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Third Session of the Joint IOC-FAO Intergovernmental Panel on Harmful Algal Blooms
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ICES-IOC WORKING GROUP ON DYNAMICS OF HARMFUL MARINE PHYTOPLANKTON:

(i) **Report of the Workshop on Modelling the Population Dynamics of Harmful Algal Blooms, Vigo, Spain, 4-7 May 1994**

(ii) **Report of the Joint Meeting of the Working Group on Harmful Algal Bloom Dynamics (WG-HABD) and the ICES Working Group on Shelf Seas Oceanography (WG-SSO), Vigo, Spain, 9-10 May 1994**

(iii) **Report of the ICES-IOC Working Group on Harmful Algal Bloom Dynamics, Vigo, Spain, 11-12 May 1994**

(iv) **Report of the ICES/IOC Workshop on Intercomparison on *In Situ* Growth Rate Measurements (Dinoflagellates), Aveiro, Portugal, 25-29 July 1994**

International Council for the
Exploration of the Sea

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REPORT OF THE WORKSHOP ON MODELLING THE POPULATION DYNAMICS OF HARMFUL ALGAL BLOOMS

Vigo, Spain, 4-7 May 1994

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WORKSHOP ON MODELLING THE POPULATION DYNAMICS OF HARMFUL ALGAL BLOOMS

1. INTRODUCTION

The ICES/IOC Workshop on "Modelling the Population Dynamics of Harmful Algal Blooms" was convened in the Instituto Español de Oceanografía (IEO, Vigo, Spain) from 4 to 7 May 1994, under the co-chairmanship of Wolfgang Fennel (Germany) and Paul Tett (United Kingdom). Twenty nine participants from fifteen countries (including five observers) took part in it. Alberto González-Garcés, Director of the Centro Oceanográfico de Vigo (IEO), welcomed participants and drew attention to the enormous socioeconomic importance of harmful algal blooms in the context of Galicia. Wolfgang Fennel reminded participants of the terms of reference, and that the central aim of the workshop was to establish a common language between biologists and physicists, so that the modelling of harmful algal blooms can be advanced.

Timothy Wyatt acted as a rapporteur.

This workshop involved participants in three distinct activities:

a) Presentation of various viewpoints relevant to modelling phytoplankton-hydrographic interactions;

b) Discussions of modelling procedures and philosophy;

c) Practical exercises in the use of pre-prepared models on PCs.

The list of participants is presented in Annex I. The presentations are collected in Annex II, and the instructional material which accompanied the PC exercises are in Annex III.

Financial support for the organization of the Workshop was provided by D.G. XIV of the CUE (Sponsorship Grant MAC/3/94, AIR Programme)), and by the Instituto Español de Oceanografía. IOC (UNESCO) supported the participation of four observers .

AddLink S.A.-Spain kindly provided twelve licences for a demonstration of the MATLAB programme during the Workshop.

2. TERMS OF REFERENCE

At the 81st ICES Statutory meeting in Dublin (23 September-1 October 1993) the Council resolved (C. Res. 1993/2:49) that:

"A Workshop on Modelling the Population Dynamics of Harmful Algal Blooms will be held in Vigo, Spain, from 4-7 May 1994 under the co-chairmanship of Dr P. Tett (UK) and Dr W. Fennel (Germany) to:

a) investigate the use of numerical models in improving understanding of the dynamics of harmful algal blooms;

b) use the above models to assist in the design of sampling strategies, interpretation, and forecasting of harmful algal blooms;

c) develop a dialogue between physical and biological oceanographers with respect to harmful algal blooms, including the role of physical inputs, and temporal and spatial scales".

3. PROGRAMME

4 May

Morning 10.00-13.30

- Welcome (Director of IEO-Vigo).
- Aims of the workshop (Fennel/Tett).
- Algal bloom models - an overview (Tett).

Afternoon 15.00-18.00

- Modelling the yearly cycle of plankton (Fennel).
- How to built a simple model (seminar with PC/ Fennel).

5 May

Morning 9.00-13.30

- Plankton population dynamics with and without physics (Wyatt).
- Nutrients in buoyant plumes (Osborn).
- Modelling the primary production in the North Sea using a coupled 3D model (Svendsen).
- Numerical experiments with a simple coupled model (Sattler/Fennel).

Afternoon 15.00-18.00

- Working with models (seminar with demonstrations Tett/Burren).

6 May

Morning 9.00-13.30

- A model of the effect of cyst germination on *G. catenatum* populations (Blanco).
- The ecophysiology of exceptional blooms (Tett).
- Dynamic modelling of phytotoxin kinetics in benthic invertebrates (Silvert/Cembella).
- The importance of bio-physical interactions in controlling bloom dynamics in patchy coastal environments (Donaghay).

Afternoon 15.00-18.00

- Diurnal variation and primary production during the spring bloom (Barkmann)
- Towards predictive phytoplankton models (Aksnes)
- Training with PC-programmes (Fennel/Tett)

7 May

Morning 9.00-13.00

- Further exercises in modelling on PCs
- General Discussion.

4. PLENARY DISCUSSION

The objectives of the modelling workshop on HAB, as defined by the terms of reference, were to explore the use of numerical models in improving understanding of bloom dynamics.

An attempt was made to unite phytoplankton biologists, physical oceanographers and modellers to achieve a common definition of the rôle of physical and biological factors integrated over various spatio-temporal scales. A debate arose early in the discussions regarding the appropriate use of ecosystem models. Some participants adopted the approach that numerical models defined by a discrete set of differential equations would serve our purpose; others wished to consider other modelling techniques including *conceptual* (i.e. box or compartment), *analytical*, and even *intuitive* models, the latter of which are employed routinely by phytoplanktologists in formulating and testing working hypotheses.

Existing models of different types might be helpful for crude estimates for risk assessment, however further research is required to refine the underlying assumptions of such models. All participants would welcome an increased participation of phytoplankton biologists in future modelling exercises. It was acknowledged that in general the forcing functions determining the hydrodynamic regime in a given system were better defined and thus more amenable to modelling than the biological determinants leading to HAB formation. At least some of the initial scepticism among biologists towards the utility of numerical modelling in understanding HAB dynamics was due to the belief that biological systems are inherently so complex (involving organismal behaviour, etc.) that the number of functions sufficient to define them could not be successfully incorporated. This was countered by statements that the complexity of a system is not necessarily a fundamental property, hence simple models are not necessarily worse at describing the coupling between physical and biological parameters than more complex ones. In this case, the appropriate level of complexity in the model is that which makes the least number of assumptions while best explaining reality.

One positive outcome of the workshop was the understanding achieved among physical oceanographic modellers and phytoplankton ecologists regarding a common lexicon for their discussions. Thus, physical oceanographers became familiar with the use of terminology associated with growth and primary production (Liebig's Law of the Minimum, cell quota, Michaelis-Menten kinetics, photosynthetic parameters, etc.) while phytoplanktologists were shown the rôle of small-scale turbulence, advective and diffusive flux, barotropic currents, etc., in driving bloom aggregation and dispersion.

