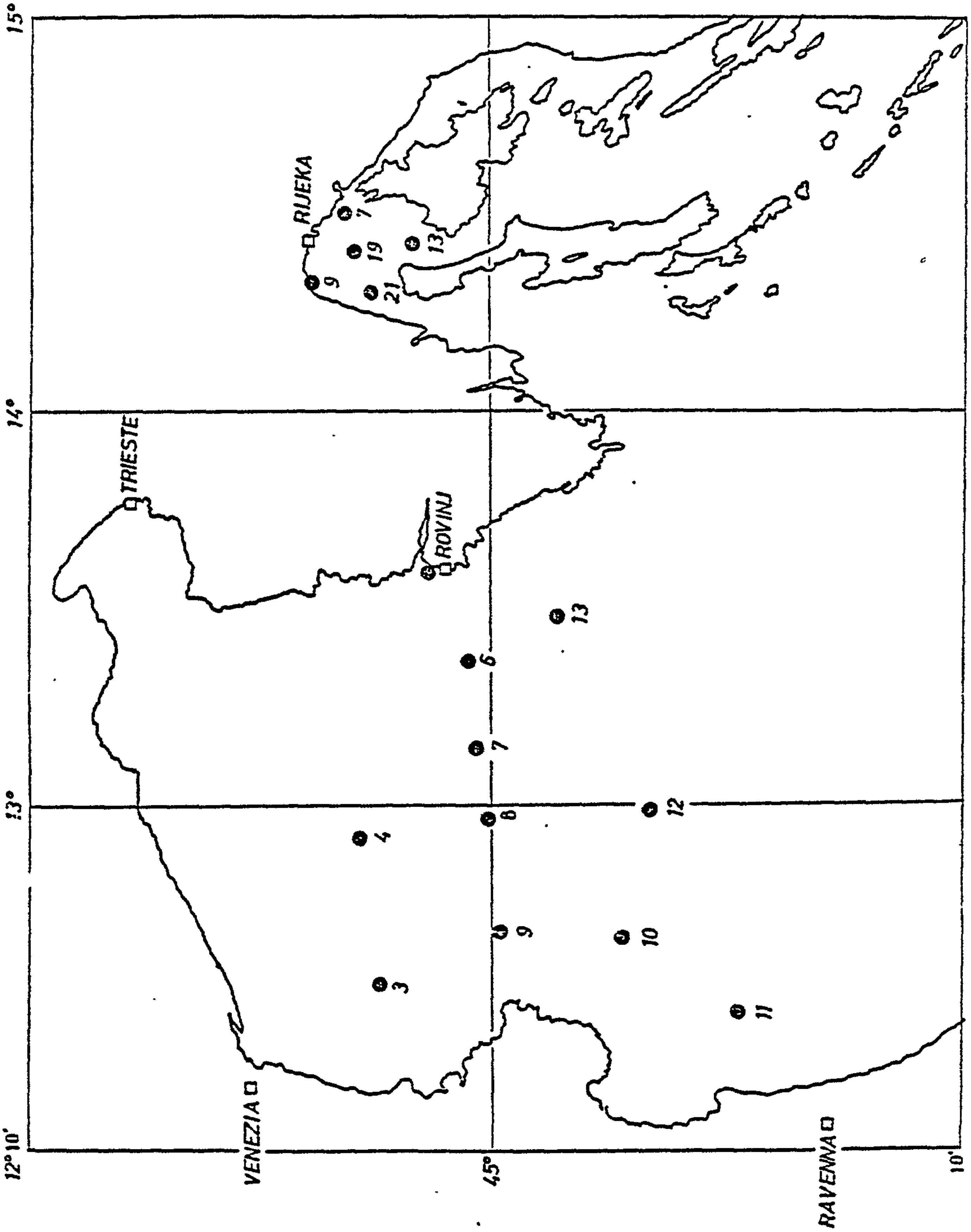


Fig. 1. Areas studied

PUBLICATIONS IN THE MAP TECHNICAL REPORTS SERIES

No. 1 UNEP/IOC/WMO: Baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters (MED POL I). MAP Technical Reports Series No. 1. UNEP, Athens 1986.

No. 2 UNEP/FAO: Baseline Studies and Monitoring of Metals, particularly Mercury and Cadmium, in Marine Organisms (MED POL II). MAP Technical Reports Series No. 2. UNEP, Athens 1986.

No. 3 UNEP/FAO: Baseline Studies and Monitoring of DDT, PCBs and Other Chlorinated Hydrocarbons in Marine Organisms (MED POL III). MAP Technical Reports Series No. 3. UNEP, Athens 1986.

No. 4 UNEP/FAO: Research on the Effects of Pollutants on Marine Organisms and their Populations (MED POL IV). MAP Technical Reports Series No. 4. UNEP, Athens 1986.

PUBLICATIONS "MAP TECHNICAL REPORTS SERIES"

No. 1 PNUE/COI/OMM: Etudes de base et surveillance continue du pétrole et des hydrocarbures contenus dans les eaux de la mer (MED POL I). MAP Technical Reports Series No. 1. UNEP, Athens 1986.

No. 2 PNUE/FAO: Etudes de base et surveillance continue des métaux, notamment du mercure et du cadmium, dans les organismes marins (MED POL II). MAP Technical Reports Series No. 2. UNEP, Athens 1986.

No. 3 PNUE/FAO: Etudes de base et surveillance continue du DDT, des PCB et des autres hydrocarbures chlorés contenus dans les organismes marins (MED POL III). MAP Technical Reports Series No. 3. UNEP, Athens 1986.

No. 4 PNUE/FAO: Recherche sur les effets des polluants sur les organismes marins et leurs peuplements (MED POL IV). MAP Technical Reports Series No. 4. UNEP, Athens 1986.

Issued and printed by:

Mediterranean Action Plan
United Nations Environment Programme

Additional copies of this and other publications issued by
the Mediterranean Action Plan of UNEP can be obtained from:

Co-ordinating Unit for the Mediterranean Action Plan
United Nations Environment Programme
Leoforos Vassileos Konstantinou, 48
116 35 Athens
GREECE

Publié et imprimé par:

Plan d'action pour la Méditerranée
Programme des Nations Unies pour l' Environnement

Des exemplaires de ce document ainsi que d'autres
publications du Plan d'action pour la Méditerranée
du PNUE peuvent être obtenus de:

Unité de coordination du Plan d'action pour la Méditerranée
Programme des Nations Unies pour l' Environnement
Leoforos Vassileos Konstantinou, 48
116 35 Athènes
GRECE