United Nations
Environment
Programme

UNEP(OCA)/MED WG.4/2
5 June 1989

Original: ENGLISH

MEDITERRANEAN ACTION PLAN

Meeting on the Implications and Control
of Undesirable Plankton Blooms

Athens, 4-6 April 1989

REPORT OF THE MEETING ON THE IMPLICATIONS AND CONTROL OF UNDESIRABLE PLANKTON BLOOMS

UNEP
Athens, 1989

TABLE OF CONTENTS

INTRODUCTION

The problem of undesirable plankton blooms, which had aggravated in recent years in the Mediterranean and other areas, was raised and widely discussed at various meetings organized in the framework of the Mediterranean Action Plan.

A Meeting on Eutrophication in the Mediterranean Sea, dealing with the scientific aspects of the problem, had already been held in Bologna, Italy, in March 1987, in the framework of the Med Pol activities.

At the Meeting of the Expanded Bureau of the Contracting Parties to the Barcelona Convention (Athens, 1-2 November 1988), the problem of eutrophication and concomitant plankton blooms was again discussed and the Mediterranean Coordinating Unit was urged to take the initiative to formulate proposals for remedial actions. As a first step, the Coordinating Unit was asked to organize a meeting on the subject.

In compliance to this decision, the Coordinating Unit together with FAO, IOC and WHO jointly convened a Meeting on the Implications and Control of Undesirable Plankton Blooms which took place in Athens, at the premises of the Coordinating Unit, from 4 to 6 April 1989.

The objective of the meeting was to concentrate on the practical issues of the problems of Mediterranean plankton blooms, to discuss the need and the preparation of guidelines for detecting and monitoring eutrophication including the selection of priority parameters for its qualitative and quantitative identification, to discuss possible measures for alleviating the effect of the phenomenon and to discuss and review the exchange of information and close cooperation with existing national and international projects.

SUMMARY REPORT

1. A meeting of experts on Implications and Control of Undesirable Plankton Blooms, jointly organized by UNEP, FAO, IOC and WHO, was held in Athens at the Office of the Coordinating Unit for the Mediterranean Action Plan, from 4 to 6 April 1989.

2. The meeting had been called by the Coordinating Unit as a response to its formal approval by the Expanded Bureau of the Contracting Parties to the Barcelona Convention (Athens, 1-2 November 1988). Twenty-one experts from six Mediterranean countries and three U.N. organisations attended the Meeting (see annex I). The Agenda adopted by the Meeting appears as annex II.

3. Mr A. Manos, Coordinator of the Mediterranean Action Plan, opened the Meeting and welcomed the participants on behalf of the Executive Director of UNEP. He referred to the recommendations of the meeting on Mediterranean Eutrophication held in Bologna in 1987 and stressed that the present meeting was using them as starting point in order to propose some practical actions. He stressed that while the phenomenon was still not fully understood, any clearly identified contributing factor of anthropogenic nature should be reduced. He concluded that the meeting should also identify priorities for further study which could be contracted to laboratories and institutions with the necessary technical and financial resources.

4. He reminded the meeting that the rules of procedures for the meeting would be the same as those used for all meetings of the Contracting Parties to the Barcelona Convention.

5. Mr S. Maestrini was elected chairman and Mr D. Degobbis rapporteur of the meeting.

6. The proposed agenda was adopted without any change and the meeting agreed to work only in plenary session with the option of convening small working groups, if necessary.

7. The participants reviewed the work being carried out at their respective institutes which is reported in annex III to this report. The coordinating work and the activities carried out by international bodies and organisations were also reviewed.

8. A lengthy discussion was held on causes and effects of plankton blooms as well as on preventive and remedial actions. In this connection some basic gaps and problems were identified by the meeting e.g., the understanding of the extent of the anthropogenic influence on plankton blooms, the lack of coordination between research as well as monitoring groups, the lack of common methods of sampling and analysis and the consequent non-comparability of results. The meeting also agreed on a draft outline to be used in the assessment document to be prepared as part of the LBS protocol implementation (see annex IV). A research proposal entitled "Prevailing terrigenic factors of enhancedeutrophication in critical pelagic environments

of the Mediterranean neritic zone" was presented by Mr. J. Stirn (annex V). The meeting supported the proposed programme stressing that its eventual results would considerably help the understanding of the problem of eutrophication in the Mediterranean Sea.

9. The meeting considered the coordination between ongoing programmes in the Mediterranean and elsewhere as priority, and agreed that the MAP Coordinating Unit should play an active role in the regional collection and dissemination of results of monitoring and research programmes. In this connection, a form for the collection of data was agreed upon (see annex VI) and its use by all Mediterranean groups was recommended.

10. As a result of the discussions, the meeting agreed on a set of recommendations which identified practical actions and priority areas of study (paragraphs 13 - 29).

11. No other business were raised by the meeting and the participants agreed to adopt only the recommendations and not the summary report which would be circulated at a later stage.

12. The meeting was closed at 13.00 hours of 6 April 1989.

CONCLUSIONS AND RECOMMENDATIONS

13. The meeting agreed on the need to pay particular attention to toxic and non toxic algal blooms linked to eutrophication and the increase in cellular density of certain toxic species such as Dinophysis and Alexandrium minutum; however, the deterministic character of their appearance was still not well known; because of these gaps, theories could not be built to allow effective measures to be taken against their occurrence.

14. On the basis of the results presented during the Bologna Workshop in 1987 and of the discussions which took place during this Workshop, the meeting noted that the algal blooms which have undesirable consequences increased in frequency and area in the coastal waters of most Mediterranean States.

15. The waters affected belonged, generally speaking, to geographically enclosed areas (lagoons, bays and gulfs) or areas temporarily immobilized because of special hydrodynamic conditions (e.g. the Emilia Romagna coast). In addition, such areas generally were known to receive considerable external inputs of biogenic elements.

16. On this basis, the meeting considered that action was needed at national and international level in order to:

- preserve the oligotrophic ecosystem considered as the main characteristic of the natural inheritance of a large part of the Mediterranean Sea as well as an essential resource for the national economies;

- prevent any further increase of eutrophication phenomena in certain areas where the eutrophication already presents a hindrance and/or negative impact upon fisheries and mariculture, tourism and recreation, thallasotherapeutic use of sea water as well as a potential health hazard, particularly as related to eventual toxicity of sea food.

17. Recognizing largely known difficulties marine ecologists are faced with while attempting to distinguish between man-made eutrophication and consequences of purely natural variability and long-term fluctuations, for the majority of relevant cases in the Mediterranean region, a scientifically justified judgement appeared feasible with a proper analysis of existing data. Some cases such as the increasingly frequent planktonic blooms in open sea areas may be assessd only on the basis of results expected from further research and long-term monitoring of selected parameters at selected sites covering the identified areas at assumingly critical eutrophication levels and comparable reference areas, free of pertinent man-made environmental modifications.

GENERAL

18. Before any practical action is taken which would aim at reducing or eliminating algal blooms, the meeting recommended that:

(i) the inputs in biogenic elements be calculated by including all chemical forms (i.e. dissolved, particulate, mineral, organic) in the water column and the mobilizable fraction of sediments, especially as concerns nitrogen and phosphorus and that silicon be taken into consideration in the calculations;

(ii) the relative value of external inputs be calculated in relation to the natural pool. A decrease in inputs would in effect not have any practical interest unless these inputs would be at least as considerable as the natural pool.

19. (i) In any event, all discharges, direct or indirect through water courses should be prohibited in enclosed or semi-enclosed areas of a limited surface, where the self-cleaning capacity is saturated. A study of the hydrographic structure of such areas should also be made. Furthermore, in areas where episodes of eutrophication and plankton blooms are regular events, it was suggested to reduce local input of nutrients by at least 50 percent.

(ii) Taking into consideration that certain factors are recognized as possibly facilitating the development of phytoplanctonic disturbances, the meeting recommended, wherever possible, the promotion of all measures which would prevent or correct density stratification of the environment and which would lessen the confinement of the waters through any hydraulic arrangement which would be likely to increase water circulation.

(iii) The meeting also recommended intervention, whenever possible and after making an estimation of possible negative effects, on the natural cycle of the environment, either through direct elimination of biogenic elements (dredging, burying of sediments), or indirectly through the development of shellfish - growing activities; the latter would on the one hand make possible the recovery of biogenic elements as an economic resource and on the other the reconcentration of biogenic material at the level of sediments. It is hoped that the European Community, within the framework of the MAST and STEP programmes, will consider the study of this type of intervention.

20. The cooperation among projects studying eutrophication and plankton blooms should be enhanced by exchange of information and regular meetings of experts especially in concomitance with exceptional phenomenas in order to identify possible causes and environmental conditions. MAP secretariat should prepare and distribute questionnaires to governmental offices and scientific institutions in order to collect and disseminate information on past and ongoing programmes on undesirable plankton blooms.

21. Considering that the problems of eutrophication and plankton blooms is already a serious and complex problem in the Mediterranean and that it is expected to worsen in the next years, the meeting recommended the establishment of a working group of specifically competent ecologists and oceanographers from the Mediterranean region who would have the responsibility to propose activities, projects and organizational details to be submitted to the MAP Coordinating Unit for consideration and eventual approval.

22. The establishment of a Centre for the toxonomic identification of species causing blooms is highly recommended.

23. It was suggested to start multidisciplinary studies (preferably together with international teams) in those areas markedly affected by external nutrients and in which significant restoration activities were planned. The studies would provide a model of ecosystem functioning in different nutrient load conditions, and offer information on the effects of reducing nutrient load compared to those due to changes of oceanographic and climatic conditions, e.g. the northern Adriatic, since a large restoration recovery program of the Po River, the largest external nutrient source in the region, has been launched.

MONITORING

24. It was recommended that for Mediterranean sites known to be affected by frequent plankton blooms, a collection of coordinated and comparable information should be made on agreed forms containing physical and biological data which would give a full picture of the geomorphological, environmental and biological characteristics of the bloom area.

25. It was recommended that continuous recording sensors be developed and implemented in particularly sensitive areas at least during critical periods. In particular, continuous monitoring should be implemented including stratification of density, velocity field, dissolved oxygen in the bottom layer and chlorophyll. Specific monitoring campaigns should allow the intercalibration of instruments and the collection of samples needed for the study of biogenic compounds and of phytoplankton quantity, structure and density as well as the dominant species.

26. A Standard Reference Method on eutrophication monitoring should be developed. It should include, among others, sampling strategies, methods of measurement (including aerial surveys) and interpretation of results.

27. On the long-term, any effort should be made to establish simultaneously in several Mediterranean areas, both affected and unaffected by external nutrient sources but particularly in those already contaminated by plankton products, a plankton bloom monitoring programme, based on essential but reliable set of parameters and conducted with a common methodology.

28. Such a monitoring would be useful for some practical purposes:

a) these activities should represent an early warning system, efficient at least in already well investigated regions (Adriatic and Aegean areas, Gulf of Lyon, etc);

b) monitoring would provide comparable data, useful to evaluate the regional scale of undesirable events, as well as the relative importance of natural (e.g. unusual oceanographic and climatic conditions) and anthropogenic factors;

c) the comparison between data from different areas would contribute to put in evidence common and/or specific characteristics of each area and give indication for specific field and laboratory experiments to explain plankton bloom mechanisms;

d) such a monitoring would provide evidence of the relative importance of different external sources of nutrients indicating priorities of interventions.

29. Monitoring of toxic plankton species should be intensified and enlarged to those areas in which they did not yet occur but changes in the plankton composition were observed.

ANNEX I

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ANNEX III

Review of work being carried out in the Mediterranean

EUTROPHICATION IN EGYPTIAN MEDITERRANEAN WATERS

Y. Halim

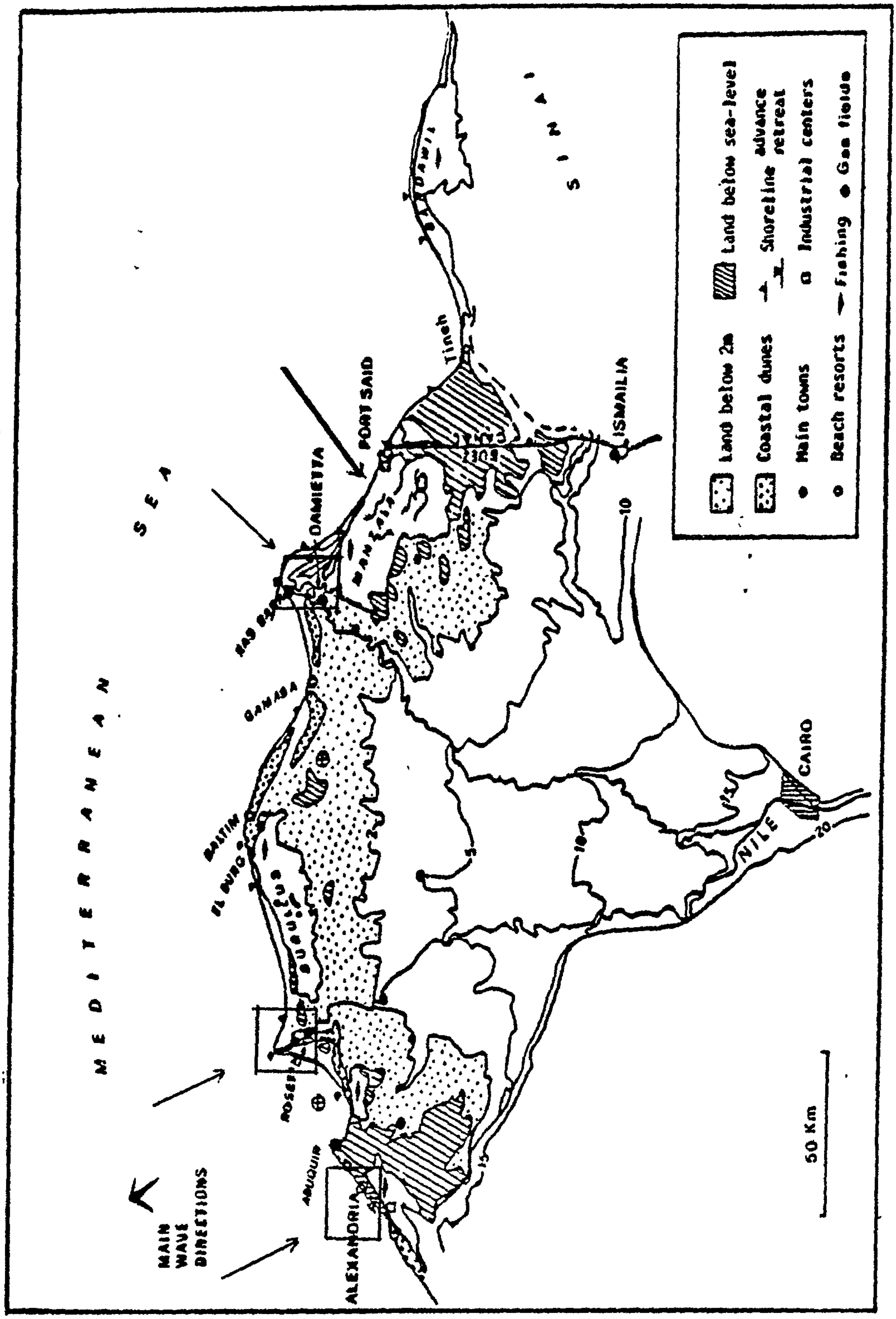
Abnormally dense phytoplankton blooms with occasional undesirable effects occur in at least three areas: Menzala lagoon, the Nile estuaries and the Eastern Harbour of Alexandria (see fig.).

The brackish Menzala lagoon (about 2000 sq.km) is located between the Nile delta and the Suez Canal and drains millions of cube meters of agricultural runoff, with its heavy load of agrochemicals and humic materials. It is in a steady state of abnormally high phytoplankton production. The standing stock however shows pronounced fluctuations caused by the dense populations of herbivores (Cladocerans, Rotifers, Copepods). Successive fluctuations in the stock of both microalgae and hebrivores recall the predator - prey model. The lagoon appears to be in equilibrium, but observations over two decades point to a slow decrease in relative oxygen saturation and an increase in the average nutrient concentrations. The relatively high flushing rate is a decisive factor for maintaining healthy conditions in this lagoon.

The lower reaches of the two Nile branches (about 20-30 km) are cut off from the river by dams and barrages. They present fjord-like conditions, with a two-layer structure. The surface layer is strongly diluted by agricultural runoff from neighboring fields, with an abnormally high phytoplankton standing crops of mixed marine and brackish water species (Diatoms and cyanobacteria). The saline lower layer (below 3m) is anoxic, with formation of hydrogen sulphide over the bottom.

The Eastern Harbour of Alexandria is a semi-closed bay receiving a heavy load of domestic waste water. Its flushing rate is approximately twice a year. It is in steady state of abnormally dense blooming, occasionally checked by herbivores. The sea-water bottom layer is poorly oxygenated and the sediment anoxic. In this bay outbreaks of red-tides caused by Alexandrium minutum are a recurrent summer phenomenon since first observed in 1957. Fish-kills occur, caused by clogging of the gills, but no toxicity has been reported.

It is concluded from the three cases outlined that eutrophication is the result of a combination od factors: (1) a heavy load of terrigenous input, agricultural runoff or domestic sewage or both, (2) an excess of plant production over consumption or oxygenation, (3) the water body is always horizontally bounded either by a physical barrier or a water front and vertically by a pycnocline. Stable stratifications and a low flushing-rate are necessary conditions for the outbreak of red-tides or eutrophic blooms, (4) higher temperature (See Fig.).


MEDITERRANEAN SEA
SINAI
Land below 2m
Land below sea-level
Coastal dunes
Shoreline advance retreat
Main towns
Industrial centers
Beach resorts
Fishing
Gas fields
PORT SAID
DAMIETTA
ISMAILIA
Tineh
MANZALA
RAS EL BAR
GAMASA
BALTIM
EL BURG
BURULLUS
ROSETTA
ABUQUIR
ALEXANDRIA
CAIRO
NILE
MAIN WAVE DIRECTIONS
50 Km
10
15
20

STATE OF THE EUTROPHICATION PROBLEM IN FRANCE

Leveau M., Maestrini S., Nival P., Romana A.

General aspects

"Discolored seawater" and/or harmful algal blooms have probably occurred along the coast of France since long time ago. However, since beginning of regular survey (1975), 26 events have been reported for the Mediterranean, and 185 for the Atlantic coast. (Fig. 1). During this period (i) the total annual number of events has regularly increased (Fig. 2), (ii) with fractional growing importance of Dinoflagellates, (iii), especially species belonging to the genus Dinophysis (Fig. 3, 4).

From routine measurements, two important features appeared: (i) toxic blooms are not directly related to anthropogenic nutrients leads in coastal environment (see Fig. 5 and 6), and (ii) areas where heavy grazing is acting are free from deleterious effects from bulk discharges (see Fig. 7, bassin de Marennes-Olesen, where 54000 $T.y^{-1}$ NO_3 are released by the Charente River, but where 94000 T. of oysters are actively filtering the suspended water; residence time of water is there ≈ 5 days).

Mediterranean aspects (French Coasts)

On French Mediterranean coasts, the phenomena of eutrophication and the flourishing of toxic or non-toxic algae exist widely, but do not affect all coastal zones in a permanent fashion. However, all the known effects of eutrophication, including dystrophy, have been observed at regular intervals. The range of possible effects is therefore wide; from a simple enrichment in biogenic elements without any immediate visible effects on the marine environment, to the excessive development of toxic algae (Dinophysis) in shellfish producing areas, passing through the excessive growth of SH_2. These are symptoms of "malaïgues", or "bad water", which is at the origin of the death of high densities of shellfish.