The practical examples of extant phytoplankton dynamic models presented to the workshop were essentially oriented towards modelling primary production, biomass, net carbon flux and spring diatom blooms. The implicit assumptions of these models is that there exists a defined suite of first order properties (e.g., nutrient kinetics, photosynthetic rate, etc.) which govern the phytoplankton population growth rate. There was disagreement regarding the utility of general primary production models for understanding HAB dynamics, since the critical property is the harmful effect of such blooms, rather than a common ecophysiology. Biologists also questioned the reductionist approach of the physical modellers towards the biological components; simplifying assumptions such as reducing the primary producer and secondary grazer to single components and fixing the grazing rate as constant in time were considered to be unrealistic. From the point of view of modelling individual harmful species, it was pointed out that individual life history features might be of considerable or even over-riding importance to their population dynamics. On the physical side, while the impact of for example a meteorological front might be adequately known for diagnostic purposes, prognosis would require a detailed ability to predict the time of arrival of that front, which is not generally possible. These views did not inmediately deflect the course of the debate, which concerned the mathematical expressions of functional relationships (such as the Michaelis-Menten equation for nutrient kinetics), step functions and truncation procedures, and whether there is a need for feedback between the physical and biological components of models.

Since it is not clear that the biological forcing functions governing HAB population growth are necessarily those of nutrient dynamics, an overemphasis on nutrient kinetics in modelling may be seriously misleading. Some participants expressed the pessimistic view that HABs will prove particularly intractable to modelling since their net population growth may be a function of *secondary* or *tertiary processes* (allelopathy, water conditioning, complex nutrition or behaviour, etc.) which are currently unknown or at best are ill-defined. Some discussion took place of the different modelling approaches which might emerge depending on whether one took the view that harmful algal events result from the opportunistic behavior of individual species, or alternatively, that they occur as a result of changes to the system at large. It was commented that for example PI curves of harmful species do not appear to differ from those of other species, but that special features such as encystment/excystment cycles, vertical migrations, and heterotrophy need to be incorporated into HAB models.The problems of identifying first and higher order processes were briefly alluded to, with particular reference to the forms of functional relationships, and several people drew attention to biological feedback mechanisms which need to be considered, such as the relationships between algal biomass and light-absorption, or the production of extracellular polymers, viscosity and turbulence. The fact that HABs may arise in response to catastrophic environmental disruptions which are themselves not predictable contributes additional complications.

A fundamental dichotomy was established between *diagnostic* models, for analyzing and explaining bloom events which have already occurred, and *prognostic* models for forecasting and bloom prediction. There was some agreement that diagnostic models need to be developed now to improve our understanding of the ecological and oceanographic mechanisms involved in HAB occurrence, and that prognostic models lie further in the future. But it was also felt that at a practical level, models are required now which will give early warnings of potential dangers to shellfish producers or fish farmers, i.e. real time guidance, and that the kinds of model which are successful in such contexts do not necessarily lead to better understanding of the underlying biological and oceanographic mechanisms. In the interim, greater emphasis should be placed on the development of "species of interest" models to focus on specific harmful species. Furthermore, it was pointed out that it is not necessary to model entire ecosystems to provide useful recommendations to public health officials and fisheries and aquaculture managers. Models capable of generating short-term predictions (over a few days or weeks) based upon risk assessment probabilities generated from monitoring data can assist in the implementation of mitigating strategies for HAB effects. The development of *holistic bloom dynamic models* coupling biology with three-dimensional models of circulation and mixing await further definition of the requisite rate processes and parameters.

Some participants felt that the discussion had not yet succeeded completely in achieving an understanding between physicists and biologists, in part due to the fact that it was being conducted in a language unfamiliar to biologists. Bloom prediction and some other matters already dealt with may belong more properly to a future workshop, while the current session should have addressed fundamental questions about how to begin modelling and the requirements for background information.

Participants felt the workshop was an excellent start towards the goal of strong interaction between biologists, physicists, and modellers on the problems of harmful algal blooms. The multitude of problems associated with the oceanographic complexity of the problem will necessitate many different modelling approaches.

5. CONCLUSIONS

Discussions during the workshop had revealed a diversity of views on the utility and purposes, as well as the methods, of modelling of harmful algal blooms. Some participants remained unconvinced of the value of numerical modelling. In this final remarks, Dr Tett attempted a synthesis of these views. Modelling, he thought, could help in understanding and predicting harmful blooms. Three approaches

seemed likely to be useful.

(1) As part of the scientific process. Relatively simple models of life cycles and biological-physical interactions can act as tools for testing hypotheses about HABS and thus for gaining better understanding of their causes and dynamics.

(2) For risk assessment. Appropriate models could provide objective estimates of HAB risks in particular localities. For example, a 2-D circulation model of a ria coupled with a semi-stochastic model of dinoflagellate population dynamics could be forced with data for a range of typical meteorological and oceanographic conditions to give bloom probabilities for particular locations and conditions.

(3) Day-to-day prediction of bloom evolution. In the same way that it was not possible to predict weather more than a few days in advance, it seems unlikely to be possible to predict particular bloom events any further ahead, if for no other reason that phytoplankton growth was strongly influenced by weather. However, by analogy with modern methodes of weather forecasting, it should be possible to provide forecasts, updated daily, and valid over the next few days, of the evolution and movement of blooms in a given region. The basis for such predictions would be (a) high-resolution, 3D physical transport models, accurate over irregular topography, and tuned to the region in question; (b) numerical models for the dynamics of relevant harmful algae (or cyanobacteria) engineered for modular coupling with the physical model; (c) networks, including remote sensing, for real-time monitoring of relevant aspects of water physics, chemistry and biology; and (d) procedures for combining these real-time observations with the output of a model driven by actual and forecast weather.

Dr Tett distinguished the type of effort and funding necessary to advance each kind of modelling. Type 1 was part of the scientific process, and was taught as such in many institutes of higher education. He hoped that the workshop had successfully given some flavour of this approach to persons who considered themselves not to be modellers. Type 2 could be seen as applied research and as a way of drawing together existing knowledge. Where there was adequate local knowledge of hydrography and biology, a modeller skilled in this approach should be able to provide useful estimates of risk with about a year's work. His experience had been that both types of modelling helped the dialogue between scientists and the fishing and fish-farming industries and their regulators.

Finally, he saw type 3 modelling as an engineering problem, which would draw upon the scientific understanding gained with type 1 models and applied in type 2 models. All parts of the methodology for type 3 models were now available, but implementation for a given location would be costly, and would clearly only be justified in regions where the economic consequences of HABs were large and where such consequences could be ameliorated by predictions of bloom evolution.

6. RECOMMENDATIONS

The dialogues between physical and biological oceanographers, modellers (theory) and non-modellers, laboratory work and studies at sea shoud continue in order to improve our understanding of the scientific principles involved in HAB.

A practical workshop on building models from scratch using participants data sets should be organized.

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ANNEX II: COLLECTION OF SCIENTIFIC COMMUNICATIONS

MODELLING TOXIC ALGAL BLOOMS

A dozen points by way of Introduction

Paul Tett

1. **Simple view** - phytoplankton are green stuff that require light and nutrients. When stratification provides ample light, a bloom will occur if nutrients are sufficent.

2. **Complications** - the bloom might be prevented by grazing, sinking or physical dispersion; the bloom might be concentrated by physical processes; the bloom might contain harmful algae, and their harmfulness [/toxicity] might be enhanced by bloom conditions.

3. **Equation** for rate of change of phytoplankton biomass **X:**

$$\partial X/\partial t = -V\cdot\partial X/\partial y - (W+X_w)\cdot\partial X/\partial z + \partial(K_y\cdot\partial X/\partial y)/\partial y + \partial(K_z\cdot\partial X/\partial z)/\partial z + (\mu - G)\cdot X$$

Where:

y (horizontal) and z (vertical) are spatial co-ordinates;

(a)
V, **W** are horizontal and vertical water velocities;
$\mathbf{K_y}$ and $\mathbf{K_z}$ are horizontal and vertical turbulent diffusivities;
(b)
$\mathbf{X_W}$ is vertical phytoplankton velocity relative to water;
μ and **G** are phytoplankton relative growth and grazing loss rate.

(a) terms are physics;
(b) terms are biology, and differ between species; in addition,

$\mu = \mathbf{f(I,S)}$

and thus depends also on the effect of physical processes on irradiance **I** and on nutrient concentration **S**.

4. What is best way of describing **the physical framework**?:
   - eulerian, fixed Cartesian (or similar) co-ordinates, with time- and depth- varying turbulent diffusivities parameterising small-scale (rapidly fluctuating) velocities [as equation above);
   - time-varying mixed (boundary) layers, transferring water etc. by entrainment;
   - eulerian, fixed compartments, with all transports parameterised as exchange rates between compartments;
   - lagrangian, particle-tracking models, with turbulence/mixing effects represented by time- and depth- varying step length.

5. **What other physical processes** (other than transports) must be included?:
   - deposition/resuspension for (a) algae with benthic stage, and (b) light absorbing SPM;
   - optical processes, including effects of algae themselves as well as SPM on light attenuation, leading to prediction of **I**.

6. **How to link physics and biology:**
   - *statically*: take physical parameters either from observation (or deduction from observation), or from physical model run independently of biological model, then applied as time-series to biological model;
   - *dynamically*: solve physical and biological equations simultaneously.

7. **The purpose** of models:
   - *diagnostic*: to aid understanding, often by using the model for analysis or what-if questions: needs only typical or generalised initial and forcing data;
   - *prognostic* - to predict what will happen: needs accurate initial and forcing conditions (and may need to make predictions about evolution of forcing - e.g. of weather).

8. Model **time-scales**:
   (not the same as the computational time-step)
   - for understanding/predicting annual cycle - resolve to 1-day time-scale;
   - for understanding/predicting detailed time-courses of blooms - need to resolve physical processes within tidal cycle and day, and diel biological cycles of growth, grazing and vertical movement?

   (the importance of understanding the effect of averaging time-scales for the forcing data)

9. **Biological models:**
   - bulk, or biogeochemical: for total chlorophyll or organic carbon; compartmentalisation on functional basis, e.g. microplankton-detritus;
   - trophic network, representing selection of types of organisms and flows of energy/material amongst them: species differ in terms of: ability to get and use nutrients; use of light; vertical movement; susceptibility to grazing.

   (understanding the biological models - reduce physical effects by simulating laboratory culture, microcosm or mesocosm)

10. **Seeding bloom models:**
    - what (in reality, in a model) controls the biomass or species innocula present at the start of a bloom (at the end of winter; in the case of a summer bloom);
    - seeding from the benthos (e.g. cyst-forming dinoflagellates), or from outside the model domain;
    - importance of individual life-cycles (e.g. *Phaeocystis*);
    - is seeding a largely deterministic or largely stochastic process?

11. **Predicting the consequences** of blooms:
    - development of toxicity;
    - oxygen consumption by bloom biomass;
    - release of organics (e.g. ---> foaming; DMS --> acid ppt.);
    - trophic effects.

12. **Optimism and pessimism** about models:
    - models based on conservation (e.g. potential energy, total nitrogen) can make reliable over-all predictions, even if initial data inadequate: especially when model (and nature) includes stabilising feedback;
    - models based on non-linear interactions with positive feedback (e.g. turbulence-generation, predator-prey) may have chaotic behaviour, so that outcome depends critically on exact knowledge of initial conditions.

MODELLING THE YEARLY CYCLE OF PLANKTON

How to construct a model of a marine ecosystem

Wolfgang Fennel

Models of marine ecosystems require coupling of physical and biogeochemical models.

What is a model? In a formal sense a set of differential equations which describe the dynamic behaviour of a system.

Dynamic Equations - describe changes in time. In physics the changes are caused by forces, and formulation of equations follows from basic laws (conservation of energy, momentum, mass, etc..)

How to formulate dynamical equations of a marine ecosystem? What drives the changes in a marine ecosystem? There is no general rule to formulate the biogeochemical relationships in terms of differential equations. Formulation requires SIMPLIFICATION of a properly addressed problem.

EXAMPLE

'Description of the annual cycle of plankton'

Consider nutrients, plankton, and detritus in terms of concentrations (relative to the concentration of the limiting nutrient)

N - nutrients
P - phytoplankton
Z - zooplankton
D - detritus

This implies neglect of several dynamical aspects (e.g. individual behaviour)

What drives the changes of N, P, Z, and D in a simple ecosystem?

- growth and loss of phyto- and zooplankton
- redistribution through currents and mixing

$\Delta(N,P,Z,D)/\Delta t =$ (redistribution - currents, mixing)(N,P,Z,D) + (gain and loss) (N,D)+ (growth and loss) (P,Z).

growth of P:
consider one day as time scale,
(physical control - light, temperature, etc. has been summarized under V_{max} ,can be 'zoomed in' by more detailed assumptions) fundamental relationship - nutrient limitation
growth(N) = $V_{max}\ N^2/(\alpha^2 + N^2)$
low growth rates for low nutrient levels
α = half-saturation constant
growth (N) = V_{max} for $N >> \alpha$
growth (N) = $V_{max}\ (N/\alpha)^2$ for $N << \alpha$

Dynamical relations
$\Delta P/\Delta t \sim$ growth(N) P
$\Delta N/\Delta t \sim$ -growth(N) P

LP = loss of phytoplankton (extracelluar release, mortality)
LPN, LPD = loss of P converted to N, D
LP = LPN + LPD

$\Delta P/\Delta t \sim$ growth(N)P-LP P
$\Delta N/\Delta t \sim$ -growth(N) N + LPN P

$\Delta D/\Delta t \sim$ LPD P

growth of Z through food limited grazing
graz(P) = β [1- exp(-I P^2)]
I = modified Ivlev constant
graz(Z) = β for P > > 1
graz(Z) = β I P^2 for P < < 1
$\Delta Z/\Delta t \sim$ graz(P) Z
$\Delta P/\Delta t \sim$ -graz(P) Z

LZ = loss of zooplankton (egestion, mortality, etc)
LZN = loss of Z converted to N
LZD = loss of Z converted to D

$\Delta N/\Delta t \sim$ -growth(N) N + LPN P + LZN Z
$\Delta P/\Delta t \sim$ growth(N) P - LP P -graz(P) Z
$\Delta Z/\Delta t \sim$ graz(P) Z - LZ Z
$\Delta D/\Delta t \sim$ LPD P + LZD Z

ignore loss of Z by higher predators (included in mortality)

TRUNCATION OF THE HIERARCHY

Coupling of physical and biological dynamics

B = (N, P, Z, D)
$\underline{v}$ = (u, v, w) - current vector
A_h, A_v - horizontal and vertical eddy diffusivities

ADVECTION DIFFUSION EQUATION

$B_t + \underline{v} \cdot \nabla B - A_h \Delta_h B - A_v \Delta_v B$ = biological dynamics
ocurrence of $\underline{v}$ and $A_{h,v}$ requires input from a circulation model

COUPLED MODELLING

Reduction to a simplified BOX MODEL
- integrate horizontally
- consider two vertical layers

$<B_t>$ = <biological dynamics> + fluxes through boundaries

upper layer
N_t = -growth(N) N + LPN P + LZN Z + A_{mix}(D-N) + SN^{ext}
P_t = growth(N) P - LP P -graz(P) Z
Z_t = graz(P) Z - LZ Z

lower layer
D_t = LPD P + LZD Z - A_{mix}(D-N) + SD^{ext}
vertical fluxes by sinking - LPD and LZD
A_{mix}(D-N) controls vertical fluxes by mixing
SN^{ext} and SD^{ext} prescribe external fluxes (sources and sinks)

Assume that the biological activity is controlled by physics through formation and destruction of stratification

in the box model - switch from one layer to two layers

for day 92 to day 273:
grow, graz nonzero; A_{mix} zero

for day 0 to 92 and 273 to 365:
grow, graz zero; A_{mix} nonzero

overwintering of P and Z?

assume, that P and Z decrease to a certain low background concentration, P_B, Z_B.