The causes of eutrophication are well known, even if they are not always quantified: natural effluents, urban and industrial waste, deposits carried by the sea-bed as a consequence of excessive mineralisation, atmospheric deposits. Moreover, whatever the quantity of biogenic element deposits, their effect varies in time and space according to local climatic and meteorological conditions, the season, and also the geomorphological and hydrological structure of the affected environment (open sea, bay, coastal lagoons).

In France, in order to apprehend these phenomena and try to fight against their appearance, the consequences of which may be catastrophic for the economy and our biological heritage, various administrative and scientific structures have been put into place with the aim of surveying the causes and effects on the affected environment (Agences de Bassin, Réseau National d'Observation du Milieu Marin, Côntrole et Surveillance des Ressources et de leur Utilisation - Basin Agencies, National Marine Environment Surveyance Network, Inspection and Surveyance of Resources and their Utilization,...)

Overall look at existing problems

The French Mediterranean coast areas can be ground into three main zones:

- The western zone stretching from the Spanish frontier to the outlet of the Rhône. It is characterised by the presence of a large number of coastal lagoons, an extensive continental shelf, a largely non-developed industrial make-up and a very small number of large towns dumping their sewage directly into the sea.
This continental shelf is largely affected by deposits from the Rhône which amass the agricultural, urban and industrial waste from a 95 000 km2 depositing basin.
- The eastern zone which stretches from the Rhône to the Italian frontier (Côte d'Azur) has a diminished continental shelf and receives direct waste from the large coastal towns (Marseille, Toulon, Cannes and Nice), as well as that from the important industrial zone in the Fos region.
- Corsica, with its few coastal lagoons (Diana, Urbino), its towns (Bastia, Ajaccio) and a low degree of industrialisation.

From east to west on the French Mediterranean coasts the problems of eutrophication and the flourishing of algae come head to head in (see Figure 1):

- The coastal lagoons of Languedoc-Roussillon.
- The outlet of the Rhône and its immediate surroundings.
- The Etang de Berre (Berre Lagoon; coastal lagoon).
- Major urban coastal effluents.

Deposits of biogenic elements

Figure 8 shows the data concerning deposits of nutritive compounds, evaluated solely in the zones experiencing eutrophication problems. For coastal lagoons in the Languedoc-Roussillon area, no reliable data is available due to the difficulty in formulating an appreciation of the generally large and periodical deposits produced during storms. For the other sites, more precise information is available, allowing us to calculate Mediterranean deposits. We may note, that the majority of nitrogenous and phosphorous deposits (70%) come from the Rhône. However, the chemical make-up of the main nitrogenous deposits varies according to their source: amoniacal in urban waste, nitrates in deposits from the Rhône. Concerning phosphorus, it must be pointed out that 12 out of 15 metric tons per day brought in by the Rhône are the product of localised industrial activity downstream from Lyons.

The eutrophication situation in each coastal area evaluated in terms of chlorophyllous biomass or cellular density is shown at the base of Figure 1. Unfortunately, little data exists concerning primary pelagic production which would allow for a better appreciation of the eutrophic nature of these different sources. Apparently, it is the closed sites (coastal lagoons) which represent the greatest problem.

The effects

In Figure 9 we have resumed the main undesirable effects of the "phytoplankton blooms" for the different Mediterranean sites. We have categorised the effects in accordance with the headings suggested by J. Stirn (1988) to which we have added a fifth one: - Effects on human health; - Loss in production of living resources; - Drop in touristic and recreational activity; - Damage to the ecosystem; - Direct economic consequences.

Effects on human health

We possess few examples concerning direct effects on human health, with the exception of a few cases of poisoning due to the ingestion of mussels contaminated by Dinophysis sp. in the region situated outside the Etang de Thau (Thau Lagoon). Moreover, child-allergies have been reported in the Cannes area.

Loss in production of living resources

French marine lagoons have an economically important part to play. Apart from touristic activities, the lagoon has three major roles:

- It is a refuge zone for the young of economically important species, who return there frequently in order to feed and hence complete their biological cycle.
- It is a highly lucrative fishing zone.
- Certain lagoons (The Thau Lagoon in particular) support a considerable amount of marine industry (mussels and oysters).

Among these lagoons, the Thau Lagoon has an estimated annual production of 17 to 20 000 metric tons of hollow oysters and 8 000 metric tons of mussels. From a biological viewpoint, the Thau Lagoon is characterised by a high trophic capacity and major dystrophic crises of which the most famous, the "malaïgue" phenomenon (Provençal for "bad water") occurs periodically, usually during the summer period, accompanied by particular climatic conditions: absence of wind over a long period accompanied by strong sunshine. The organisms death-rate is concomitant with a progressive colouring of the water, purple-red in small; lagoons and white in the Thau Lagoon. This colouring depends, moreover, on the species of bacteria concerned.

The "malaïgue" is a permanent menace to a number of producers of shellfish. Over the last fifteen years, the malaïgue appeared in 1975, 1982 and 1987. In 1987, losses were estimated at 10 000 metric tons. No known means of defence exists against the malaïgue. The term "malaïgue" describes any of these four phenomena which follow on from each other:

- The eutrophication of the environment. In certain lagoons, the deposits of nutritive salts and organic matter resulting from industrial, urban and agricultural activity has led to an excessive enrichment of the environment. This richness affects the phytoplankton in deep lagoons (as in the case of the Berre or Thau Lagoons), with the appearance at times during the summer period of the classic "coloured waters", which are generally non-toxic. In shallow lagoons, this enrichening benefits bentic algae of the enteromorphic type or green algae (Ulva lactuca).

- Water anoxy.
- Reduction in compound oxydes.
- Sulphoxydising bacteria. The production of sulphur allows for the development of phototrophic bacteria (capable of using light energy), generally of the Thiocapsa type (Caumette, 1986), and capable of oxydising the H_2S into molecular sulphur (S) or sulphate in an anaerobic environment. It is the proliferation of these bacteria which is responsible for the purple or white colouring of the sea water. Their appearance corresponds, in fact, to the beginning of the restoration of the environment after the dystrophic crisis. From an economical viewpoint, it is these first three stages which constitute the root of the problem.

Drop in touristic and recreational activity

Visible and olfactory disturbances have been at the origin of a number of occurrences along the French coastline. Let us point out in particular the appearance of coloured water (red tide) at Noctiluca sp. in July 1984 between the Rhône and Marseille, and of the almost permanent presence of coloured water at Prorocentrum minimum and Chlorella sp. in the Berre Lagoon).

Damage to the ecosystem

Of all the French Mediterranean zones, the Berre Lagoon is that which has undergone the most major disturbances from the point of view of bentic ecosystem modification. This lagoon, covering an area of 15.500 hectares and of a maximum depth of 9 m. receives urban waste (from 11 communes totalling the equivalent of 220 000 inhabitants), the deposits from three rivers (depositing basin of 155 000 hectares of 5 hydroelectric power-plant. The lagoon communicates with the sea by means of a navigational channel of 9 m in depth,. The diversion from the Durance represents an annual discharge equivalent to four times the volume of the lagoons; the significance of these discharges (up to 800 m^3/s) and the great difference in salinity in the vertical plane induce the formation of a highly distinctive stratification density. The enrichment of the lagoon as a result of the direct (industrial and urban) or indirect (streams, rivers and waterways) dumping of organic matter and nutritive salts has led to a progressive eutrophication of the environment. The breaking down of the dumped or "in situ" created organic material leads to an important consumption of the oxygen dissolved at depth, aggravated by the presence of the gradient density which prevents reoxygenation by the surface. As a consequence, the Berre Lagoon is often in an anoxic state, particularly during the summer period.

Since 1972 important efforts have been carried out to reduce the effects of industrial and urban waste, leading to a reduction of more than 90% in the dumping of organic matter. The main results of studies carried out since the 1970's can be resumed as follows:

- Deposits of nutritive salts and organic matter (Figure 1) are significant; due to its rate of discharge, the Durance contributes essentially to these deposits in spite of the low dosages found in its waters. Our knowledge is at present insufficient to allow us to estimate the percentage of deposit from the Durance contributing to the enrichment of this semi-closed lagoon environment in relation to the percentage rejected into open sea.

- The lagoon waters are extremely rich in organic matter and nutritive salts. This eutrophication is represented by the progressive appearance of anoxies and phenomena such as that of coloured water and surface foam in summer-time.

- The macrobentic populations have more or less disappeared (70% of beds are biotic). The remaining populations have highly deteriorated. The reasons for this situation are multiple: alterate salting - desalting, eutrophication and anoxy of beds, chemical contamination resulting from high industrial activity, and sedimentary instability due to the extension of silting.

Direct economic consequences

The appearance over the last few years of toxic blooms has led the authorities to set up a quality control network for the overseeing of French shellfish. This system resolves the "human health" aspect, yet gives rise to another problem, this time of an economic nature, linked to the non-commercialisation of the shellfish at risk, in particular at economically viable periods. As a result, the number of non-saleable days has risen from 7 to over 90 in the space of three years on the Carteau site.

The ever-increasing incidence of foam in the Berre Lagoon, as a consequence of phytoplanktonic excretions, constitutes a considerable handicap during the pumping of water for industrial cooling purposes. It also represents a considerable financial loss resulting from the partial stoppage of pumping equipment.

Surveyance programmes

There are three surveyance programmes concerning the eutrophication problem.

1. Rivers "Réseau National de Bassins" (Figures 10, 11, 12)- Initiated 1971. Dedicated to rivers, but data can be used for calculating river outputs into marine waters 15 Mediterranean rivers monitored 4-12 sampling campaigns per year. One survey per year at key locations once every three year at others. No special attention to industrial and domestic wastes.

2. Coastal marine environment R.N.O. (figure 13) - Initiated on 1974. Monitoring of potentially-polluting elements (Cd, Cu, Hg, Zn...) and substances (PCB, DDT...)

- in oysters and mussels: 14 Mediterranean stations, 4 times $.y^{-1}$

- in sediments: 14 Mediterranean stations, once a year

- in surface water: 5 Mediterranean stations; 6-12 campaigns per year
- in addition: nutrients, chlorophyll $\underline{a}$ S°/oo, O_2

3. Survey of harmful algal blooms and shellfish toxicity C.S.R.U. (figure 14) - Initiated in 1984. Since 1988 : 6 Mediterranean stations.

- Survey (routine) system:

One sampling per week from April to September. Two samplings per month from September to April. Phytoplankton cell counting/microscope) + t°C, S°/oo

- Emergency strategy:

Increase of sampling sites, and frequency (2 or more per week) counting of toxic cells in mussel stomachs + mouse test for D.S.P.

Recommendations:

1. need for observations at sea:

When a bloom of undesirable species is visible to the users of the sea water either for recreation, or for growing food species, it is usually too late to make the necessary observations to understand the mechanisms involved.

It is recommended to make routine measurements of basic parameters in selected area:

- nutrients
- amount of herbivorous zooplankton
- amount of chlorophyll
- numbers of species

2. need for research on mechanisms

The undesirable species are rarely species cultivated in the laboratory at the present time. It is necessary to estimate:

- the possibility to extrapolate the known physiological functions to them (nutrient assimilation versus nutrient concentration, growth rate versus temperature, photosynthetic rate versus light, etc.)
- the ability to live in high light intensity
- the ability to store nutrients

3. need to detect the direct influence on other components of communities:

   - study the competition with normal components of the biomass
   - determine the chemical nature of excretats of the undesirable species.

4. need to know the life cycle of the species:

   - determine the sexual phase of the species
   - determine the ability to make resting stages (diapause)

5. need of long term studies with the aim of detecting the start of a bloom of undesirable species:

   - the observation point (or grid) must be located in an area where such blooms have been noticed (high probability of occurrence);
   - the time interval between samples must be short relative to the time needed to the development of the bloom (from daily to weekly sampling);
   - the sampling frequency must be increased some time before the period of high probability of occurrence of the species;
   - the best compromise between cost (money and man-hours) and sampling frequency should be determined before sampling with the aim of detecting the start of a rapid and exponential phenomenon.
   - existing data bases should be analysed to look at correlation between occurrence of undesirable species and modification of parameters of the environment, and they should be published.

6. need for the development of automatic sampling and observation devices.

   - development of buoys with sensors must be designed to measure to help counting in the laboratory.

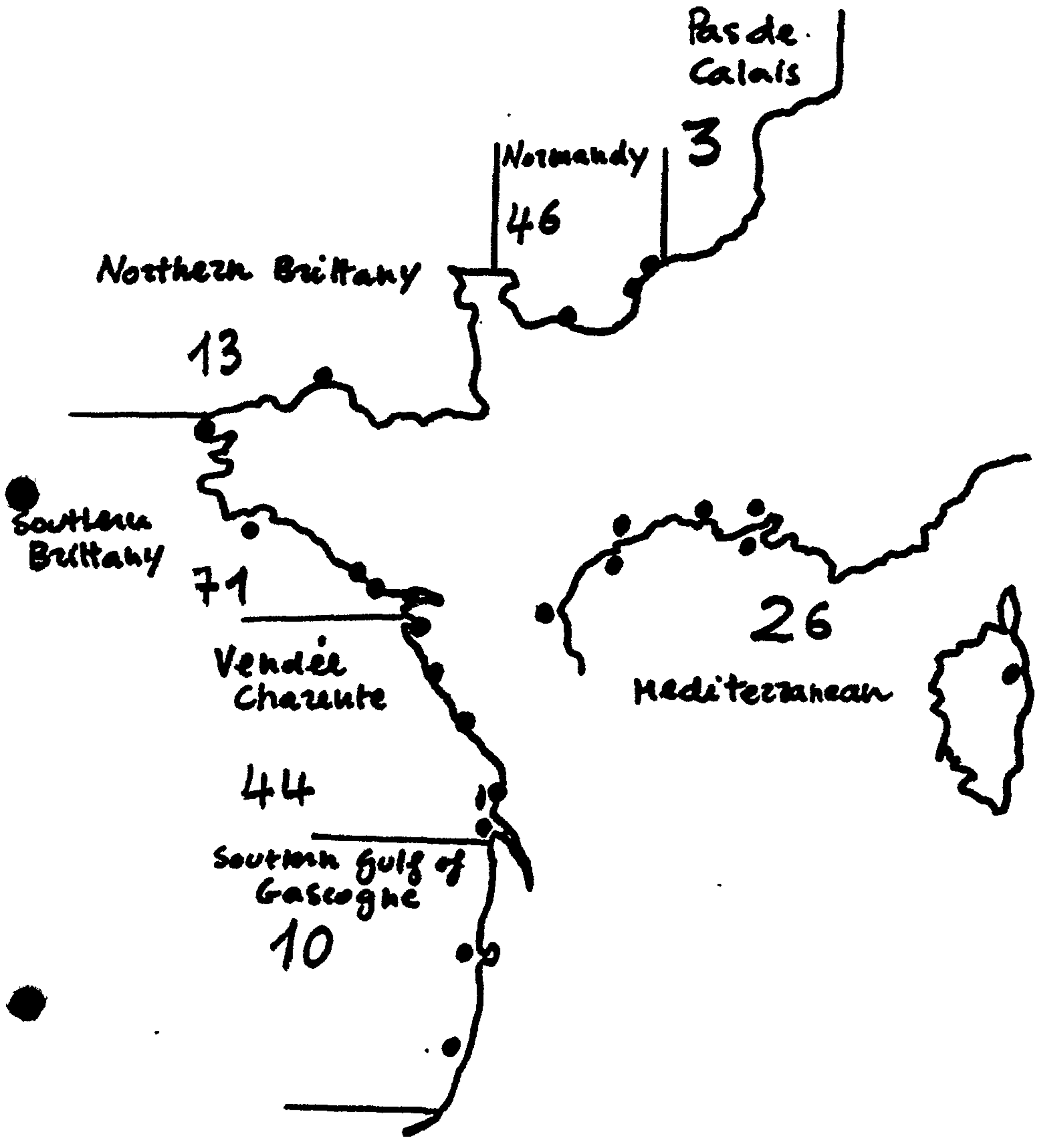


Fig. 1 Total number of discolored seawater events along the french coast, between 1975 and 1988.

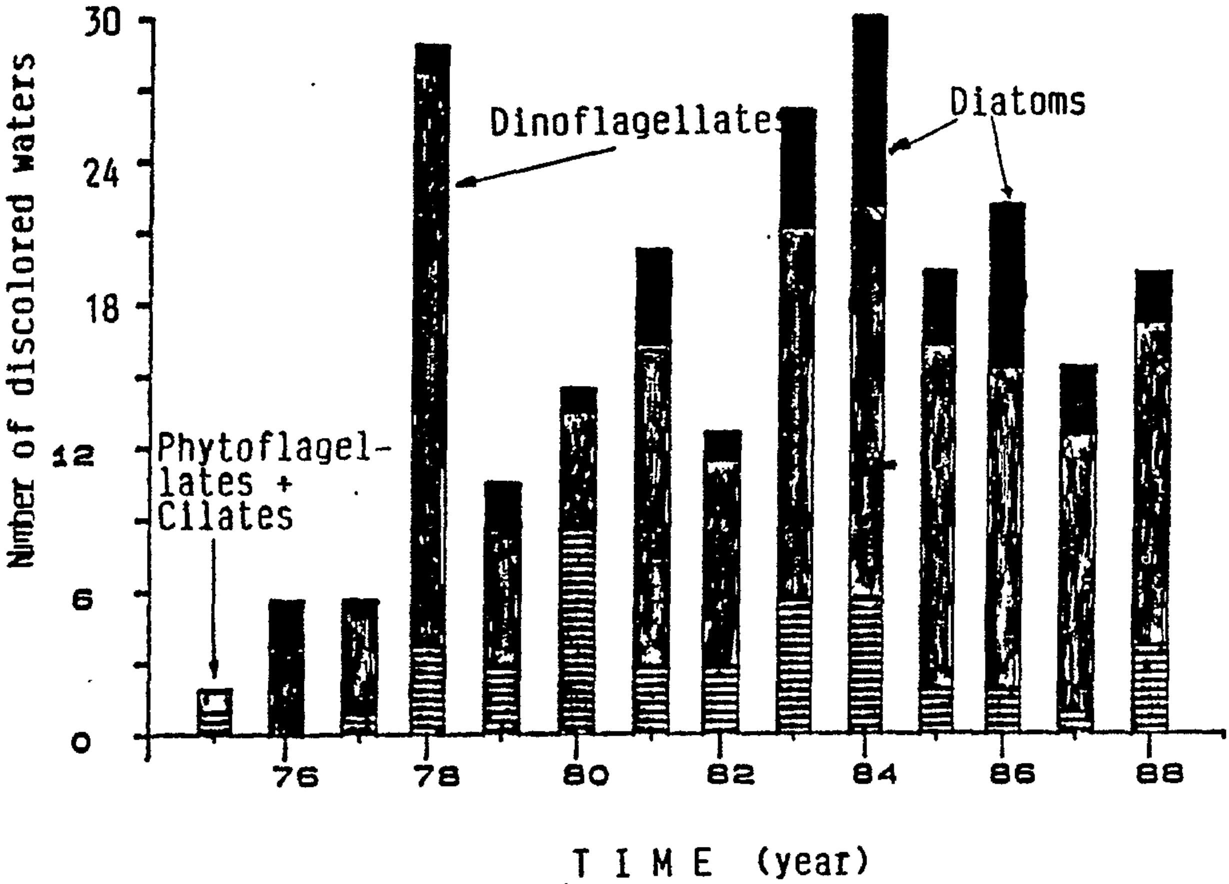


Fig. 2 Occurences of discolored waters along french coasts between 1975 and 1988 : compiled number of cases for diatoms, dinoflagellates and phytoflagellates.

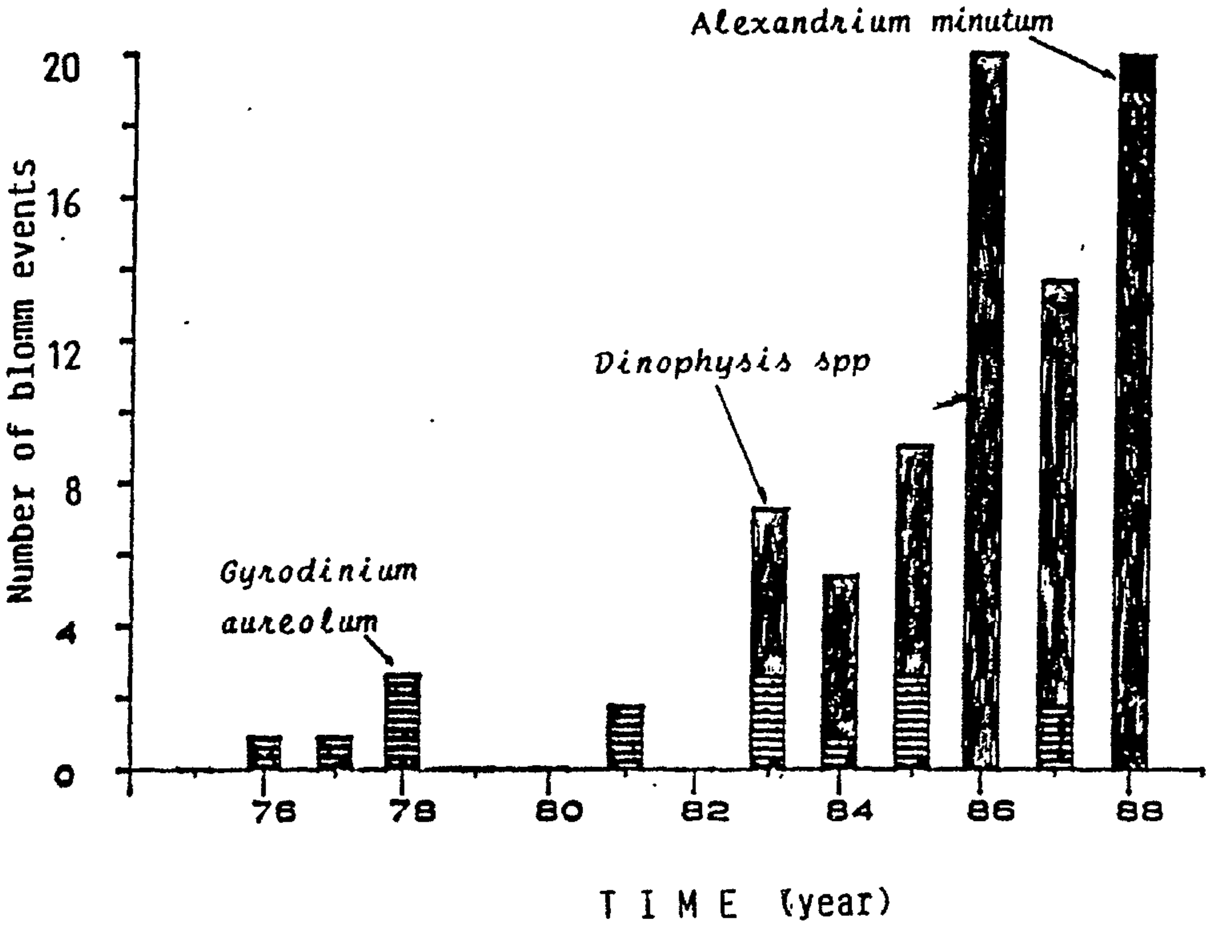
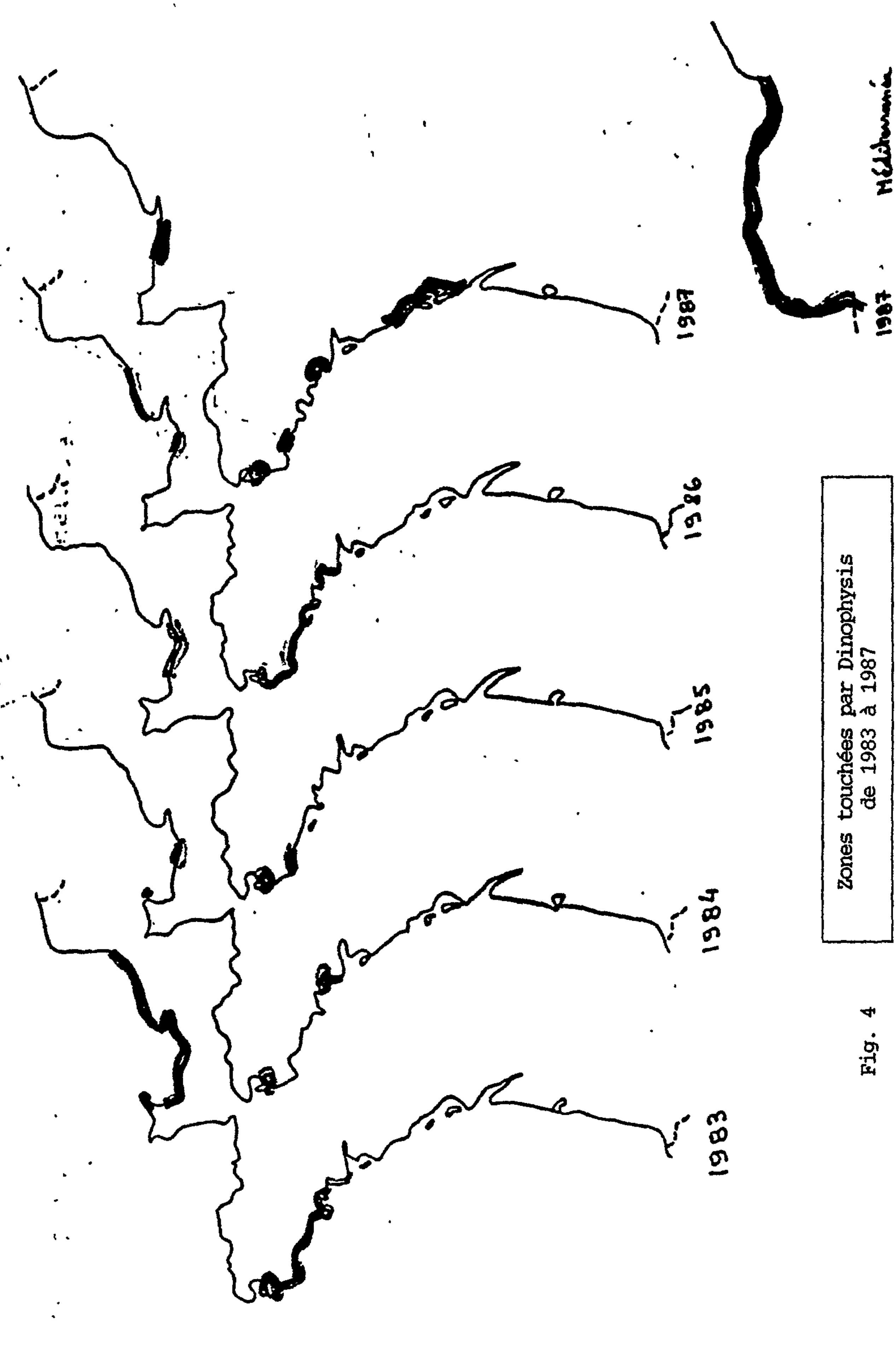


Fig. 3 Compiled numbers of toxic-bloom events from 1975 to 1988.



Zones touchées par Dinophysis
de 1983 à 1987

Fig. 4

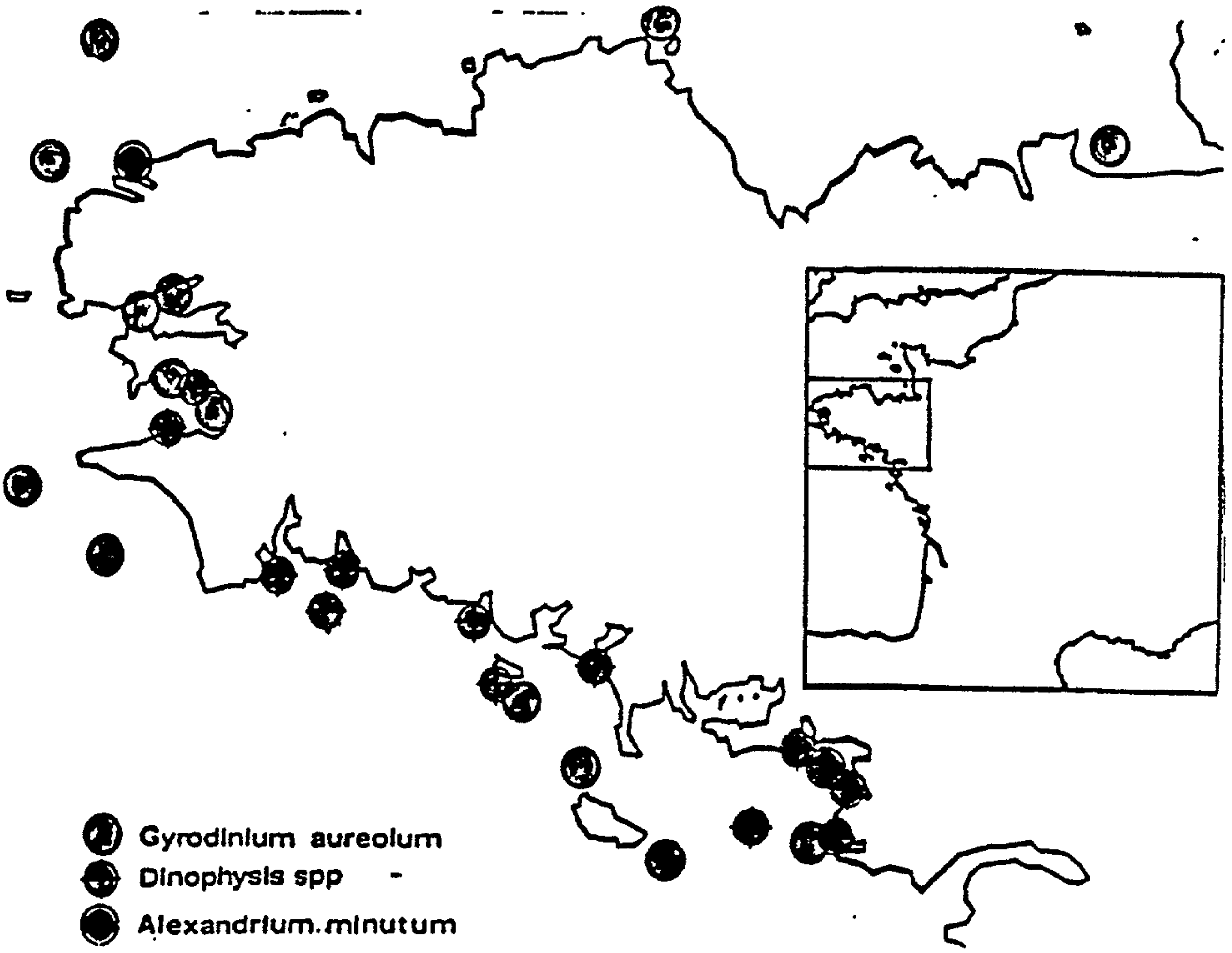


Fig. 5 Locations of toxic-dinoflagellate blooms along french Brittany coast, between 1975 and 1988.

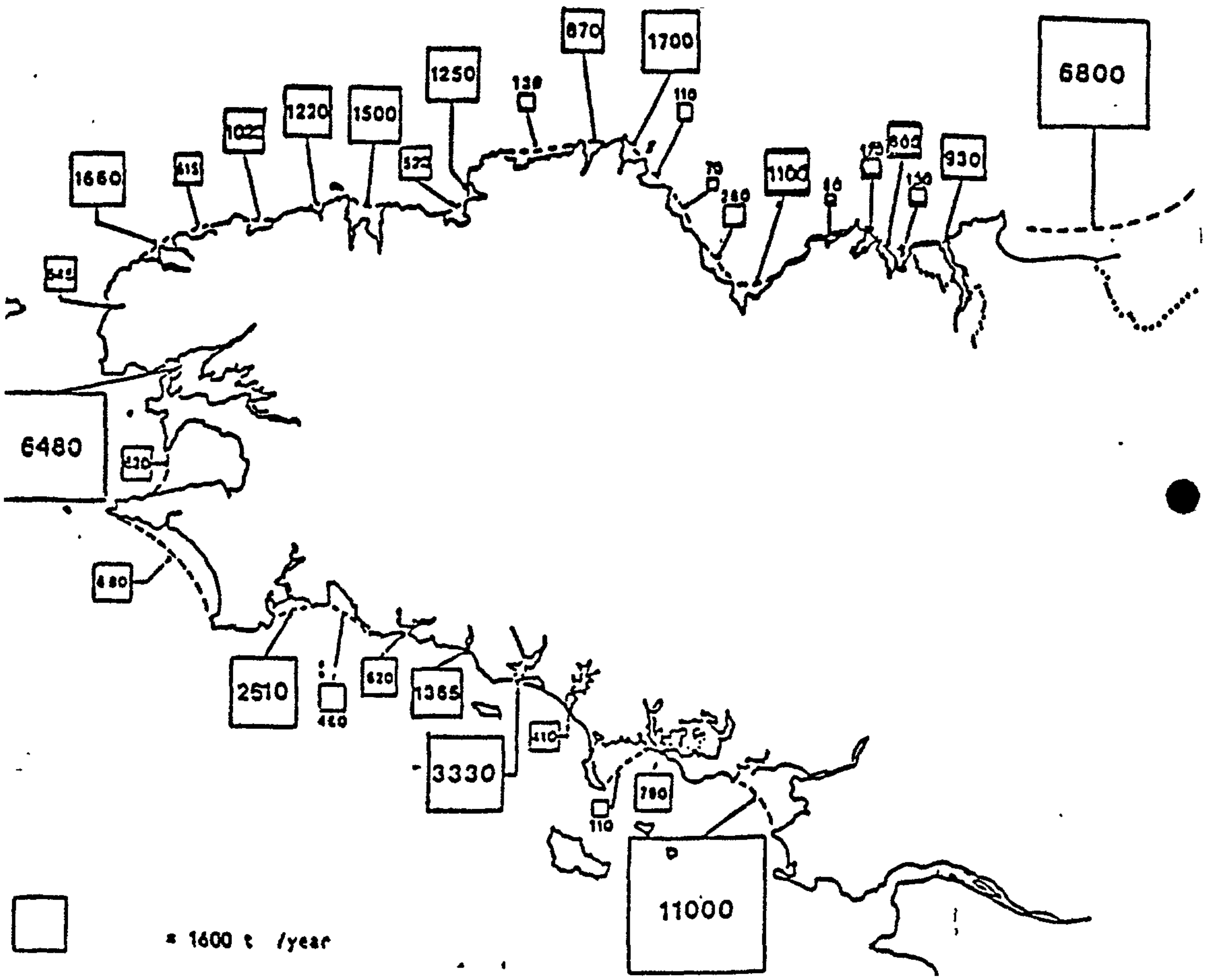


Fig. 6 Nitrate outputs along the Brittany coast in 1984.

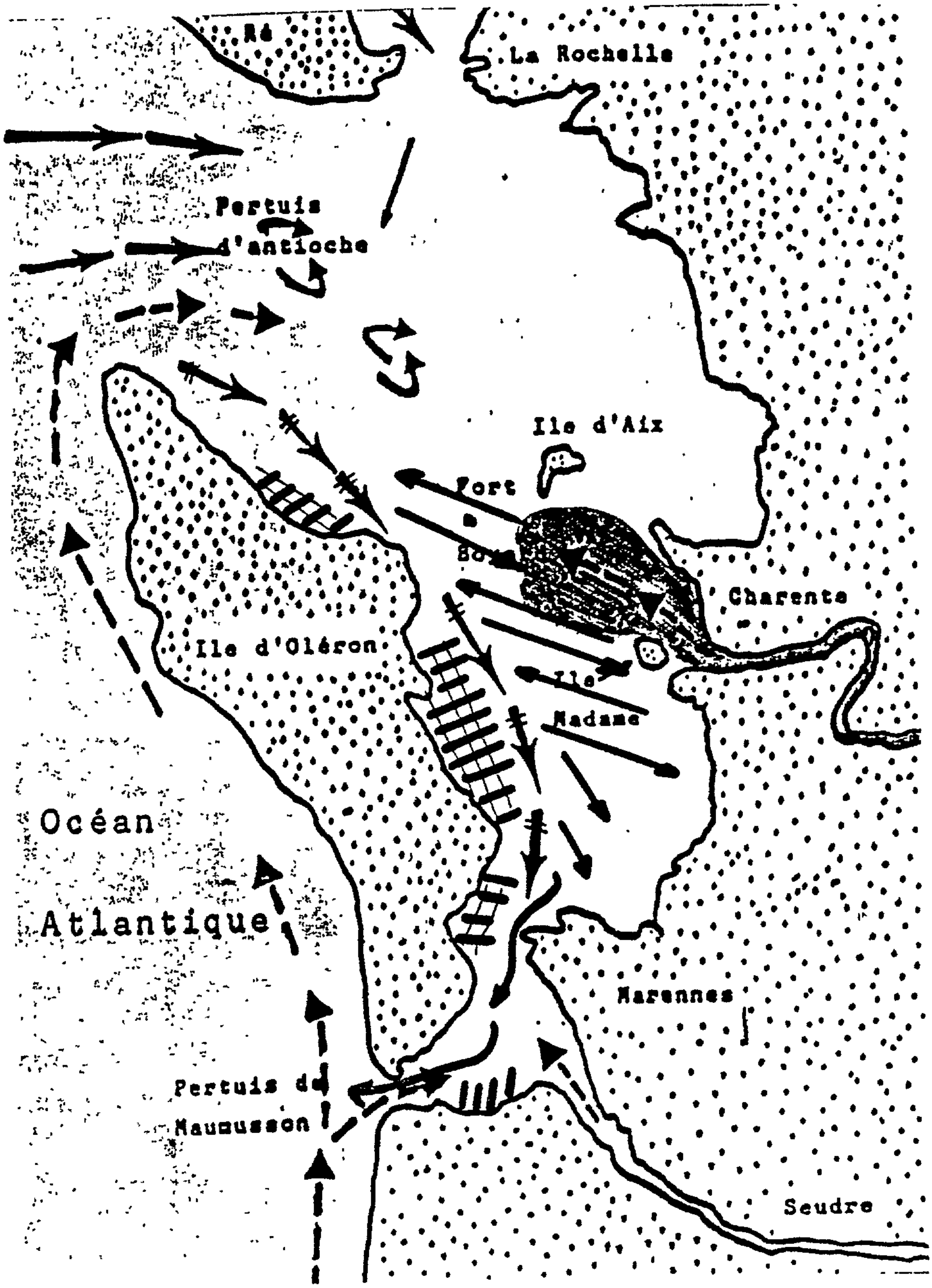
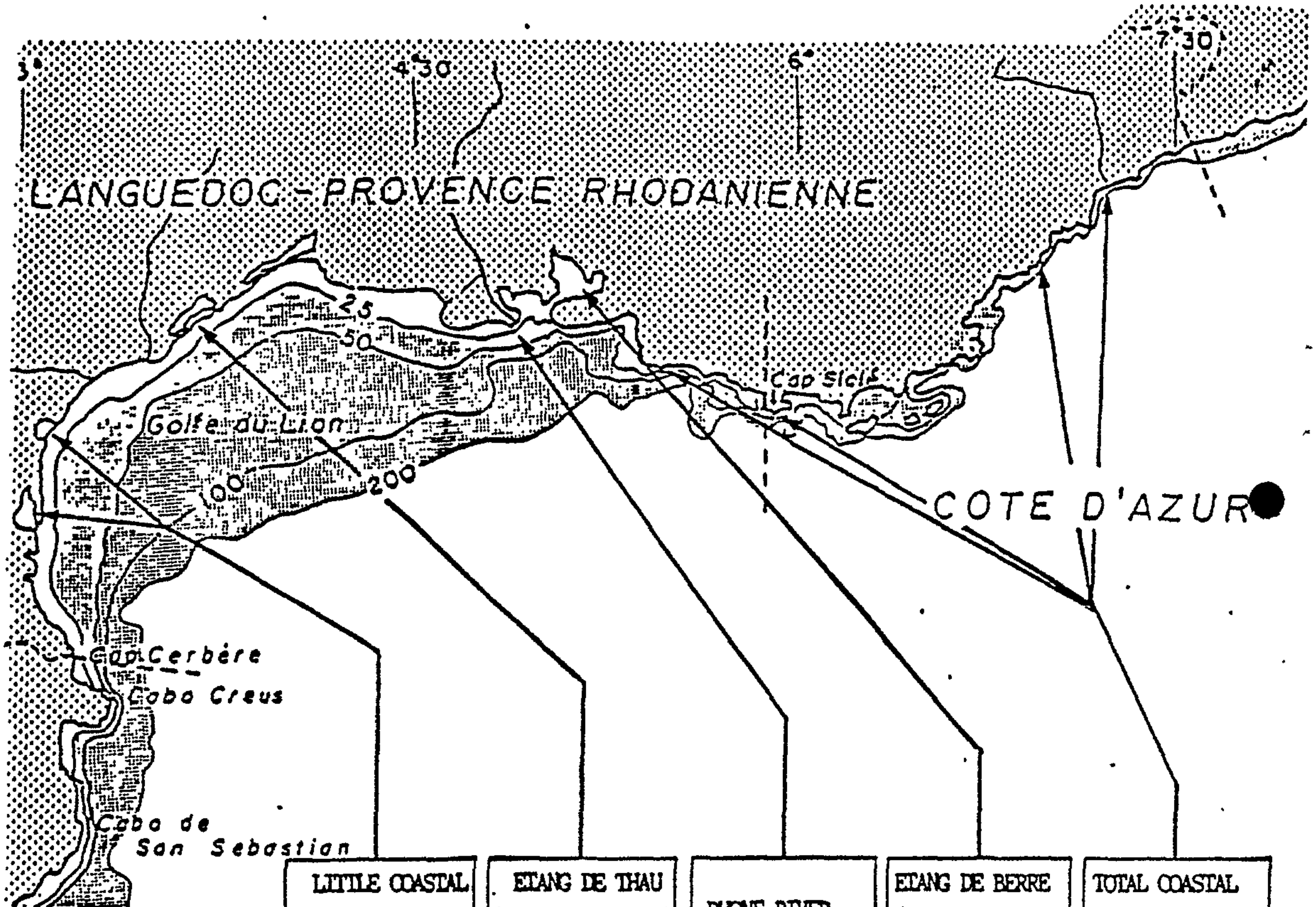