Fig. 1
Model run of the yearly cycle of nutrients, N, phytoplankton , P, zooplankton, Z, and detritus, D, with constant rates.

Fig. 2
Model run of the yearly cycle of nutrients, N, phytoplankton , P, zooplankton, Z, and detritus, D, with time dependent rates.

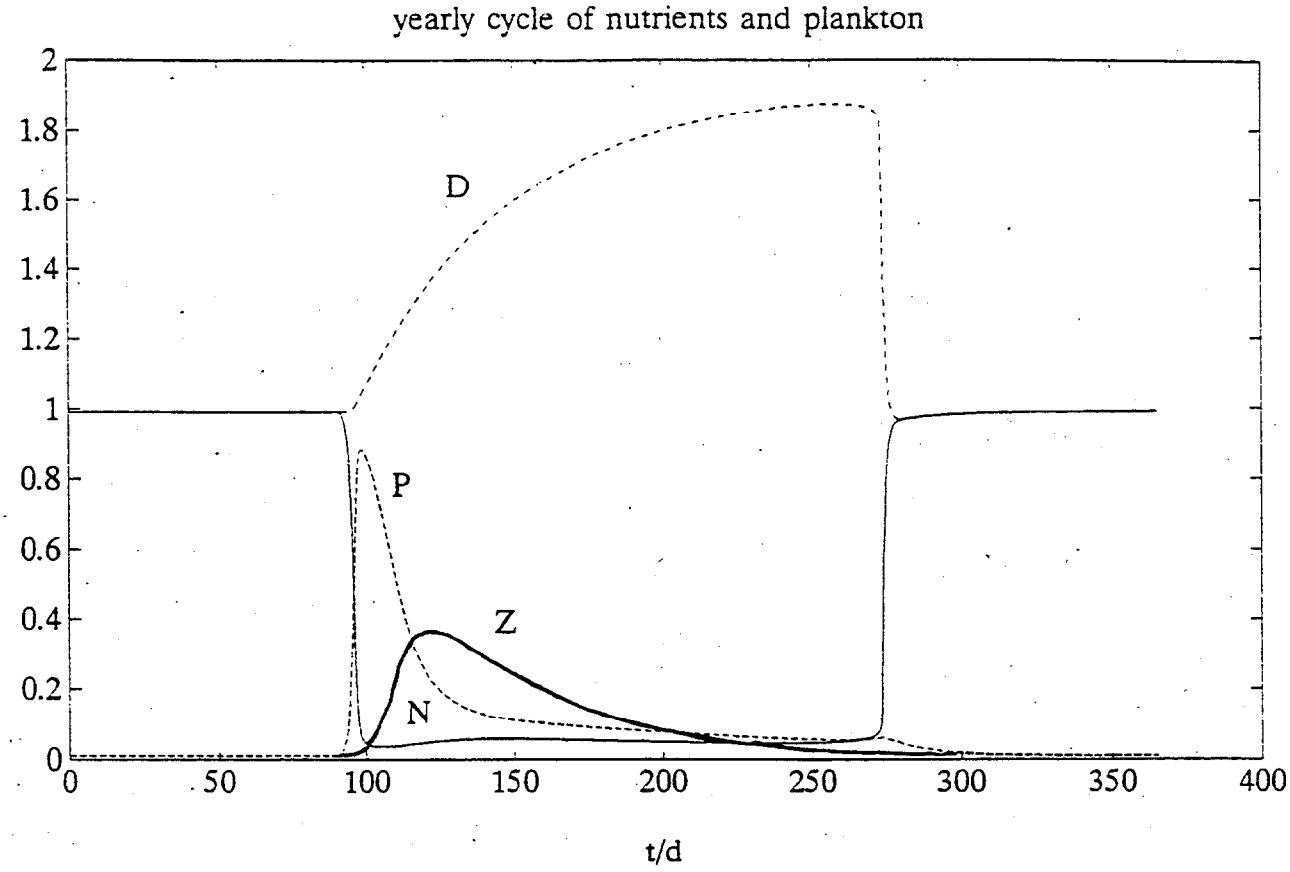

Fig. 1 (Fennel)

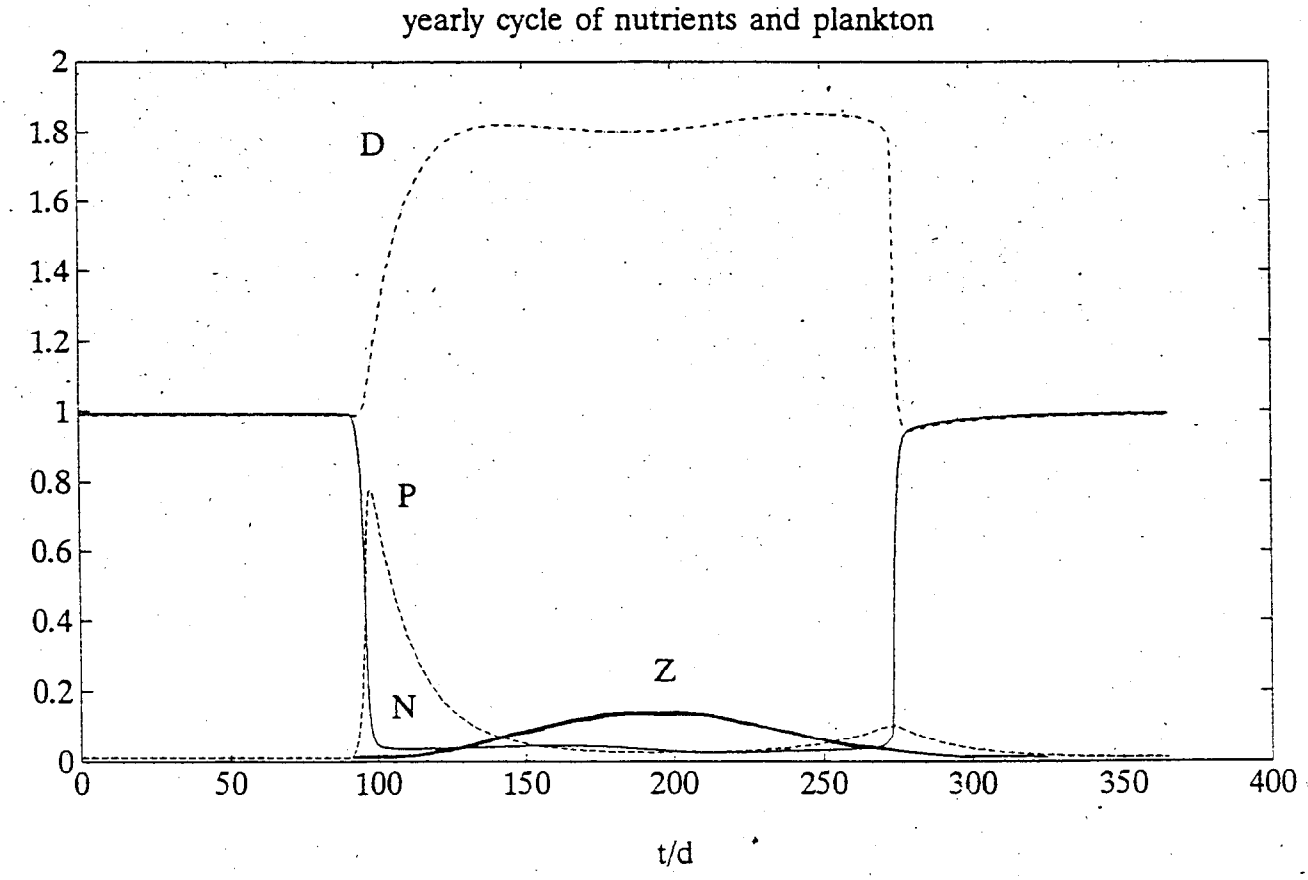

Fig. 2 (Fennel)

BUOYANT COASTAL PLUMES: SOME SIMPLE COMMENTS ABOUT THEIR DYNAMICS

Thomas Osborn

The dynamics of coastal currents are much more complicated than the open ocean, due to the significant role of bottom friction and the large variability in temporal and spatial coordinates. However, let us consider very simplified force balances to compare an open ocean front, to a coastal front, and to an estuary.