Fig. 7 Marennes-Olesen bassin (atlantic coast of France): output plume of River Charente ▆, surface currents -->, mixed waters (sea water + river water) alternative transport governed by tide currents ------>, and oyster beds ###

Fig. 8 NUTRIENT INPUT FLUXES IN FRENCH MEDITERRANEAN COAST (TONS/DAY)

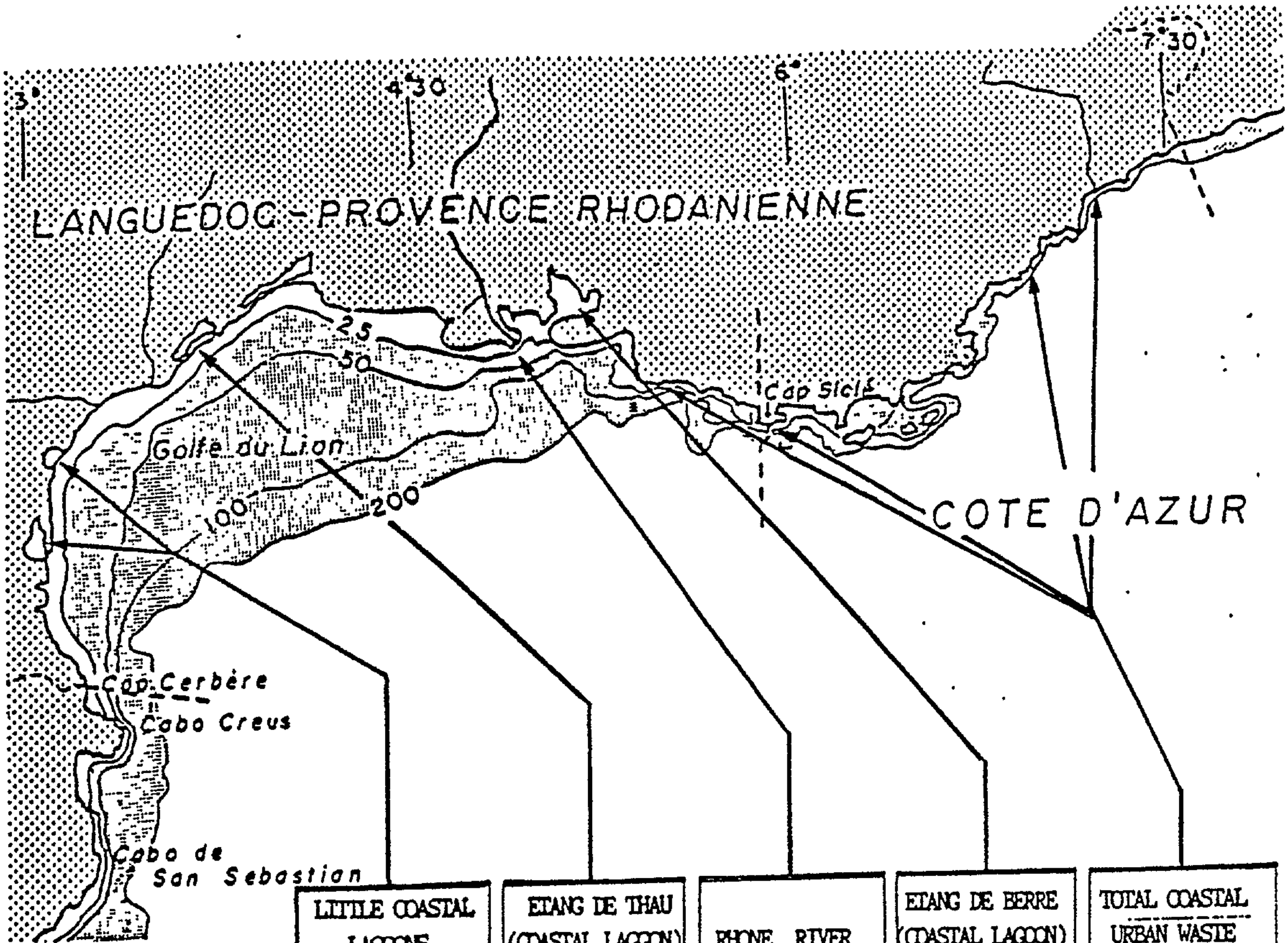


	LITTLE COASTAL LAGOONS	ETANG DE THAU (COASTAL LAGOON)	RHONE RIVER	ETANG DE BERRE (COASTAL LAGOON)	TOTAL COASTAL URBAN WASTE WATERS
ORGANIC NITROGEN			?	10,7	15
$N - NH_4^+$			10	2,6	38
$N - NO_2^-$			4	0,3	0,2
$N - NO_3^-$	?	?	170	6,6	0,7
TOTAL NITROGEN			200	21,5	54
$P - PO_4^-$			15	0,8	3
TOTAL PHOSPHORUS			20	2,7	5
$Si - SiO_3^-$			220	60	17

COASTAL EUTROPHICATION

CHLOROPHYLL (ug/l)	20 - 100	1 - 4	0,5 - 20	7 - 60	0,2 - 3
NO of CELLS / Liter	?	?	$5.10^4 - 2.10^7$	$2.10^5 - 7.10^8$	$3.10^4 - 3.10^5$

Fig.9 **UNDESIRABLES PLANCTON BLOOMS IN FRENCH MEDITERRANEAN COASTAL AREAS**



	LITTLE COASTAL LAGOONS	ETANG DE THAU (COASTAL LAGOON)	RHONE RIVER	ETANG DE BERRE (COASTAL LAGOON)	TOTAL COASTAL URBAN WASTE WATERS
HUMAN HEALTH EFFECTS	NO	YES Dinophysis DSP outside of the lagoon in August 1987	NO	NO	Limited allergic effects
LOST OF FISHERIES RES.	YES	10.000 tons of shellfish lost in 1987 (SH_2)	?	NO	NO
REDUCTION OF TURIST - RECREATIONAL VALUES	YES	NO	Red tides of Noctiluca sp. observed in July 1984	* Foams * Red tides of Prorocentrum minimum * SH_2 production	ONCE: Cannes
ECOSYSTEM EFFECTS	LIMITED	LIMITED	NO	Dissolved oxygen problems (Eutrophication + stratification of density)	NO
DIRECT ECONOMICAL EFFECTS	* Dinophysis in Urbino lagoon * "Malaïgue" (SH_2 product.)	NO	Dinophysis in Carteau (Golfe de Fos)	Foam effect on pumping cooling water for industrial purposes	NO