A two-layer, open-ocean regime with a frontal region between two water masses with a density difference, is shown in figure 1. Pressure is the weight of water overhead. Since (by definition of the problem) there is no horizontal pressure gradient in the lower layer (below 2000 dbars), the sea surface must vary in height to account for the difference. In the frontal region of the upper layer, where the density transition occurs, there is a sea surface slope. There is a horizontal pressure gradient only in the region below the sloping sea surface (this pressure gradient decreases to zero at 2000 dbars). Due to the geostrophic force balance that exists in the open ocean, there is a frontal jet in the transition region but no flow anywhere else. The geostrophic balance is from the cross-stream component of the equation of motion, i.e., the east-west current is derived from the balance of forces in the north-south direction.

In an estuary, figure 2, the flow is driven by the fresh water flowing 'downhill' along the estuary. Salt water is entrained from below - increasing the volume transport dramatically. The balance of forces is now the downstream pressure gradient, providing acceleration, for the upper layer, and overcoming the interfacial stress between the upper layer and the lower layer.

In the estuary, it is the balance of forces and accelerations along the axis of the estuary which determines the axial velocity. For a simple buoyant coastal plume, it is likely to have most of the pressure gradient balanced by the Coriolis force with a fraction in the downstrean direction to overcome bottom friction. If the plume has a vertical front on the outside edge (figure 3a) then the argument used for the open ocean jet will have the current concentrated in the frontal region. The water flow is not spread across the entire fresh water plume. Intuitively one might expect flow in the plume like water running along a gutter, but rather the fresh water input is a source of buoyancy (appearing as elevated sea level); which leads to a flow in the frontal region. Sloping density surfaces (figure 3b) serve to spread out the surface slope over a wider region than the surface expression of the front. This spreads out the flow but it is still located towards the outside of the plume. Of concern to harmful algal blooms is the question of surface convergence in the frontal region, which when combined with behavioral characteristics, especially vertical swimming, would lead to the concentration of organisms into the region of maximum advection. Such may be the case with *Alexandrium tamarense* blooms in the Gulf of Maine.

In conclusion, the spatial and temporal scales of buoyant coastal plumes imply a geostrophic balance which predicts the main flow in the outer boundary, where there is a horizontal density gradient. Surface convergence into the plume in conjunction with vertical swimming can lead to concentration in the frontal flow.

A SIMPLE MODEL OF COUPLING PHYSICAL WITH BIOLOGICAL DYNAMICS

Carsten Sattler and Wolfgang Fennel

Understanding of complex biogeochemical processes in the sea by means of models requires simplifications to extract the main features of the processes involved.

The physical control of the biology implies that coupled models are necessary. A main problem is that there are no first principles which determine the mathematical relationships of the biological dynamics. We choose an Eulerian continuous model for the dynamics of the biological state variables and connect this to a circulation model. The rationale is to study a simple system where the circulation patterns are well defined and easy to understand. The question to be adressed is: How does the physics affect the biological dynamics?

The biological model was developed by W. Fennel [1] and uses for simplicity only 4 biological state variables: phytoplankton, zooplankton, nutrients and detritus. The model summerizes phytoplankton species by only one state variable and the dynamics is nutrient limited assuming there is enough light.

The circulation model is the GFDL MOM code from Princeton University[1].

The interface between physics and biology is the diffusion-advection-reaction-equation

$$\frac{\partial C_i}{\partial t} + \nabla(\bar{v} C_i) = \nabla(A \nabla C_i) + f_i(C_1,\ldots,C_N,t,\ldots) \quad (1)$$

where C_i is the i-th biological component, $\bar{v}$ is the velocity field, A is the turbulent mixing coefficient and f_i is some source and sink distribution.

In a series of numerical simulations the influence of the initial distribution of nutrients and of the physical dynamics on the biology was studied.

The model basin is a rectangular one with dimension 80 km x 40 km x 40 m.

The initial condition for salinity and temperature corresponds to the mean summer stratification in the Western Baltic Sea. Since only short time scales were taken into account, the mixed layer depth was fixed by a vertical structure of the turbulent mixing coefficient and set to the maximum of the BVF[2], in this case 12 metres. The system is driven by a switch-on wind acting on a fluid at rest and being switched-off after 5 days. The integration time is 10 days.

Several experiments were made for two different cases corresponding to spring and late summer situations. The initial condition for the late summer situation is defined by a zero concentration of nutrients in the mixed layer and a high concentration below. In the spring bloom situation the stratification has just established and the nutrient concentrations are high in the whole water column, which was well mixed before.

Furthermore we assume that the biological processes are active only in the mixed layer. This implies a step function approximation of the vertical variation of the light intensity. The simulations

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[1] GFDL MOM means General Fluid Dynamics Laboratory Modular Ocean Model developed by Pacanowski, Rosati and Dixon.

[2] BVF is the Brunt Väisälä frequency.

show that during the first 5 days the physical control is governed by the following key processes:

* coastal jets
* Kelvin waves
* Ekman transport
* upwelling and downwelling

and during the next 5 days (without forcing)

* old Kelvin waves
* new Kelvin waves (excited by switching off the wind)
* currents connected with the decay of the geostrophic pressure gradient
* inertial waves

The nutrient flux into the upper mixed layer in the late summer situation by turbulent mixing processes is increased substantially by upwelling. In all numerical experiments the distribution pattern of the biological tracers were determined by the mentioned physical processes induced by wind forcing. After switching off the wind we find two different cases for the late summer situation. In the case of strong nutrient limitation the distribution patterns are also controlled by the physics. For lower nutrient limitation, these patterns are determined by the biological processes. The spring bloom situation is only slightly affected by the circulation processes.

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DIURNAL VARIATIONS AND PRIMARY PRODUCTION DURING THE SPRING BLOOM

Wolfgang Barkmann

The response of phytoplankton photosynthesis to a changing light environment caused by astronomical cycles and vertical mixing has been studied using a one-dimensional Lagrangian modelling approach (Lagrangian ensemble method; Woods & Onken 1982, Wolf & Woods 1988, Woods & Barkmann 1993a). In this method, the phytoplankton biomass is represented by an ensemble of a few thousand particles, each of which contains a population of cells. Each particle follows a trajectory computed from its own sinking speed through the water and from vertical mixing by turbulence. The phytoplankton considered is the small oceanic diatom Thalassiosira pseudonana, which has been studied by Cullen and Lewis (1988).