RESEAU NATIONAL DE BASSIN

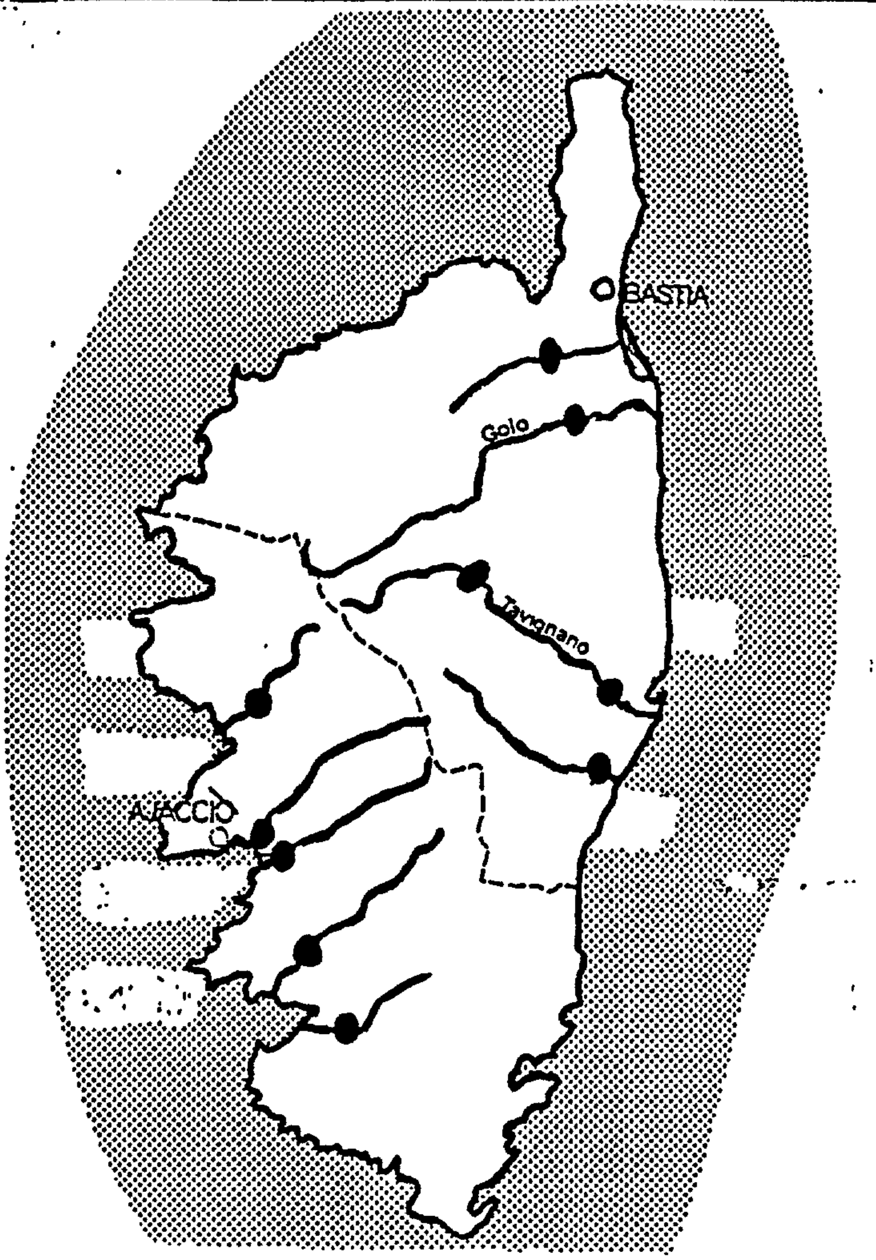


Fig. 10

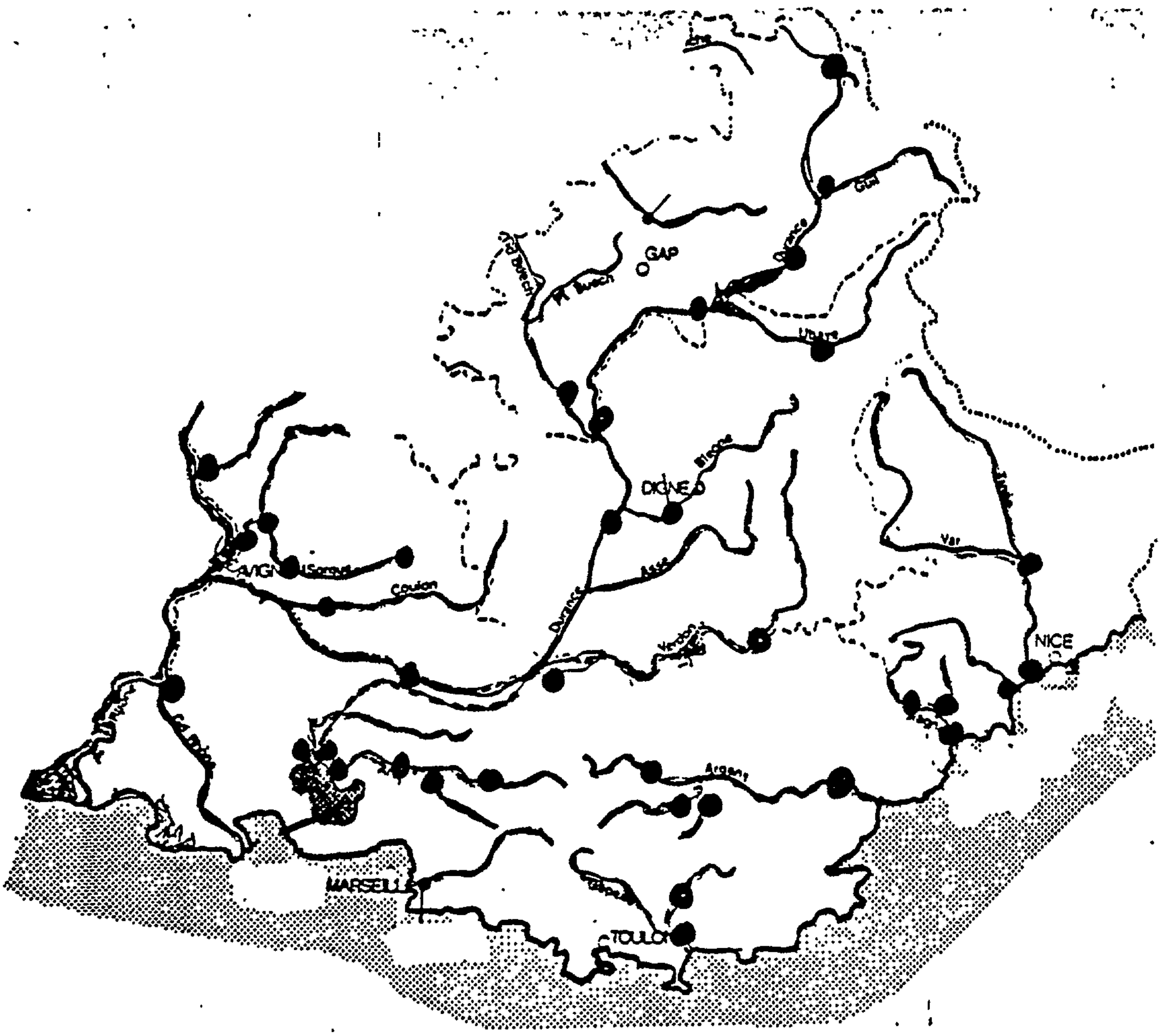


Fig. 11

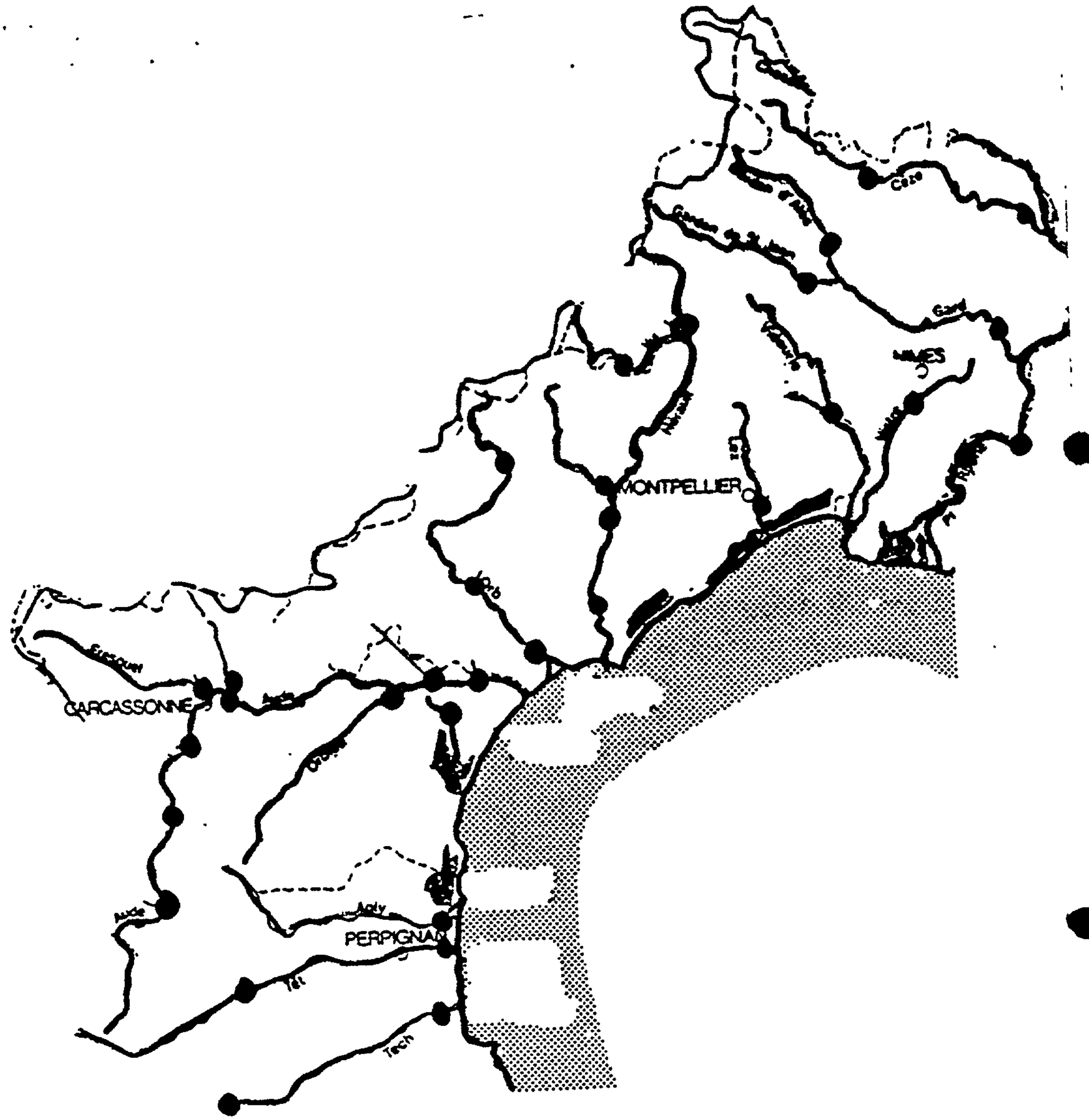

MONTPELLIER
CARCASSONNE
PERPIGNAN
Aude
Orb
Tet
Tech
Agly
Gard
Ceze

Fig. 12

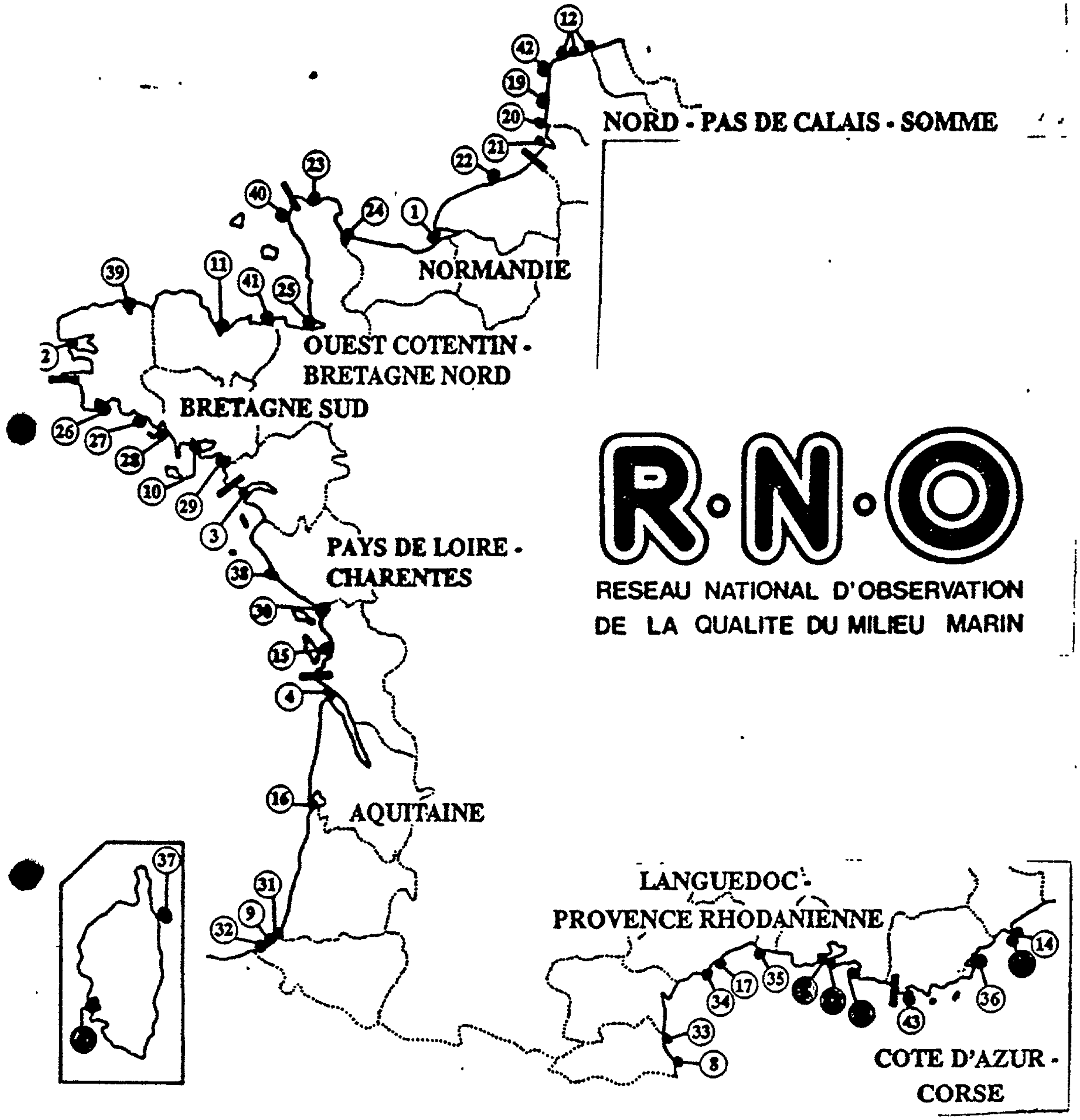

NORD - PAS DE CALAIS - SOMME
NORMANDIE
OUEST COTENTIN - BRETAGNE NORD
BRETAGNE SUD
PAYS DE LOIRE - CHARENTES
AQUITAINE
LANGUEDOC - PROVENCE RHODANIENNE
COTE D'AZUR - CORSE
R·N·O
RESEAU NATIONAL D'OBSERVATION
DE LA QUALITE DU MILIEU MARIN

Fig. 13

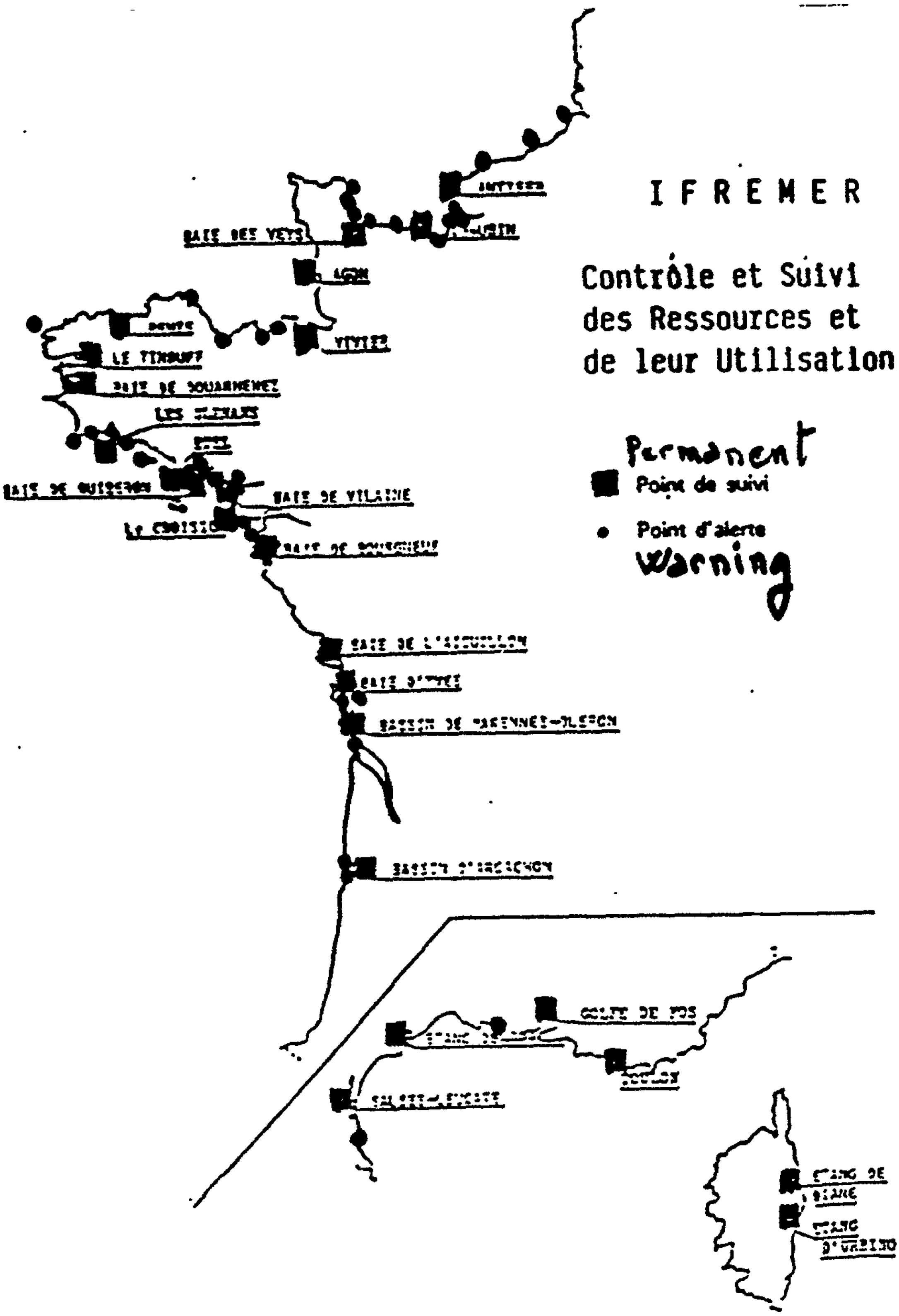

IFREMER
Contrôle et Suivi
des Ressources et
de leur Utilisation
Permanent
Point de suivi
Point d'alerte
Warning
BAIE DES VEYS
BAIE DE DOUARNENEZ
BAIE DE QUIBERON
BAIE DE VILAINE
GOLFE DE FOS

Fig. 14

EUTROPHICATION ASSESSMENT IN GREEK COASTAL WATERS

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INTRODUCTION

Detection and measurement of eutrophication through estimation of biological indicators such as phytoplankton productivity, species composition and diversity have been reported extensively.[1-4] Most of these indices have a high sensitivity, since they reflect interactions of organisms both with one another and their physical and chemical environment,[2] but they require professionalism and special elaboration with regard to the data collection and processing. Also, there have been several attempts in the literature to use simpler indices for assessing water quality. The nutrient-salinity relationship has often been used for evaluating the dilution and transportation of sewage effluents in the marine environment.[5-7] However, Satsmadjis[8] has pointed out that "the concentrations of nutrients at specific locations in the sea often vary to the extreme as a function of time, especially nearshore".

In this paper, an attempt is made to assess eutrophication levels in Greek coastal waters influenced by domestic sewage taking into consideration seasonal variations of the nutrient levels, the water masses and their volumes. The Pagassitikos Gulf is taken as an example and compared with other eutrophied Greek coastal areas. Fragmentary information on physical and chemical characteristics of the Pagassitikos Gulf was published by Gabrielides and Friligos,[9] Gabrielides, [10] Gabrielides and Theocharis,[11] Theocharis and Lascaratos.[12]

DESCRIPTION OF THE AREA AND COMPARISON WITH OTHER GULFS

The Pagassitikos Gulf is situated in central Greece on the Aegean side and to the north of Euboea Island (Figure 1). Its maximum west-east and north-south dimensions are about 30 km each. It has an area of 520 km^2, a maximum depth of 100m and an estimated volume of 36 km^3. It is an enclosed basin which is connected to the Trikeri channel and ultimately to the Aegean Sea through a passage 5.5 km wide and about 100,000, is situated on the northern-most side of the gulf. It is the biggest urban area in the Paggassitikos and has a relatively busy port. The Pilion mountain range, which is usually snow-covered in winter, lies on the north-eastern side of the gulf. There are no permanent rivers flowing into Pagassitikos, but only streams. Freshwater from

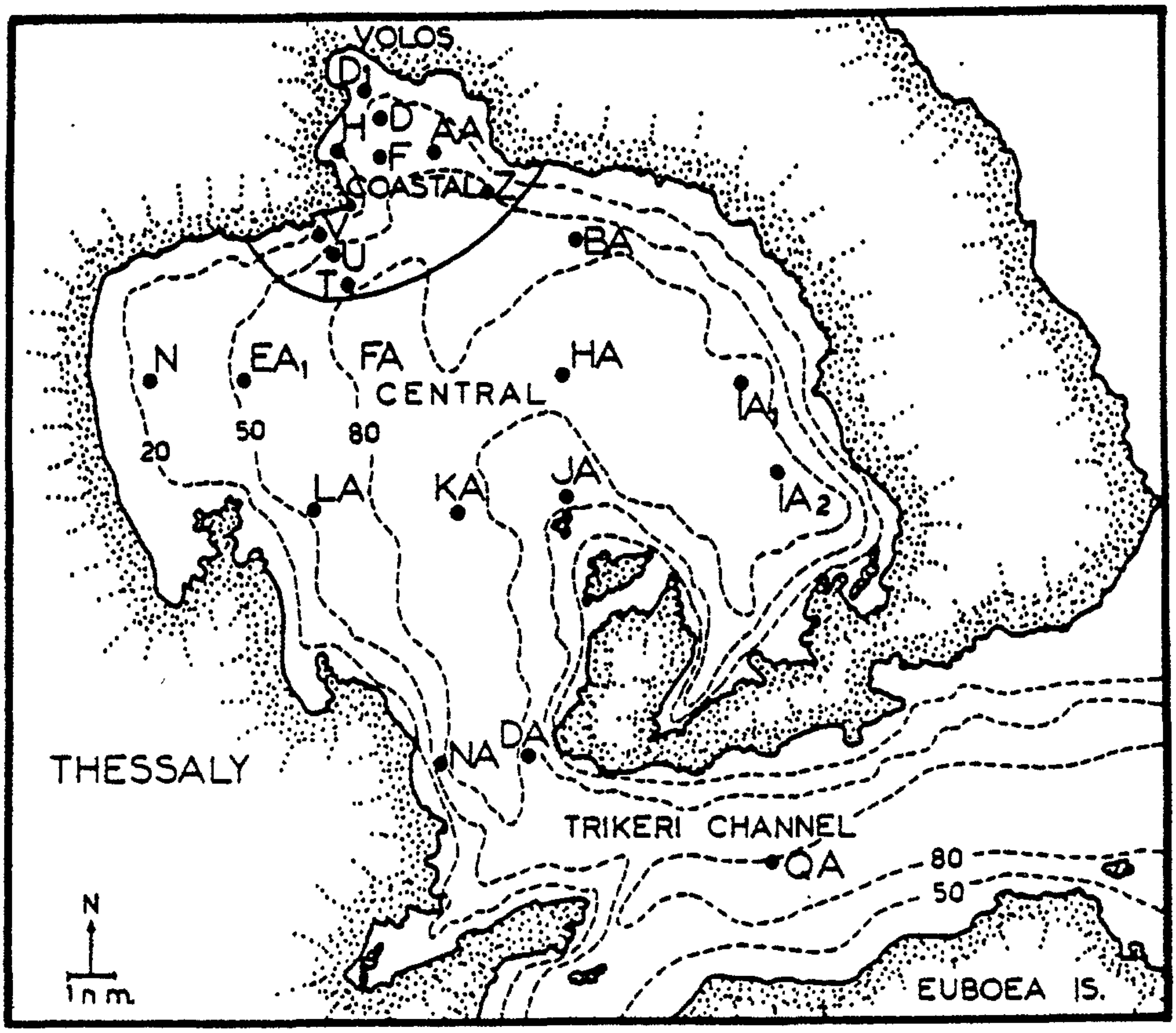

Fig. 1 Pagassitikos Gulf with location of stations.

the stream systems are the result of seasonal response to rainfall, with its maximum in winter combined with an input from spring snowmelt waters.

Important natural subregions can be identified in the shallow coastal Bay of Volos, and the central deep regions of the Pagassitikos Gulf. Metropolitan sewage is discharged in the Volos bay and a number of minor outfalls, mainly industrial, are distributed along the shore.

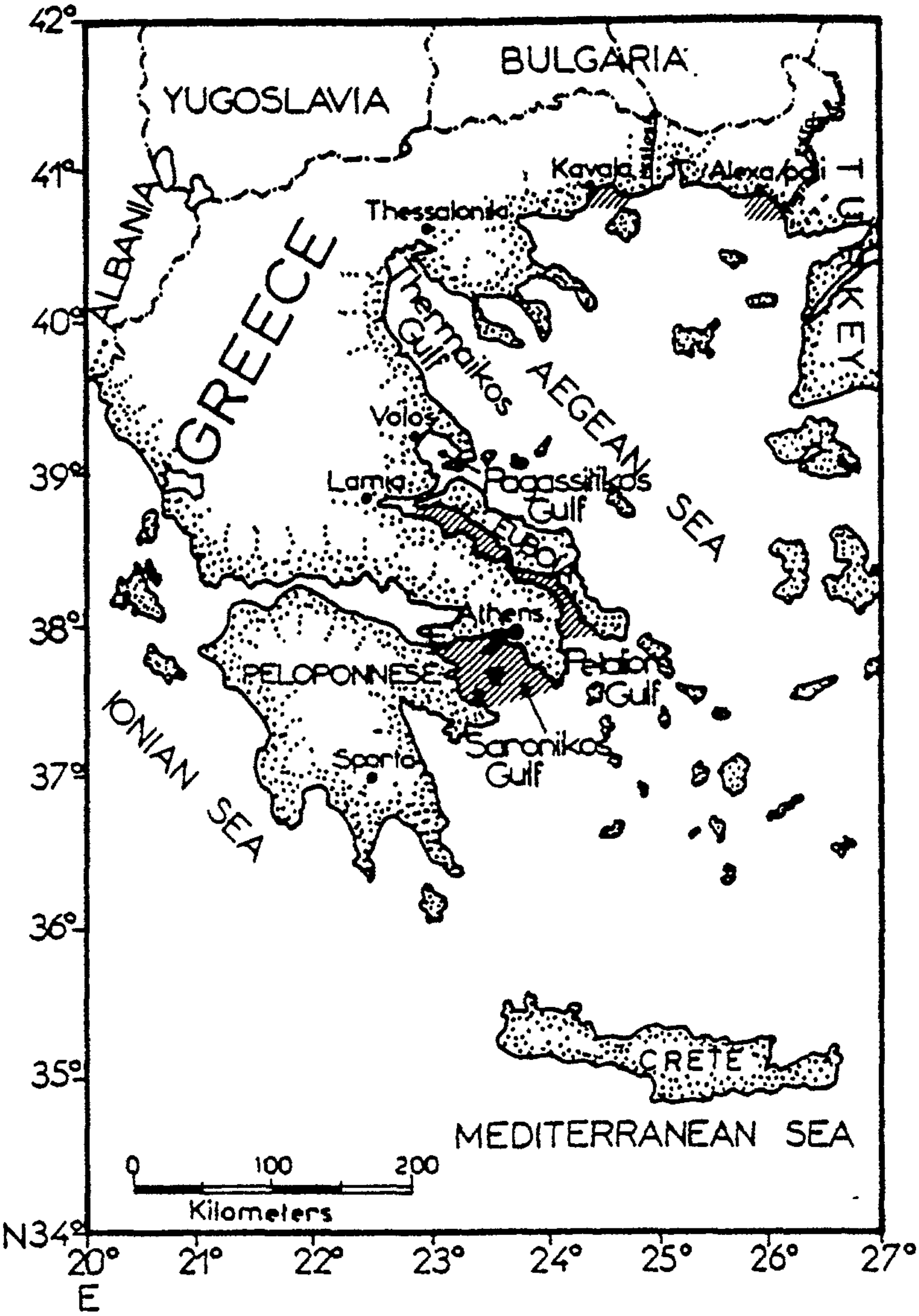

Fig. 2 Map of Greece showing the compared areas.