The model results show that the vertical distribution of the photoadaptive parameters (α, P_m, β, light-limited, light-saturated photosynthesis and photoinhibition) is characterized by a strong gradient at the base of the turbulent surface boundary layer. Photoinhibition can become important in the near surface layers during the morning and the early afternoon, when the light adaptation lags behind the ambient light level. Primary production during the spring bloom was found to be sensitive to the adaptive time scale of phytoplankton, but less sensitive to photoinhibition. We conclude that the diurnal variations of vertical mixing may be capable of shifting the onset of the spring bloom towards late winter, i.e. before a density stratification can be established (Woods and Barkmann, 1993b).

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PLANKTON POPULATION DYNAMICS WITH AND WITHOUT PHYSICS

Timothy Wyatt

1. The process of modelling a single species population trajectory involves several steps, some of which are not always made very explicit. In the first step, a biological problem is translated into mathematical terms, often in the form of differential equations. These equations are then used like a "what if" or "let's pretend" proposition from which some deductions are made. The deductions are then translated back into biological terms to assess their value in resolving the initial problem. Some benefits of these procedures are, to help focus fuzzy ideas, to identify mismatch between model results and the real world (which hopefully can generate new hypotheses), and to help us see in what ways the biological system may be able to escape from constraints imposed by the model. The new views reached can then be used to refine or modify the model (Levins, 1993), or to throw it away.

2. It is obvious that a biological population trajectory (dN/dt) depends on the growth (R) and death (G) rates, and on immigration (I) and emigration (E), so that

$$dN/dt = N(R-G+I-E) \qquad \text{(i)}$$

The terms R and G are the traditional terrain of ecologists, and in an initial approximation I and E represent the physics, i.e., in a plankton population, the gains and losses due to advection and turbulence. (This equation is formally identical with the more operational equations discussed by Fennel and Tett at this workshop).

If G, I and E all equal zero, as for example in an axenic culture, equation (i) reduces to

$$dN/dt = N(R), \quad (\text{or} \quad dN/dt = rN) \qquad \text{(ii)}$$

This equation in discrete form was used to describe population growth by Linnaeus in 1744, with r=2. Stewart (1989) traces the earliest use of a "discrete dynamical model" to Leonardo of Pisa in 1220 A.D., who used it to project future population numbers of idealized rabbits.

3. Several things have already happened to the population during the translation which leads to equation (i) or (ii). Amongst these, a) the individuals have all become alike, and there are no distinctions of age, gender, maturity stage, and so on: b) time, whether we write the equations in discrete or continous form, has become homogeneous-there are no distinctions of day/night, summer/winter; c) the growth and death rates, R and G, are defined as density-independent constants; c) a dichotomy has been established between biological and physical processes which tends to constrain future developments of the modelling process Thus the translation of a biological problem into a mathematically tractable one filters out much of the "reality" perceived by ecologists. This reflects the need for simplification, but there are many ways to do it, and considerable skill is needed to choose an appropriate one. There are also some possibly more fundamental epistemological problems (addressed by Silvert and Cembella at this workshop).

If, in a particular context, these restrictions are judged to be too severe, then the equations must be modified or substituted by others. Mathematicians might say that equation (ii) is a bad model because it "blows up". Biologists would agree it is bad because the universe is not full of rabbits. But in some circumstances, equation (ii) may be an adequate model of population growth, as in unialgal cultures during the logarithmic phase. The requirement that a model be stable over a

more extensive range than that of the intended application introduces a further dichotomy between the merits of equilibrium and non-equilibrium solutions.

4. To prevent equation (i) from blowing up, we can make the growth rate density dependent. The classical trick is to let

$$dN/dt = rN(1-N/K) \quad \text{(iii)}$$

The new term K is loosely called the "carrying capacity", but is really a mathematical artifice. In some unspecified way, it can be taken to represent light or turbulence or nutrients or any other factor which may control r. In equation (iii), r is now the maximum growth rate, r_{max}, and the realized growth rate is = r (1-N/K). So when $N<K$, r is positive, when $N>K$, r is negative, and there is a stable equilibrium at $N^*=K$. Equation (iii) is known as the logistic, and was introduced to biology by Verhulst in 1838.

Following May (1976), equation (iii) can be written in dimensionless form by letting $N'=N/K$ and $t'=rt=t/T_R$, where $T_R=1/r$ is the "characteristic return time". Then we have

$$dN'/dt' = N'(1-N')$$

which allows us to separate the factors regulating the magnitude of N^* (K only) from those which control its stability (only r). This is the basis of the well known distinction between r and K selection due to McArthur (1962).

5. In equation (iii), density dependence (1-N/K) operates instantaneously. A conventional way to introduce a time lag is to write

$$dN/dt = rN[1-N(t-T)/K] \quad \text{(iv)}$$

where T is again a mathematical artifice, rather vaguely thought of as "generation time". Regulation now depends on N at a time T earlier, and represents feedback. Equation (iv) provides a rich family of model population trajectories, which can range from monotonic damping (small rT) through damped oscilations ($T \approx T_R$) to limit cycles ($T>T_R$, or $rT>1$), and so be used to caricature a variety of real time series of population abundance. But this is not the stage at which we should sit back with a virtuous smile, since we have yet to translate the results back to the original biological context. The back translation of the essentially arbitrary devices, K, T, etc is not a straight-forward matter. In equation (iii) for example, this procedure can only lead to the "biological" conclusion that K controls r, since the model provides no alternatives. If the experimental data remains opaque on this basis, we need to recast the biological question. If this step is successfully accomplished, a virtuous smile is briefly allowed! <u>En passent</u>, note that having eliminated the physics from equation (i) and its developments (by setting I and E=O), it has to be put back in again (as K) to satisfy biological intuition.

6. A rather different way of making r density dependent was devised by Monod (1950). He wrote

$$r=\frac{r_{max}\,S}{S+Ks} \quad \text{(v)}$$

where S is the substrate concentration and Ks is the half saturation coefficient. We see that the graph of r on S must pass through the origin, which is biologically unrealistic. Nevertheless, like equation (ii), this model is a powerful tool in specific circumstances. Droop (1968) persuaded r to cross the x-axis at positive x by writing $r=r_{max}(1-K_Q/Q)$. Here K_Q is the minimum permissible cell quota for a limiting resource, and Q is the cell quota-cf equation (iii). The virtues of these and other functional forms of nutrient limitation are obviously context dependent. If grazing and regeneration processes allow algae to operate permanently at r_{max}, there is no real need to incorporate this kind of mechanism into a model. Sensitivity tests allow such decisions to be made, and are an integral part of the "let's pretend" step.

7. The contributions of Monod and Droop are just two well-known examples of how more realistic functional relations can be added step by step to very simple models. They can both be viewed as responses to the limitations of the elementary equations from which they stem, limitations which are revealed by the back translation process. They also illustrate the interplay between theoretical and empirical studies of population dynamics, since it is the models which directly suggest what new kinds of information may be required in pursuit of more adequate descriptions of population regulation.

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A MODEL OF THE EFFECT OF CYST GERMINATION ON THE DEVELOPMENT OF THE *GYMNODINIUM CATENATUM* POPULATIONS ON THE WEST COAST OF THE IBERIAN PENINSULA

Juan Blanco

Usually when trying to model harmful algal blooms, some aspects of the biological system or the biological-physical coupling are not known. This may be due to a clearly defined gap -in which case it is possible to focus additional research on the subject- or, in some other cases, to a lack in wider areas of knowledge. In this latter case, we have to decide which one of the multiple choices to study or at least which one to study first. Simple -and in most cases speculative- models may help in making this decision.