The total amount of waste discharge, in terms of BOD_5, is 15,412 kg day^{-1}, 11,902 of which are domestic origin and 3,510 industrial. The main industries are tannery, paper, cement etc.

Euboikos Gulf

The Euboikos Gulf (Figure 2) extends along the western coast of the island of Euboea, which is separated from the Greek mainland by the Euripus Channel. The north Euboikos Gulf is semi-enclosed and the depth ranges from 50 to 400m, while the south Euboikos Gulf has a maximum depth of 85m. Few industries and small rivers, some streams and underwater springs exists in the area.

Saronikos Gulf

The various waters of the Saronikos Gulf (Figure 2) separate into four water masses. The Inner Gulf, the Western Gulf, the Elefsis Bay and the Outer Gulf. In the Inner Gulf, the effect of sewage effluent (Keratsini outfall with a rate of 7 m^3s^{-1}) from the greater Athens is evident as a plume of nutrient-rich water, extending about 20 km south of Salamis island.[13] The Western Gulf presents the greater depths, with a great depression more than 400m deep in Epidavros, providing the possibility of trapping nutrients. The Elefsis Bay, which is the most industrialized area in Greece, is located in the north part of the Saronikos Gulf and has a maximum depth of 33m.

Alexandroupolis and Kavala Gulfs

The Alexandroupolis and Kavala Gulfs are located in the northern part of the Aegean Sea and the bulk of the run-off comes from the rivers Evros and Nestos (Figure 2), both draining agricultural areas. Therianos[14] reported that the annual mean flow rate of the Evros River is about $103m^3s^{-1}$ and that of Nestos River about $58m^3s^{-1}$.

Material and Methods

The gulf was visited six times between August 1975 and December 1976 at regular intervals and once in August 1983. The number of stations amounted to about 35.

Samples of water were collected at depths of 1, 10, 20, 50, 75 and 100m using Nansen reversing water samplers.

Water samples for the analyses of nutrients were collected in 100-ml polyethylene bottles and kept frozen, after the addition of mercuric chloride, until analysis. In the laboratory, they were thawed, filtered through membrane filters and processed on a Technicon CSM6 autoanalyser. The methods used were, for nitrite, nitrate and silicate that of Armstrong et al.,[15] for phosphate, that of Murphy and Riley[16] as automated by Hager et al.[17] and for ammonium, that of Koroleff[18] as automated by Slawyk and MacIsaac.[19] The chart data were processed after Satsmadjis[20] who investigated also the reliability of the determinations. The same methodology was followed for calculating the level of enrichment by inorganic nutrients as that in the case of the Saronikos Gulf,[21-23] the Alexandroupolis and Kavala Gulfs[24] and the Euboikos Gulf.[25]

Results and Discussion

The area under study has been divided into two sections, the coastal waters (10,000-10^6m^3) and the central part of the gulf. This division is based on T/S diagrams.[11] The central area could again be differentiated into a surface (16,500-10^6m^3) and a bottom layer (9,500-10^6m^3). Integrated mean values were taken for the whole column in the coastal area and for the surface layer (0-50m) and deep layer (>50m) in the central area station by station for each area, and combining these to give mean values for a given cruise. In the reference station of the Aegean typical water values of phosphate, silicate, nitrite and ammonium were 0.12, 1.22, 0.16, 0.42, 0.36 µM respectively.[21] The means are shown in Table I with the background nutrient values from the Aegean Sea.

Phosphate values had always been low through the whole period and usually varied from less than 0.1 µM to 0.2 µM. Exception to the above were some high bottom values,. No obvious seasonal trend was observed.

The values of silicate up to the depth of 50m varied between 1.5 and 6.6 µM and below that between 3.7 and 7.6 µM. In May the Pagassitikos presented the highest values. The values of ammonium were more or less uniform and no definitive vertical trend was observed. The values fluctuated around 1.0 µM. Nitrite values were generally comparable to the phosphate ones and were higher in the bottom waters. The values of nitrate varied from less than 0.2 µM in some instances to more than 2.00 µM. Nitrate was also concentrated in the deep waters where it is the dominant form of nitrogen. However, ammonium is the dominant form in the surface layers.

Mean concentrations for the various depths, areas and cruises, as shown in Tables IA and IB, were multiplied by the dissolved volumes to estimate the amount of total nutrients held in dissolved form in the Pagassitikos Gulf. The results are presented in Table IIA, IIB and IIC along with background values. All nutrients are present in all areas at levels well above background except in some cases for phosphate and nitrite. The values of Table II were then added and thus the total nutrient concentration were obtained for the Pagassitikos Gulf. As can be seen from Table III, there are no major differences between the periods of the cruises as far as total concentrations are concerned. Especially the results obtained from samples collected in August 1975, 1976. It can therefore be assumed that there was no increase in the degree of eutrophication in the gulf. In May, silicate, nitrite and nitrate values for the whole gulf were increased compared with other occasions.

Table IA Mean nutrient concentration in the coastal area: Water column averages in μg-at·l^{-1}

Date	PO_4-P	SiO_4Si	NH_4-N	NO_2-N	NO_3-N
Aug. 75	0.09	—	0.89	0.11	0.96
Nov. 75	0.14	—	1.06	0.15	0.36
Feb. 76	0.11	—	0.60	0.26	1.05
May 76	0.10	6.60	0.82	0.15	0.85
Aug. 76	0.19	1.49	1.16	0.09	0.97
Dec. 76	0.11	2.38	1.72	0.19	0.66
Aug. 83	0.08	1.73	0.22	0.05	0.17
Background	0.12	1.22	0.36	0.16	0.42

Table IB Mean nutrient concentrations in the central area (0–50 m): Water column averages in μg-at·l^{-1}

Date	PO_4-P	SiO_4Si	NH_4-N	NO_2-N	NO_3-N
Aug. 75	0.06	—	0.92	0.05	0.94
Nov. 75	0.11	—	0.84	0.16	0.42
Feb. 76	0.11	—	0.73	0.16	0.87
May 76	0.10	6.04	0.71	0.68	1.37
Aug. 76	0.12	1.55	0.93	0.09	0.57
Dec. 76	0.13	2.30	2.18	0.24	0.77
Aug. 83	0.10	2.19	0.49	0.06	0.35
Background	0.12	1.22	0.36	0.16	0.42

Table IC Mean nutrient concentrations in the central area (50–100 m): Water column averages in μg-at·l^{-1}

Date	PO_4-P	SiO_4-Si	NH_4-N	NO_2-N	NO_3-N
Aug. 75	0.07	—	0.89	0.14	1.43
Nov. 75	0.20	—	0.83	0.12	2.03
Feb. 76	0.11	—	0.83	0.17	2.10
May 76	0.12	7.57	0.75	0.75	1.78
Aug. 76	0.21	5.42	0.93	0.22	1.74
Dec. 76	0.14	3.72	2.18	0.26	1.06
Aug. 83	0.13	7.40	0.31	0.07	1.66
Background	0.12	1.22	0.36	0.16	0.42

Table IIA Total nutrients by cruise in the coastal area in g-at · 10^6

Date	PO_4-P	SiO_4-Si	NH_4-N	NO_2-N	NO_3-N	ΣN
Aug. 75	0.90	—	8.90	1.10	9.60	19.60
Nov. 75	1.90	—	10.60	1.50	3.60	15.70
Feb. 76	1.10	—	6.00	2.60	10.50	19.10
May 76	1.00	66.00	8.20	1.50	8.50	18.20
Aug. 76	1.90	14.90	11.60	0.90	9.70	22.20
Dec. 76	1.10	23.80	17.20	1.90	6.60	25.70
Aug. 83	0.80	17.30	2.20	0.50	1.70	4.40
Background[a]	1.20	12.20	3.60	1.60	4.20	9.40

Table IIB Total nutrient concentrations in the central area (0–50 m) in g-at · 10^6

Date	PO_4-P	SiO_4-Si	NH_4-N	NO_2-N	NO_3-N	ΣN
Aug. 75	0.99	—	15.18	0.83	15.51	31.52
Nov. 75	1.82	—	13.86	2.64	6.93	23.43
Feb. 76	1.82	—	12.05	2.64	14.36	29.04
May 76	1.65	99.66	11.72	11.22	22.61	45.55
Aug. 76	2.98	25.58	15.35	1.49	9.41	26.25
Dec. 76	2.15	37.95	35.97	3.96	12.71	52.64
Aug. 83	1.65	36.13	8.09	0.99	5.78	14.85
Background[a]	1.98	20.13	5.94	2.64	6.93	15.51

Table IIC Total nutrients by cruise in the central area (50–100 m) in g-at · 10^6

Date	PO_4-P	SiO_4-Si	NH_4-N	NO_2-N	NO_3-N	ΣN
Aug. 75	0.67	—	8.46	1.33	13.59	23.37
Nov. 75	1.90	—	7.89	1.14	19.29	28.31
Feb. 76	1.05	—	7.89	1.62	19.95	29.45
May 76	1.14	71.92	7.13	7.13	16.91	31.17
Aug. 76	2.00	51.49	8.84	2.09	16.53	27.46
Dec. 76	1.33	35.34	20.71	2.47	10.07	33.25
Aug. 83	1.24	70.30	2.95	0.67	15.77	19.39
Background[a]	1.14	11.59	3.42	1.52	3.99	8.93

[a]Value obtained by multiplying background concentrations by volume of basin under consideration.

Table III Total nutrients by cruise in the Pagassitikos Gulf in g-at · 10^6

Date	PO_4-P	SiO_4Si	NH_4-N	NO_2-N	NO_3-N	ΣN
Aug. 75	2.56	—	32.54	3.26	38.70	74.50
Nov. 75	6.52	—	32.32	5.28	29.82	67.42
Feb. 76	3.97	—	25.94	6.86	44.81	77.61
May 76	3.79	237.58	27.05	19.85	48.02	94.92
Aug. 76	5.88	91.97	37.79	4.48	35.64	75.91
Dec. 76	4.58	97.09	73.88	8.33	29.38	111.59
Aug. 83	4.69	123.73	13.24	2.16	23.25	38.65
Background*	4.32	43.92	12.96	5.76	15.12	33.84

* Value obtained by multiplying background concentrations by volume of basin under consideration.

The tendency of the Pagassitikos Gulf water to accumulate nutrients above background is shown more clearly in Table IV, where the data of Table III have been reduced to ratios of total nutrient to background level. The Pagassitikos Gulf contained two times more inorganic nitrogen than the background. This was mainly due to ammonium and nitrate. Also, it presents a great accumulation of silicate, about three times greater than the background.

Table IV Ratios of total nutrient per cruise to background nutrient in the Pagassitikos Gulf

Date	PO_4-P	SiO_4-Si	NH_4-N	NO_2-N	NO_3-N	ΣN
Aug. 75	0.59	—	2.52	0.57	2.56	2.20
Nov. 75	1.51	—	2.49	0.92	1.97	1.99
Feb. 76	0.92	—	2.00	1.19	2.96	2.29
May 76	0.88	5.41	2.09	3.45	3.18	2.80
Aug. 76	1.36	2.09	2.76	0.78	2.36	2.24
Dec. 76	1.06	2.21	5.70	1.45	1.94	3.30
Aug. 83	0.85	2.82	1.02	0.38	1.54	1.14
Means	1.02	2.80	2.60	1.25	2.36	2.28

Table V Ratio of total nutrient per Gulf to background nutrients

Area	PO_4^{-3}-P	SiO_4^{-4}-Si	NH_4^+-N	NO_2^--N	NO_3^--N	ΣN	Reference
Elefsis Bay	5.11	4.15	15.80	3.05	7.00	9.67	Friligos (1981)
Western Saronikos Gulf	2.25	2.95	2.50	1.11	6.39	4.00	Friligos (1983)
Inner Saronikos Gulf	2 50	1.39	4.10	1.55	2.60	3.97	Friligos (1982)
North Euboikos Gulf	2.87	13.20	1.66	0.49	10.20	5.27	Friligos (in press)
Kavala Gulf	1.80	1.49	1.00	0 51	1.41	1.10	Friligos (1985)
Alexandroupolis Gulf	1.32	3.28	1.00	0.65	6.21	3.27	Friligos (1985)
South Euboikos Gulf	1.46	1.41	0.65	0.48	1.17	0.86	Friligos (in press)
Pagassitikos Gulf	1.02	2.80	2.60	1.25	2.36	2.28	—

In order to estimate the extent of eutrophication in the Pagassitikos Gulf a comparison with previous data collected in different polluted coastal waters of the Aegean could be useful. The same background values were used in various regions of Aegean waters (Figure 2). The relative factors of increase from the background following the same methodology are summarized in Table V.

The Pagassitikos and the South Euboikos Gulf have only slightly greater concentrations of nutrients than those of the Aegean Sea. The North Euboikos Gulf presents a great accumulation of nitrate and silicate due mostly to the great depth and to underwater springs.

The nutrient content in the Saronikos Gulf was examined according to the division of the water masses. Elefsis Bay, the most industriliazed area in Greece, shows a tendency to concentrate all nutrients, but especially ammonium (up to 16 times background). The Inner Gulf, which is influenced by the sewage outfall and the Western Gulf, with the greatest depths, appear to hold phosphate about equally. However, the tendency for silicate to be depleted in the Eastern Gulf is again clear, while the Western Gulf tends to accumulate silicate and phosphate equally. Nitrate tends to be accumulated even more than silicate in the Western Gulf. The Alexandroupolis Gulf, like the Western Saronikos Gulf, contained three times as much silicate and six times as much nitrate as background, owing to the contribution of the Evros River. The Kavala Gulf presented phosphate levels twice background, due mainly to the presence of a fertilizer factory there.

Generally one can say that the quality of the receiving waters, with respect to nutrients, in the gulfs examined, is a function of the different sources of nutrients, as well as the morphology of each area and the circulation of the waters.

Moreover, Dugdale and Hopkins[26] considered the eutrophication processes and productivity in the waters of the Aegean Sea. They concluded that the productivity of the Aegean Sea is generally low, except in some areas affected by urban pollution, specifically nutrient input (eutrophication). This process contributes to the enhancement of the rates of primary production in these areas and constitutes a typical response characteristic of oligotrophic waters. Secondary production follows the same pattern in most cases.

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PROBLEMS OF EUTROPHICATION AT PLANKTON BLOOMS IN SPAIN

(A. Cruzado)

Plankton blooms are known to occur in parts of our coastal waters. Blooms of diatoms occur periodically along the southern shores from Gibraltar Straits to Almeria as a result of upwelling. A semi-permanent bloom is known to occur at the eastern boundary of the Alberan Sea, in what is known as the Almeria-Oran front, recently described by Tintoré et al (1988), as well as in other areas of the open sea in such a region.

Local eutrophic conditions occur in various coastal areas, mostly connected to the discharge of sewage from the larger cities (Barcelona, Valencia, Malaga, Palma de Mallorca, etc) and commercial harbours. However, due to the mostly open coastline such conditions apply only to the sediments and no reports of dystrophy in the water column are available. High productivity areas are naturally occurring in various estuaries systems along the Mediterranean coasts, all showing signs of eutrophication and some of them becoming at times highly eutrophic with production of sulfate reducing bacterial blooms.

Planktonic blooms have been reported in areas along the Mediterranean coast formed by large densities of salpae, of jellyfish and of Noctiluca miliaris (red tides). In early 1986 a large red tide was seen to cover a few meter wide nearshore strip originating in the Bay of Rosas and stretching for more than 120 km of coast to the south.

Toxic dinoflagellates develop during summer months affecting some of the shellfish (mussel) culture areas, particularly in some of the areas in the NW of Spain (Atlantic Ocean) forcing to the temporary closure of their exploitation. There developments do not necessarily constitute blooms.

Studies are being carried out in various coastal lagoons systems, namely Aiquamolls de l'Empordà, Els Alfacs, Albufera de València, Mar Menor, etc.

Studies of large estuaries, particularly of the Rhône and Ebro, rivers, are being carried out in the framework of the EEC sponsored EROS 2000 programme and of bilateral cooperative programmes in particular between CNRS and CSIS. A bilateral programme is being organized between Spain and Yugoslavia for the study of eutrophication in the North Adriatic.

As part of the National Monitoring Programme, both the sources of anthropogenic eutrophicating substances and the levels in selected coastal stations are being monitored and the results reported to UNEP.

UNUSUAL PHYTOPLANKTON BLOOM IN THE OPEN SOUTH ADRIATIC WATERS

(A. Benovic)

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Summary. Phytoplankton bloom in the central area of the south adriatic is analyzed, and its possible cause and effects are discussed.

In the 14 to 29 April 1987 period, the oceanographic research was performed along 37 stations in the central and south Adriatic by RV "Andrija Mohorovicic" (Fig. 1). Temperature, salinity, transparency, water colour, concentration of oxygen and nutrients (P-, N-, Si-salts), as well as phytoplankton population density and biomass (biovolume) were measured. Physical and chemical parameters were measured on board. Phytoplankton cell counts and cell morphometry were performed by means of inverted microscopy within two months after the cruise.

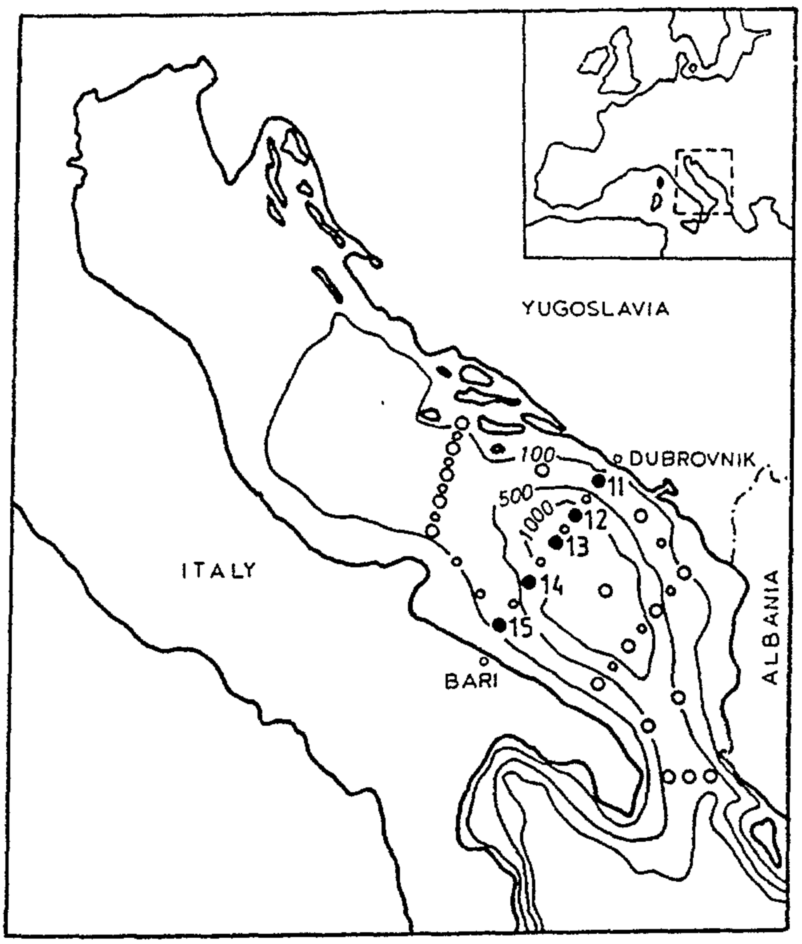

Fig. 1 Location of stations

Unusually high cell density and volume values (9.0 x 10^3 to 9.7 x 10^5 cells l^{-1}, 1.2 x 10^7 to 5.9 x 10^9 μm^3 l^{-1} of nanoplankton; 1.1 x 10^5 to 1.5 x 10^6 cells l^{-1}, 5.0 x 10^6 to 3.7 x 10^6 μm^3 l^{-1} of nanoplankton) were recorded in the Dubrovnik - Bari profile, and the Strait of Otranto (in the 0 to 100 m layer). Maximum phytoplankton quantity was determined at Station 13 (Fig. 2), in the central area of Dubrovnik - Bari profile, in the layer between 20 and 50 m (9.7 x 10^5 cells l^{-1}, 5.90 x 10^9 μm^3 l^{-1} of microplankton; 5.98 x 10^9 μm^3 l^{-1} of total phytoplankton). Such an intensive phytoplankton blooms in the open south Adriatic waters has not been registered to date. Secchi disc transparencies ranged from 8 to 14 meters, presenting values nearly three times lower than the multiannual spring mean. Water colour values (according to Forel - Ule scale) ranged between IV and VII (from blue green to dark green colour), while the multiannual spring mean did not exceed III. Surface stream-lines estimated on the basis of drift-card distribution, showed a strong incoming current from the Ionian Sea throughout the whole transversal profile, excepting the narrow Italian coastal zone. A considerably strong transversal (south-westward) circulation in the Dubrovnik - Bari and Vis - Mt. Gargano profiles was observed as well. Such a dynamics of water masses resulted in a marked increase in salinity ($S > 38.7 \times 10^{-3}$). According to the frequency distribution analysis of all disposable data, the April 1987 nutrient concentrations were slightly decreased, but in the range characteristic for southern Adriatic open sea waters.

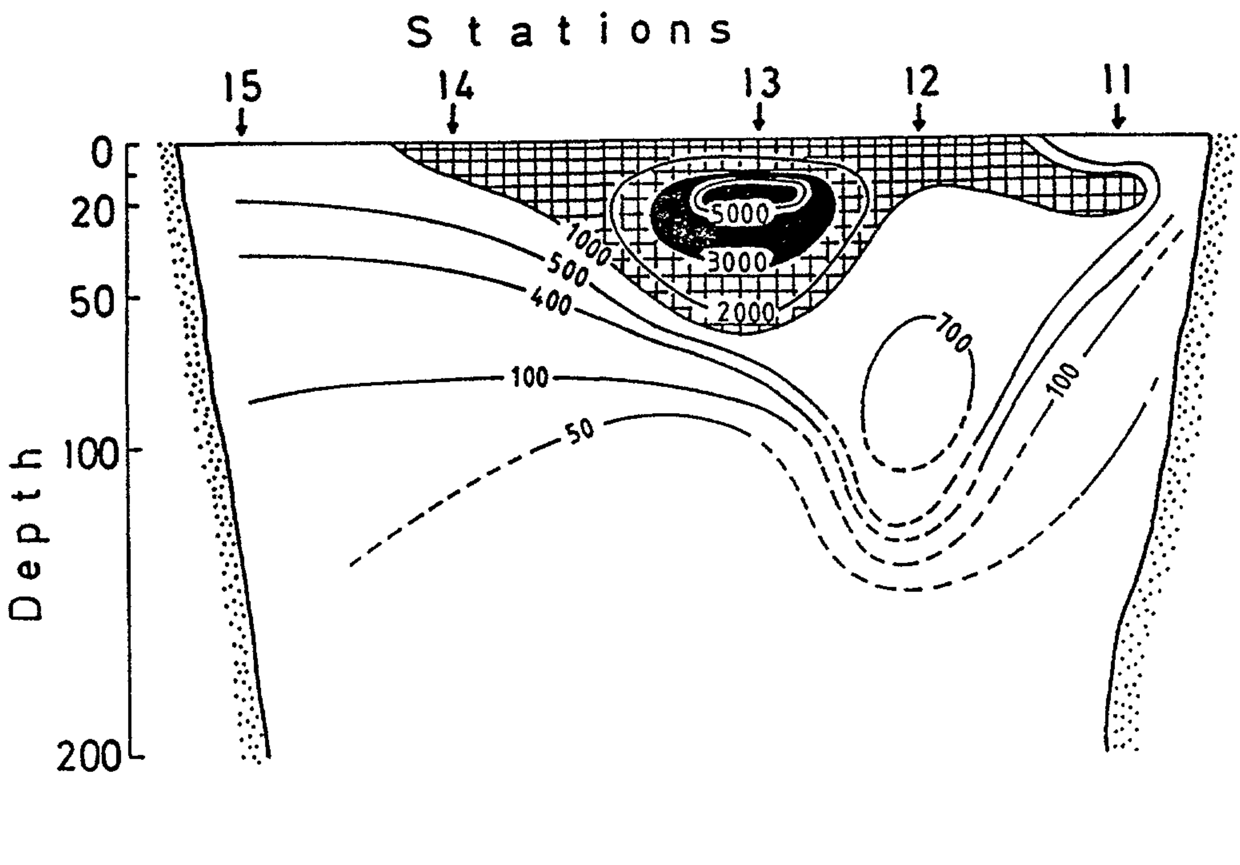

Fig. 2 Distribution of phytoplankton biomass (microplankton + nanoplankton volume, 10^6 μm^3 l^{-1}) at the Dubrovnik - Bari profile, April 1987.

INCREASED EUTROPHICATION OF THE NORTHERN ADRIATIC SEA - SECOND ACT*

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Abstract

Very calm and warm weather in late spring and early summer 1988 supported intense nonseasonal phytoplankton blooms in the western part of the northern Adriatic, which is under direct influence of Po River discharge. Surface salinity decreased to 16 $\times 10^{-3}$, and concentration of chlorophyll *a* increased up to 17 mg m^{-3}, with oxygen supersaturation to 203 $\times 10^{-2}$. Nannoplankton dominated the blooms (up to 76 $\times 10^{9}$ cells m^{-3}), but diatoms, particularly *Chaetoceros* spp. (up to 17 $\times 10^{9}$ cells m^{-3}), also occurred in large numbers. Large "organic" aggregates were formed in the water column with dimensions (up to 2 m long) and in quantities never previously observed. During late summer and early fall aggregates were distributed over the coasts occurred. Oxygen concentration was dramatically reduced in the bottom layer of the entire region: an event not observed to such a degree since 1977. During that year, in contrast to 1988, large quantities of freshwaters spread over the entire northern Adriatic causing extended phytoplankton blooms. In 1988 extremely low horizontal advection (current velocities usually below 20 cm s^{-1}) primarily favored an accumulation and high aggregation of detritus, and greatly reduced oxygen concentrations in the bottom layer.

Introduction

The northern Adriatic (19000 km^2, 635 km^3, mean depth 35m) receives freshwater from numerous rivers and streams, among which the Po River (1500 m^3/s; Cati, 1981) contributes more than 50% of the external nutrient input (Degobbis *et al*., 1986c; Degobbis & Gilmartin, 1989). The Po watershed is very large(75000 km^2; Cati, 1981), and includes highly developed Italian regions with 15 million resident people and an industry equaling an additional 40 million equivalent inhabitants (Anon., 1977). The Po Valley is intensively cultivated with heavy use of natural and artificial fertilizers. Consequently, river waters have a high nutrient content (Marchetti *et al*., 1985), and markedly influence the rate of primary production in the northern Adriatic (Gilmartin & Revelante, 1983), the microbial heerotrophic activity (Fuks, 1986), as well as the biomass, composition and relative importance of autotrophic and heterotrophic plankton (Revelante & Gilmartin, 1976a,b, 1988; Benovic *et al*., 1984; Fuks & Devescovi, 1985; Revelante *et al*., 1985).

Some coastal areas of the northern Adriatic are highly eutrophicated, and anoxic bottom layers occur frequently in summer (e.g. in the Emilia-Romagna region of Italy, south of the Po Delta; Montanari et al., 1984). Periodically, near anoxic conditions occur in the open northern Adriatic (e.g. Degobbis et al., 1979) or in its subregions: the area off the Po Delta (Degobbis, 1988) and the Gulf of Trieste (Faganeli et al., 1985).

In 1988 eutrophication in the northern Adriatic was greatly increased, bottom layer oxygen concentrations reached low levels previously only measured in 1977. During July and August 1988 the beaches along the coasts fouled with large quantities of mucous matter concentrated in large organic aggregates. Since 1966 the Center for Marine Research (CMR) has conducted a program to monitor primary production and the associated nutrient regime of the northern Adriatic. In this paper the unusual conditions observed during 1988 are discussed and compared with the historical data and the eutrophication events of 1977.

Materials and methods

From May to December 1988 seven cruises were performed along a 5 station transect across the open water of the northern Adriatic (Fig. 1). Additional observations and sampling were carried out in August on a 4 station transect from the mid-point on a line from Rimini, Italy to Cape Premantura, Yugoslavia, i.e. the southernmost border of the investigated area, to the midpoint on a line from Zadar, Yugoslavia to Ancona, Italy, in the central Adriatic. In May and October measurements were extended to a 21 station grid covering the entire northern Adriatic in the framework of a Yugoslav-Italian research program (Degobbis et al., 1986a). Additional research was also conducted in eastern coastal waters off the Istria peninsula, Yugoslavia (CMR, unpubl. data).

Water samples were collected with 5 1 Niskin, and Van Dorn samplers. Most of the analyses were performed aboard immediately after sample collection using standard oceanographic methods (for details are Gilmartin et al., 1972, Strickland & Parsons, 1972; Degobbis, 1988). Water temperature was measured with reversing thermometers and salinity by a Beckman RS 7C high precision salinometer. Dissolved oxygen was analyzed by Winkler titration. Current velocities and directions were measured at 10-min intervals with moored RCM-4 AAnderaa currentmeters during May/June and August/December 1988. The absorbance readings for all nutrient analyses were made on Beckman DU spectrophotometers with 10 cm cells. Organic phosphorus and nitrogen were determined after UV-irradiation of samples (Degobbis et al., 1986b). A Farrand A-4 fluorometer was used for chlorophyll a determinations. Carbohydrates (Dubois et al., 1956), proteins (Kjeldahl digestion), and lipids (Folch et al., 1957) were determined in mucous material). Additionally, "unbound" lipids (extractable fractions) and "bound" lipids (released by alkaline hydrolysis; Meyers et al., 1984) were analyzed by a Hewlett Packard 5730A gas-cromatograph with capillary columns. Bacteria in acridine-orange stained samples were counted by epifluorescence microscopy (Hobbie et al., 1977) using a Leitz LAB-D microscope with 3- PLEOMOPAK incident-light fluorescence illuminator and their activity was assayed by incubation with ^{14}C-glucose (Harrison et al., 1971). Opton inverted microscopes and a JEOL JSM 840A

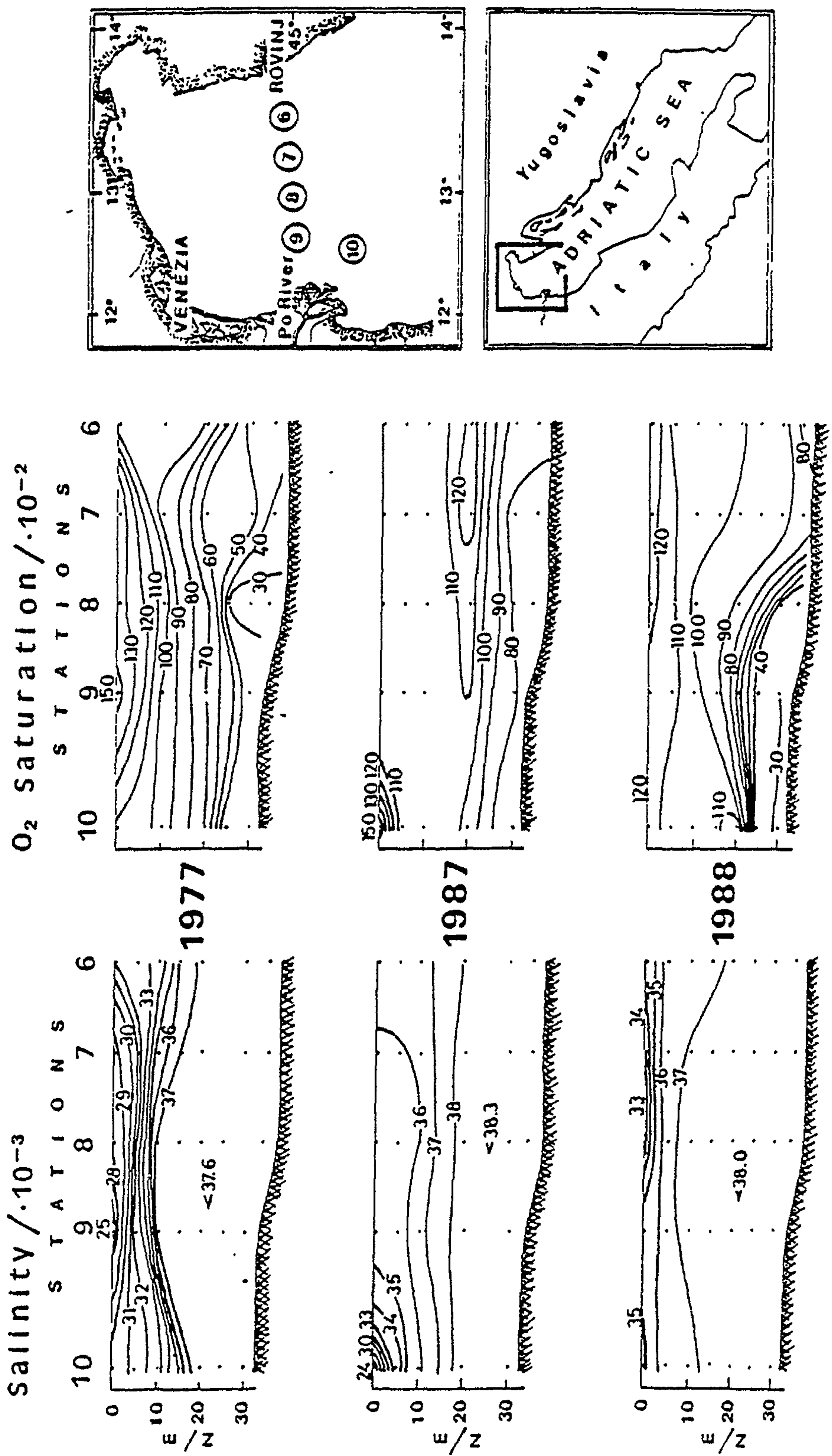
Salinity/·10⁻³
O₂ Saturation/·10⁻²
STATIONS
1977
1987
1988
z/m
VENEZIA
Po River
ROVINJ
Yugoslavia
ADRIATIC SEA
Italy

Fig. 1

scanning electrone microscope (SEM) were used to study phytoplankton community and samples of organic aggregates. Visual observations in the water column were performed at several stations (6, 9, and 10) by scuba divers.

Results and discussion

Eutrophication processes in the northern Adriatic reflect the integrated effects of primary production, nutrient assimilation, and heterotrophic nutrient regeneration, moderated by the intensity of water column stability combined with horizontal fluxes from river nutrient input and circulation. The region behaves as an open sea during the fall and winter, but as a semi-enclosed sea during spring and summer when the external nutrient input to the ecosystem is maximal (Smodlaka, 1986; Degobbis, 1988; Gilmartin et al., 1989). In late spring freshwater discharges (and associated nutrients) are near their maximum, light levels and temperature in the euphotic zone favor photosynthesis, and the most strongly developed phytoplankton crops of the year occur, with an export eastward (Revelante & Gilmartin, 1976a). During summer the water exchange between the northern and central Adriatic is at a minimum. As a consequence, riverine nutrients, and the products of the increased primary production are distributed (and nutrients recycled) over a major part of the region. Thus the monitoring of late spring phytoplankton bloom can provide an index of regional eutrophication and also allow an early warning of possible low oxygen events in the subsequent summer. Subsequently, the August ecological conditions quantify the consequences of the spring external nutrient impact on the northern Adriatic ecosystem.

The August distributions of salinity and oxygen saturation in 1977, 1987 and 1988 along the trans-Adriatic transect between Rovinj, Yugoslavia and the Po Delta in Italy are presented in Fig. 1. In spring and summer 1977 unusual hydrometeorological conditions prevailed causing extremely high freshwater discharge rates (daily means about 7000 m^3 s^{-1}; L. Cati, personal commun.). Freshwater "flooded" the entire area markedly increasing the stratification of the water column due to decreased salinities in the surface layers (Degobbis et al., 1979). During this period a series of phytoplankton blooms occurred over the entire region (chlorophyll a concentrations up to 14 mg m^{-3}) producing "surplus" organic matter which could not be consumed by the extand food web. The excess organic matter sedimented, and decomposed in a bottom layer separated from the upper part of the water column by a very strong pycnocline. This caused a higher than normal oxygen demand, and created near anoxic conditions in the bottom waters of the entire northern Adriatic.

Oceanographic and biological conditions during 1987 did not signal the unusual events of the 1988. On the contrary the 1987 data approximated averages calculated for August from a 1966-1986 data series (Degobbis, 1988). The Po River influence (daily mean discharge rates below 3000 m^3/s) was concentrated in the extremen western region represented by station 10 (maximum chlorophyll a concentration of 7.7 mg m^{-3}). Moderate freshwater quantities (surface salinities even higher than the 20 yr average) were advected throughout the region, and the phytoplankton standing crop was not increased (chlorophyll a concentration below 1 mg m^{-3}). Bottom oxygen concentration were near long-term averages, or even slightly higher for the western stations.

Conditions in August 1988 were quite different compared to 1977 (high riverine discharge), or 1987 (slightly lower than average discharge). Salinity values were near averages, i.e. no excess freshwaters (like e.g. in 1977) were discharged into the region, even if very low surface salinities (down to 16 x 10^{-3}) were measured in May and at the beginning of July in the area southeast of the Po River delta (station 10). In contrast, bottom oxygen saturation of the western and central parts of the northern Adriatic decreased in August (Fig. 1) to the same extremely low levels of 1977. Oxygen saturation decreased even further during the fall and in October was around 10 x 10^{-2} over a large area, since the hypoxic bottom layer extended eastward. However, in December 1988, like in 1977, oxygen was completely renewed in the entire northern Adriatic, due to increased horizontal water advection from the central Adriatic, a reduced phytoplankton crop, and vertical mixing in the water column, (CMR, unpubl. results).

Other data collected in 1988 have shown that, in contrast to 1977, marked freshwater influence and high production of organic matter was limited only to the station 10 in May and at the beginning of July (Tab. 1).