Gymnodinium catenatum dynamics on the Atlantic coast of the Iberian peninsula and more concretely in Galicia, is one of these cases and we have developed a simple model of cyst germination along the coast in order to have an idea of the possible importance of this mechanism of water inoculation. There is some controversy about the source of motile cells used to inoculate the water masses in the area. Some hypothesize that the populations are initiated by cysts (Figueiras and Fraga, 1990) and others suggest that the motile cells are always present in the water mass (Fraga et al., 1990,1993).

The resting cyst population in the sediments of the area studied is not very abundant (Blanco, 1988; Bravo and Anderson 1994). If we consider an enclosed area, germination, even of the top several centimetres of sediment, is not enough to explain the local increases of motile cell populations. This situation opens two possibilities: a) they are not important, or b) a different mechanism exists, and if we found it we will have an idea of the actual importance of the resting stages.
In the case of the Iberian Peninsula several papers have suggested that *G. catenatum* populations are associated with a warm water mass(sometimes referred to as poleward current) that during the summer or autumn goes to the north, and reaches the Galician coast(Fraga et al., 1990,1993;Moita, 1993).

We hypothesize that the warm water mass affects the shelf bottom in a way that is proportional to the downwelling intensity during an upwelling-downwelling cycle, assumed to be 3-7 days. The effect of the warm water mass on the sediment is to produce cyst germination (at rates given in Bravo et al. 1994) and the subsequent incorporation of the motile cells to the water mass. We also assumed very conservative concentrations of cysts in the sediments, and that only the cysts in the top millimetre of sediment can germinate.

When we compare the estimated development of the population in the foremost area of the warm water mass due to this kind of process to the possibility of a small (1 cell/m^3) motile phase inoculation in the early progression of the water mass, assuming the growth rate to be constant (0.3 day^{-1}), final cell concentrations are higher in the case of cyst inoculation, lending support to the view that inoculation from the sediment cannot be discarded as a fundamental mechanism, and that it too must be studied.

If the hypothesis on which this model is based were true, then an interesting aspect of the dynamics would emerge that would have great importance when trying to obtain a predictive model: the final cell concentration would be very dependent on the phase and period of the upwelling-downwelling cycles and, because of that, it would be very difficult to obtain a predictive model.

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NOTES ON PATCH DYNAMICS AND ASSOCIATED PROBLEMS

Percy Donaghay

There are at least 35 hypotheses about the patchiness of plankton organisms, and none of them can be rejected or proved. All are fully 3-dimensional problems. Retention in patches may derive solely from biological mechanisms, and thus features such as the swimming speeds of dinoflagellates become critical.

Furthermore, in this example, the uncertainty of prediction may be dominated by variations in the swimming speed, so that not only do we need to know its mean value, but also how it varies.

There is a growing recognition that the vertical distribution, abundance, and behavior of motile plankton is not only related to the coarse scale (meters to tens of meters) distribution of parameters, but also to the fine scale (cm to tens of cm) features of the environment, including its biological components. Direct measurements of physical, chemical, and biological parameters are needed, on scales relevant to organisms and processes, as a first step to defining the scales of interest for modelling the in situ population dynamics of species of interest.

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Modelling the Shelf Break Ecosystem.

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ABSTRACT

Interactions between vertical mixing and biological production in a shelf sea environment have been investigated through the development of a one dimensional model capable of simulating the dynamics of suspended particulate matter (SPM) and the evolution of the vertical distribution of phytoplankton. The model, which employs turbulence closure physics, cell-quota threshold limitation biology (Sharples and Tett, 1994), and deposition and resuspension of SPM from a bottom 'fluff' layer (Jones *et al.*, 1994), has been used to simulate seasonal cycles of chlorophyll on the Malin Shelf, to the west of Scotland. Model results predict a spring phytoplankton bloom shortly after the water column becomes stratified in April, which continues until nutrient levels in the surface waters become depleted. As the thermocline becomes weaker in autumn, a smaller bloom occurs lasting until the water column becomes completely mixed during winter. Vertical profiles of SPM show periodic entrainment from the seabed, with material confined to the bottom 10m over most the of annual cycle due to weak tidal currents.

Comparisons of model results with observational data of chlorophyll, nutrients and temperature show good qualitative agreement. No data exists to compare SPM concentrations with model output. Despite the numerous research cruises undertaken in this area, the phytoplankton spring bloom event has not yet been fully observed. It is suggested that either these discrete observational programs have missed the periods of highest phytoplankton biomass or that the spring bloom is subject to heavy grazing pressure in this region.

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ECOLOGICAL MODELLING IN COASTAL WATERS: TOWARDS PREDICTIVE PHYSICAL-CHEMICAL-BIOLOGICAL SIMULATION MODELS.

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ABSTRACT

A simple, but general, simulation model is specified according to the state-of-the-art within phytoplankton modelling: Process representations are based upon prevailing theoretical and empirical representations given in the literature, and a set of earlier published values of model coefficients that have demonstrated good fit to reliable observations was selected. The emerging phytoplankton model was then validated against data obtained from enclosure experiments with light-, N-, P- and Si-limitations. No tuning of the coefficients were applied as the purpose of this test was to estimate the predictability of the proposed model. The general standard deviations between model predictions and observations were on the range 0.04-0.36 and 0.13-0.42 for the nutrient and phytoplankton state variables respectively. Not surprisingly, these values are higher than those obtained in tuned simulations. Nevertheless, several characteristics such as growth rates and the balance between diatoms and flagellates were predicted by the model. The phytoplankton model was then set up and driven by a 3-dimensional physical model for the North Sea. The period February-June 1988 was simulated and forced with realistic topography, meteorological data, riverine freshwater and nutrient input. Simulated development in nutrients, diatoms and flagellates are presented with references to actual observations and the *Chrysochromulina polylepis* bloom in 1988. Several important characteristics, such as the timing of two diatoms blooms in March and April and one flagellate bloom in May together with vertical and horizontal distributions of nutrients, were simulated quite realistically without any tuning of the model to the actual observations. The present simulations support the general idea that flagellates in the coastal areas of the North Sea are stimulated by anthropogenic nutrients, but more specifically that a strong flagellate bloom in the Kattegat-Skagerrak area, corresponding to the observed *C. polylepis*, was stimulated by such nutrients in May 1988. Although the model should be improved before it is applied in a management context, the potential of using such models is demonstrated.

DYNAMIC MODELLING OF PHYCOTOXIN KINETICS IN BENTHIC INVERTEBRATES

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ABSTRACT

Modelling the uptake and detoxification kinetics of phycotoxins in benthic invertebrates is discussed and illustrated by a case study involving blue mussels (*Mytilus edulis*) in the lower St. Lawrence estuary in eastern Canada. A dynamic model was fit to empirical data acquired during a study of differential responses of mussels transplanted from sites characterized by differing history of exposure to toxigenic blooms responsible for paralytic shellfish poisoning (PSP). Although it is difficult to collect sufficient data to calibrate complicated models, it appears that one- and two-compartment models are fully adequate for this type of modelling. Measuring phycotoxin levels in shellfish can be a useful and cost-effective way to monitor phytoplankton toxicity in the water column, since continuous filtration by shellfish provides an integrated estimate of the toxin levels to which they are exposed.

MODELING THE PRIMARY PRODUCTION IN THE NORTH SEA USING A COUPLED 3 DIMENSIONAL PHYSICAL CHEMICAL BIOLOGICAL OCEAN MODEL

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ABSTRACT

A coupled 3-dimensional physical-chemical-biological model system, is implemented and for the first time applied to study mass and volume transports and primary production throughout the North Sea. The model is run twice for 1985 with specified (for the North Sea Task Force) time series of riverine and atmospheric inputs of nutrients, and also with these nutrient inputs reduced with 40 and 50 % respectively. Especially the evolution of the chemical and biological variables in the two situations is studied.