In May and July the phytoplankton bloom was dominated by nannoplankton (cells less than 20 m). At the beginning of July microplankton cell densities were also very high. Measured values for nano and microphytoplankton (diatoms+dinoflagellates; Tab. 1) were much higher than maxima reported in the literature for the area off the Po Delta (47 and 10 x 10^9 cells m^{-3}, respectively; Revelante & Gilmartin, 1983). Noteworthy, while in May chain forming diatoms _Chaetoceros_ spp. occurred at all stations with increasingly densities from east to west, in July these species were observed only at station 10, but in much higher densities (up to 17 x 10^9 cells m^{-3}; Tab. 1), strongly dominating the microplankton community in summer (Revelante & Gilmartin, 1976b; Smodlaka, 1985).

The marked phytoplankton bloom in the western Adriatic "crashed" in mid-summer, and was not observed from late July to September 1988 even at station 10 (o.2-1.0 mg m^{-3} chlorophyll _a_, phytoplankton counts 1-11 x 10^9 cells m^{-3}, mostly nannoplankton and diatoms). However, in October another phytoplankton bloom (chlorophyll _a_ 3-6 mg m^{-3}) occurred over the entire region, apparently triggered by increased freshwater discharge (surface salinities from 28-32 x 10^{-3}). This bloom additionally contributed "fresh" organic matter to the increased oxygen demand observed in the entire region.

From May to the end of August 1988 the weather was extremely calm and hot (Bulletins of the Marine Meteorological Center, Split, Yugoslavia), and high temperatures occurred in the surface layer (river plumes excluded) in July and August (25.5-29.0°C), much higher than the historical range for these months (21.0-27.60°C; CMR, unpubl. data). In addition, during spring 1988 horizontal current velocities were significantly lower than in the same period of 1986 and 1987 (Fig. 2), and current directions were highly variable. Low velocities, with a frequency maximum in the interval 10-15 cm s^{-1}, were also characteristic for the last week of August and September (Fig. 2) and even during October 1988 (CMR, unpubl. data). Unfortunately, no current measurements were available for 1977.

TABLE I

Value ranges for salinity (S), temperature (t), oxygen saturation (O2 sat), Secchi disk depth (zs), concentrations of total inorganic nitrogen (TIN), organic nitrogen (ON), orthophosphate (PO^4), organic phosphorus (OP), orthosilicate (SiO^4) and chlorophyll *a* (Chl *a*), densities of nanophytoplankton, diatoms, dinoflagellates and *Chaotoceros* spp., and heterotrophic activity (Vmax) in surface layer of the northern Adriatic Sea on 23 May and 7 July 1989.

Parameter	Stations 6 - 9	Stations 10
$Sx10^{-3}$	32.4-35.1	14.4-27.8
t/°C	18.6-25.5	21.5-27.5
O_2 sat/10^{-2}	117-143	170-203
zs/m	4.5-15	0.8-1.4
c(TIN)/mmol m^{-3}	0.3-1.0	3.5-6.8
c(ON)/mmol m^{-3}	3.5-10.5	11.3-36.6
c(PO_4)/mmol m^{-3}	0.05-0.12	0.11-0.15
c(OP)/mmol m^{-3}	0.12-0.43	0.76-1.38
c(SiO_4)/mmol m^{-3}	0.0-5.1	11-45
c(Chl *a*)/mg m^{-3}	0.9-2.4	10.1-17.4
A(nano)/10^9 cells m^{-3}	4-14	73-76
A(diatoms)/10^9 cells m^{-3}	0.09-0.6	1.3-19
A(dinoflag)/10^9 cells m^{-3}	0.02-0.08	0.01-0.5
A(*Chaetoceros*)/ 10^9 cells m^{-3}	0.05-0.3 (May) 0.009 (July, stat.9 only)	1 (May) 17 (July)
Vmax/10^{-3} mgC m^{-3} h^{-1}	24-80	63-119

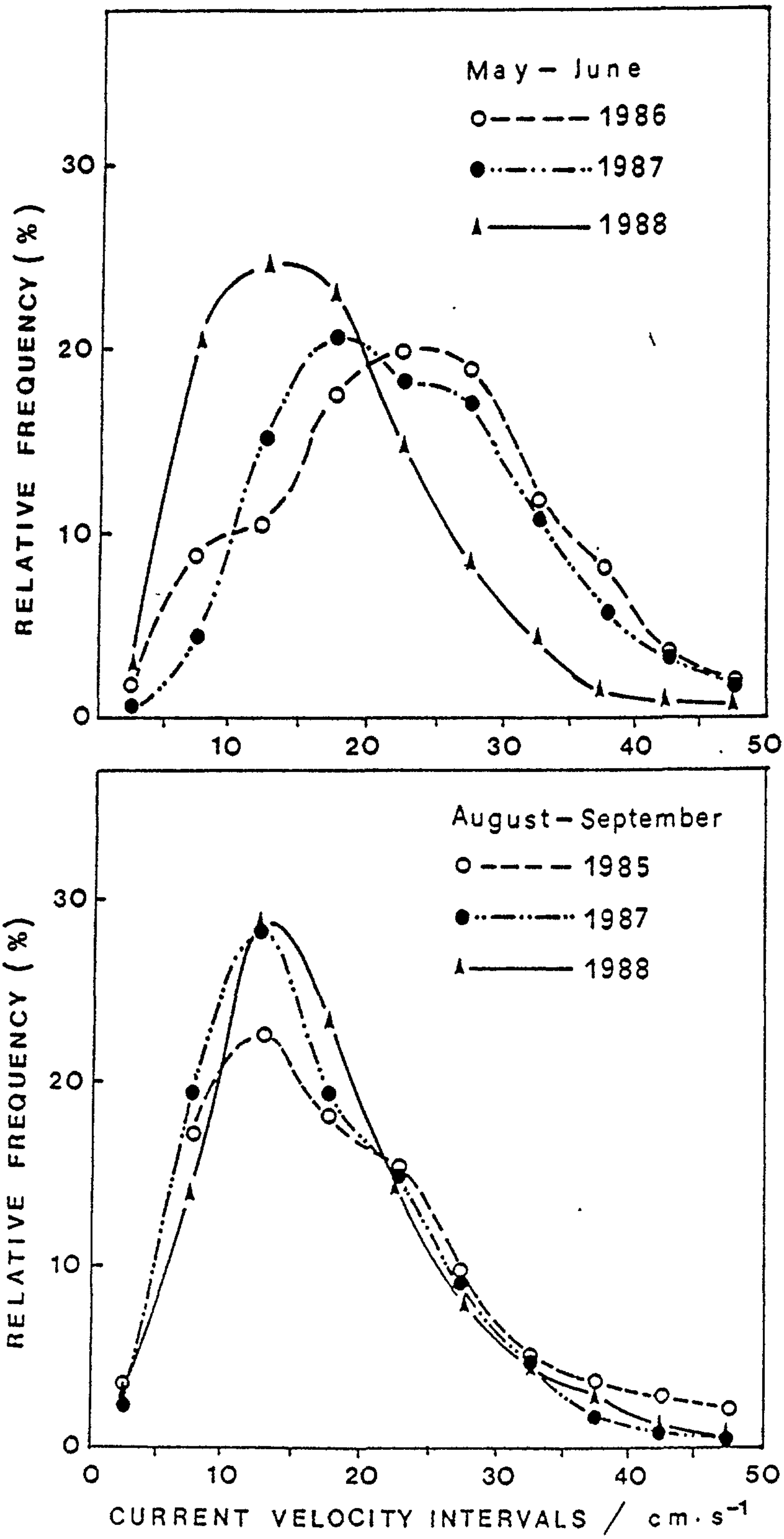

Fig. 2 Currents at station 6

From these data we hypothesized that in the 1988 spring extremely low water exchange rates occurred between the northern and the central Adriatic regions. In addition, strong vertical stratification occurred in the water column during spring and summer with density differences from surface to bottom (3.8-7.5 kg m^{-3}), in rages similar to 1977. However, while in 1977 density gradients were caused primarily by salinity gradients , in 1988 they were mostly due to temperature gradients. The lack of significant horizontal adection was probably more important in determining eutrophication events in 1988 than in 1977, when external nutrient imput influenced a larger region. In 1988 organic products were largely retained, biologically ecycled, an nutrients regenerated within the region, but with a similar impact on the oxygen budget as the 1977 eutrophic event.

The 1988 eutrophic event differed greatly from the 1977 event. Large quantities of mucous aggregates accompanied the event. These were mostly light-brown or light-green in color and ranged from few centimeters to about 2 m, were suspended in a relatively transparent water. Additional condensed yellow-brownish mucous material floated on the surface in "sheets"", several meters long, and/or in fronts, hundreds of meters long. Aggregates, as extensively developed as in 1988, had never been observed during CMR research in the open northern Adriatic (since 1965). Noteworthy, organic aggregates up to 20 cm in diameters were collected in the pucnocline layer in the Gulf of Trieste of the northern Adriactic in summer 1986 and 1987 (Herndl, 1988; Herndl & Peduzzi, 1988.

In the 1988 event herewith reported aggregates were most densely distributed in the region off the Po Delta (station 10). Amorphous elongated clumps were connected with filamentous structures throughout the water column and condensed ""sheets" covered about 30% of the surface. Along a southly transect (from station 10 to the central Adriatic off Ancona, Italy on 20 August) and eastwards (towards station 6 on 16 August) the density of the aggregates gradually decreased and were confined in the upper part of the water column. The surface coverage by condensed aggregates was also reduced. Such a distribution suggested a transport of aggregates from the western part of the northern Adriatic eastward and southward. Throughout the event large quantities of surface condensed aggregates fouled the coasts of the northern Adriatic reducing the recreational value of beaches (Fig. 3). This material particularly accumulated when light winds blew from the sea to the land.

Condensed mucous material was collected from the sea surface and near bottom in the eastern part of the northern Adriatic near the Istrian coasts, and analyzed chemically. About 80% of the dry weight was inorganic, mostly carbonates (weight loss in HCl). Carbohydrates strongly dominated in the organic fraction (weight loss at 500°C), while lipids and proteins accounted for few percentages, indicating that this matter originated mostly from exoproducts of phytoplankton and bacteria (Lancelot & Billen, 1985). "Unbound" lipid concentrations in mucous material (Tab. 2) collected above the bottom were an order of magnitude higher than in the surface sediments at the beginning of June (0.43 g kg^{-1}, dry weight). Generally, during diagenesis of organic matter, sediment concentrations of approximating "bound" fraction concentrations (CMR unpub. data; Nishimura, 1977). In contrast, in the mucous material collected above bottom, "bound" fraction increased with time, while "unbound" fraction remained almost constant (Tab. 2), but an "unbound"/"bound" ratio near unity was also established.

A wide variety of living and detrital material was incorporated in the organic matrix (Fig. 4), as already reported by Herndl and Peduzzi (1988). Diatom frustules dominated over biogenic remains. Numbers of silicoflagellate and ebridian remains were higher, relatively to diatoms, than in recent sediments of the norther Adriatic (Puskaric, 1988).

Bacteria also accumulated on aggregates (Fig. 4a; Herndl & Peduzzi, 1988). This may explain why higher total heterotrophic bacteria numbers were found in 1988 in the eastern, generally oligotrophic part of the northern Adriatic (5-18 x 10^{11} m^{-3} at station 6) than in 1986 and 1987, (1-10 x 10^{11} m^{-3}). In contrast, bacterial activities, measured by uptake of ^{14}C-glucose (Vmax), and ranging from 0.011-0.050 mg C m^{-3} h^{-1}, were not substantially different in 1988 compared with previous years. Lastly, glucose mineralization in summer 1988 (11% on average at station 6) was lower compared to previous years (35%) and may reflect the refractory nature of the organic aggregates.

The mechanism of aggregation is not yet well understood. Kranck & Milligan (1988) observed aggregation and formation of macroflocs during late phases of bloom dominated by Chaetoceros in Bedford Basin (Canada). Other authors (e.g. Biddanda & Pomeroy, 1988) reported detritus aggregation during degradation of phytoplankton material by heterotrophic bacteria. Large quantities of mucous were also produced during Phaeocystis poucheti blooms in the North Sea (Lancelot et al., 1987). Probably various mechanisms contributed to the formation of aggregates in the northern Adriatic. However, it is obvious that in 1988 extremely calm weather and low vertical advection strongly favored an exceptional development of organic aggregation.

Conclusions

The nutrient input (331000 t y^{-1} nitrogen and 28200 t y^{-1} phosphorus), mostly anthropogenic, plays an essential role in the biological processes of the northern Adriatic (Degobbis, 1988; Degobbis & Gilmartin, 1989). Synergistic interactions between unusual hydrometeorological conditions, water column stratification, water mass exchange rates, and external nutrient input can result in anoxic events in the bottom waters of the northern Adriatic. A major 1988 event hee reported suggests that the rates, frequency, and intensity of such events is increasing. Clearly, man cannot control oceanographic conditions, but he can moderate the anthropogenic nutrient load and decrease eutrophication of this marine environment.

SOME IRREGULAR PHENOMENA AND ONGOING ACTIVITIES IN THE GULF OF TRIESTE (YU)

(A. Malej)

Description of some irregular phenomena in the Gulf of Trieste (Northern Adriatic) in the last decade is given.

Besides summer 1988 bloom, which attracted the greatest attention due to its widespread distribution several other phenomena were mentioned.

During spring 1980 we registered a red tide which lasted (with interruptions) few months, the causative agent was Noctiluca miliaris (Malej, 1984). Oxygen difficulty in the deep water (>20m) has been reported in September 1983 (Faganeli et al. 1985). Proceeding this phenomenon a silicoflegellate Distephanus speculum was found in bloom concentrations in the bottom layer (Fanuko, 1989). A minor oxygen difficulty was reported also in late summer of 1987. The summer bloom of 1988 lasted altogether more than a month with interruptions. It was detected in the southeastern part of the Gulf and presumably originated outside the Gulf. The microscopic examination revealed that the bloom was dominated by diatoms, namely Nitzsdria closterium, Leptocylindrus danicus, Chaetoceros simplex, and Skeletonema costatum. The concentrations of particulate organic matter ($\approx 3 mgl^{-1}$) indicate the presence of "marine snow" (large detrital material embedded in an organic matrix and which contained also intact phytoplankton as well as numerous bacteria). Detailed description of the phenomenon will be given in Fanuko (in prep.), first results are presented by Malej Faganeli (1988).

Research activities at our laboratory include regular determinations of standard oceanographic parameters, nutrient concentrations, oxygen conditions, phytoplankton, bacterioplankton.

The research of the causes and consequences of the deep water oxygen difficulties includes the biogeochemical cycling of C, N, P vertical mixing, microbial loop and benthic community studies.

ANNEX II

Agenda

1. Opening of the Meeting

2. Rules of procedure

3. Election of officers

4. Adoption of the Agenda

5. Organization of work

6. Review of previous and ongoing activities

7. Causes and preventive actions

8. Effects and remedial actions

   8.1. Existing measures in other regions
   8.2. Guidelines for detecting and monitoring eutrophication in the marine environment
   8.3. outline of an assessment document

9. Coordination with existing national and international programmes

10. Conclusions and recommendations

11. Other business

12. Adoption of the report

13. Closure of the meeting

ANNEX IV

ASSESSMENT OF THE STATE OF EUTROPHICATION IN THE MEDITERRANEAN SEA AND PROPOSED MEASURES

ANNEX V

PREVAILING TERRIGENIC FACTORS OF ENHANCED EUTROPHICATION IN CRITICAL PELAGIC ENVIRONMENTS OF THE MEDITERRANEAN NERITIC ZONE
(Experimental Research Proposal)

by M. Aubert and J. Stirn

Outline

Justifications

- Preserving oligotrophic ecosystem as the main characteristics of the natural inheritance as far as the major part of the Mediterranean Sea is concerned and as an essential resource for the national economies.

- Prevention of further increases of eutrophication phenomena and possible improvements of conditions in certain areas where the eutrophication presents already a hindrance and/or negative impact upon:

  - fisheries and mericulture,
  - tourism and recreation,
  - thallasotherapeutic use of sea water,

  as well as a potential health hazard, particularly as related to eventual toxicity of sea food.

Rationale

Considering as critical in the concept of this proposal those specific environments in which the pertinent receiving capacity appears as to be at least temporarily surpassed, the only realistic alternative for the majority of cases seems the requirement for a significant reduction of relevant bioactive inputs from land-based sources of industrial, domestic and agricultural origin. Apart from measures for the elimination of detergent-phosphates, the present legislative and engineering trends are focused towards advanced treatment of sewage, finalized with the precipitation of phosphorus. This concept is partly due to rather non-critical transfer of practices as common for fresh-waters, and partly laying upon already historical doctrine of phosphorus-limited primary productivity of the Mediterranean Sea. However, the relevant evidence is rather poor and also it never has been proved experimentally. Therefore the relevant scientific advice to the engineering is risky and so are the envisaged capital investments that may not lead to any significant improvements. In addition to the above limiting macronutrient-dilemma there is a number of other questions to be answered that are particularly relevant to the dynamics of dinoflagellate populations, e.g. bioavailability of microelements and vitamins as well as the function and/or disfunction of telemediatons (exocrines) being blocked by certain non-biodegradable pollutants. Therefore the purpose of the proposed research is to investigate the above problems in a succession of project tasks and to transfer the results obtained, advising the management and engineering on rationally selected targets for remedial actions.

Programme Outlines

(Listed in an approximate follow-up of research operations)

- Selection of critical environments to be studied and compilation of pertinent data that have been gathered previously.

- Identification of environmental and trophic conditions during the entire cycluses of given bloom-phenomena within the areas of their appearance by continuous and/or high frequency measurements.

- Gathering data for the inventory and budgets of terrestric and atmospheric inputs of nutrients, selected microelements, chelating and eventually toxic effluent.

- Formulation of artificial growth-media which simulate environmental and trophic compositions that can be most likely expected at the initial phase of a bloom development.

- Technical and methodological development of chemostat-type system for flow-through bioassays and its application for the following aspect of the experimental research:

  - macronutrient-controlled productivity, population dynamics and ecophysiology of species that appear as dominant components of blooming phytoplankton associations, in monocultures in the first and in simulated mixed cultures in the following phases of experiments.

  - Identification of actually limiting species and forms of macronutrients and the relevant variability as related to both, changing properties in the growth media and intracellular nutrient pools, extrametabolic recycling, etc.

  - Limiting and/or promoting trophic factors which partly control proliferations of pertinent and as monoculture available dinoflagellate species, including eventual influence of bioavailable microelements, particularly the iron, vitamins and diatom-produced antagonistic telemediators.

  - Preparation of antagonistically active growth media and research in their eventual disactivation due to the molecular blockage by a number of potentially toxic components of agricultural and industrial pollutants as being assumingly relevant.

Site	Surface volume	Residence time		Normal concentrations ($\mu M.l^{-1}$)			Annual biogenic inputs											Inputs of inhibitors of grazers and competitors	Stratification		State of algal blooms (eutrophication) (see 1 to 8)	Frequency	Main Species	Comments
				N	P	Si	ΣN					ΣP					Si		S°/oo t°C	Wind				
		Physical	Biogenic				Wastes	Indust.	Agric.	Atmosph.	Tot.	Wastes	Indust.	Agric.	Atmosph.	Tot.								

Minimum chlorophyll
1. Green waters
2. Red tides
3. O_2 depletion (sporadic)
4. Summer-continuous O_2 depletion
5. Production of H_2S, CH_4
6. Growth of sulphur-oxidant bacteria
7. Death of benthic organisms
8. Abiotic (permanent)

ANNEX VI

Form for collection of eutrophication data