The model output agrees quite well with the general quantitative and qualitative knowledge of the total yearly production. The intercomparison with some salinity profiles also indicates that the model fairly well handles the large scale circulation and vertical mixing. Estimates for the transport of excess nutrients to Skagerrak and Kattegat in the highly pulsating Jutland coastal current are given, and demonstrates the need for such models for calculating transport of matter from one area to another. Significant reductions in both primary production and transport of matter is seen from comparisons between the two runs.

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COMPLEXITY

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ABSTRACT

Complexity is presented as a property of models, not of systems. It is shown that the complexity of a system is not a well- defined quantity, and that the complexity implicit in a model is connected to the amount of information about the system that the model is able to process.

ANNEX III: INSTRUCTIONAL MATERIAL FOR PC EXERCISES

USING UCNW BIOLOGICAL MODELS ON MACINTOSH COMPUTERS

Paul Tett

Algal bloom models - an overview

- The basic components of a physical-biological model.

- Seasonal cycle models provide context for short-period algal bloom models? The seasonal models must include water-column, and in some cases, sediment mineralization processes. In estuaries and upwelling regions, must take account of lateral inputs of buoyancy and nutrients.

- Algal bloom models need only simulate periods of a few days, so do not need to include remineralization; they must, however, include an adequate description of the response of water-column structure to short period (including sub-diurnal?) changes in physical forcing, and of x-z circulations that may transport and concentrate biomass.

- Physical frameworks can be (i) fixed compartments with time-varying exchanges taken from separate physical model or observations; (ii) dynamically coupled, using either (a) slab-mixing or (b) turbulence closure for vertical structure; (iii) particle-tracking.

- Optical models must include self-shading effects.

- Is there an agreed, general-purpose algal model that can be used to provide a basis for bloom simulation? Should it include sub-diurnal effects (such as the unlinking of photosynthesis and nutrient uptake from population growth)?

- Biological component of bloom model should: (a) allow vertical motion; (b) include one or several species of alga? (c) include life history e.g. *Phaeocystis*, *Alexandrium*? (d) parameterise grazing from mesozooplankton and planktonic protozoans? (e) deal with postbloom - e.g. development of toxicity or of harmful organic material (which may require sedimentation submodel)?

Familiarity with "windows" is assumed.

1. Open the 'Biological models' folder.

2. 'Double-click' the appropriate icon; the program will then start to run. Respond to prompts as necessary. At the end of use, the program will return control to the operating system.

Each simulation outputs, or can be directed to output, an ascii text file (with comma-separated values) to the folder containing the application. These files can be read into standard spreadsheets, such as EXCEL.

The following are available:

- **CULTURE**: a menu-driven simulation of the growth of a single species of alga in laboratory culture, You can alter the algal and culture parameters interactively. The program contains a complete explanation of the model used.

  POLYCULTURE: a menu-driven simulation of the growth of 5 competing species of algae in laboratory culture. You can select which species to use, and change culture parameters, interactively. The program contains some explanations.

  L3VMP 94: a batch-job simulation of the microbiological-detritus model, with 2-layer physics and sediment resuspension, of Tett (1990, Proudman Oceanographic Laboratory report 14), forced by

sine functions for meteorological and tidal variables. Model parameters cannot be changed, but initial and forcing conditions can be altered by editing the (ASCII) text files L3-INIT.TEXT and L3-PARAM.TEXT (which must be in the same folder as the application icon).

These applications were compiled from Pascal source code using the THINK Pascal programming environment. Source code is available for L3VMP. Model parameters can be changed by editing the source code file L3-PARAMETERS (which contains a Pascal **unit** of the same name) and recompiling. In this case it is possible to run the program from within THINK. Consult P. Tett for details.

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Exploration of the Sea

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REPORT OF THE JOINT MEETING OF THE WORKING GROUP ON HARMFUL ALGAL BLOOM DYNAMICS (WGHABD) AND THE ICES WORKING GROUP ON SHELF SEAS OCEANOGRAPHY (WGSSO)

Vigo, Spain, 9-10 May 1994

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1. OPENING OF THE MEETING

The ICES/IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD) met in the Instituto Español de Oceanografía (Vigo) from 9-12 May 1994 to address the terms of reference set out in Section 2. Terms of reference *a* , *b*, *c*, and *e* were dealt in a joint session (9-10 May) of this Group with the WGSSO, co-chaired by Beatriz Reguera (Spain) and Hans Dahlin (Sweden). Terms of reference *d*, *f*, *g*, and *h* were addressed on 10-11 May, and the results are given in another report (ICES C.M.1994/L:5, Ref.C). Fourty-four scientists from eighteen countries, including ten members of the Working Group on Shelf Seas Oceanography (WGSSO) and five observers, took part in the Joint Session. A list of participants is given in Annex I.

Allan Cembella (Canada) acted as a rapporteur.

By way of introduction, H. Dahlin provided an overview of the importance of the interaction between phytoplankton biologists and physical oceanographers, particularly those who employ numerical modelling in describing coastal systems. The purpose of the joint session was to focus attention on the multidisciplinary aspects of HAB problems. Since it is recognized that an understanding of the population dynamics of HABs involves physical, chemical and biological interactions, and not merely a general study of plankton ecology, it is imperative to interest hydrographers and chemical oceanographers in the problem. B. Reguera explained and gave her comments about the terms of reference, some of them too broad and extensive as it is usually the case when a new group is set up. Therefore, it was important to identify relevant issues to plan future activities related with the terms of reference.

2. TERMS OF REFERENCE

At the 81st Statutory meeting in Dublin the Council resolved (C.Res. 1993/2:47) that:
The ICES/IOC Study Group on the Dynamics of Algal Blooms will be re-established as the ICES/IOC Working group on Harmful Algal Bloom Dynamics (Chairman: Ms Beatriz Reguera, Spain) and will meet in Vigo, Spain from 9-12 May to:

a) continue the development of an understanding of the dynamics of harmful algal blooms, including experimental aspects of harmful algal bloom dynamics;

b) review progress in the implementation and/or execution of physical-biological interaction investigations in the pilot study areas (Gulf of Maine, Skagerrak-Kattegat, Iberia);

c) review the results of the Workshop on Modelling the Population Dynamics of Harmful Algal Blooms, and propose further steps to improve the dialogue between physicists and biologists;

d) finalize planning of the Workshop on Intercomparison of *in situ* Growth Rate Measurements;

e) consider the integration of ongoing research activities on harmful algae phenomena in the ICES area into the existing global international programme on harmful algal blooms (IOC-FAO /OSLR/HAB).

f) evaluate strategies useful in investigating HABs and in mitigating their detrimental effects on marine ecosystems, e.g. the efficacy of regional HAB monitoring systems;

g) consider the development of a HAB database;

h) collate and discuss national reports on harmful algal blooms (HABs).

3. REVIEW OF THE WORKSHOP ON MODELLING HAB POPULATION DYNAMICS

The objectives of the modelling workshop on HAB, as defined by the terms of reference, were to:

a) investigate the use of numerical models in improving understanding of the dynamics of HABs;

b) use models to assist in the design of sampling strategies, interpretation, and forecasting of HABs;

c) develop a dialogue between physical and biological oceanographers with respect to HABs, including the rôle of physical inputs, and temporal and spatial scales.

An attempt was made to unite phytoplankton biologists, physical oceanographers and modellers to achieve a common definition of the rôle of physical and biological factors integrated over various spatio-temporal scales. A debate arose early in the discussions regarding the appropriate use of ecosystem models. Some participants adopted the approach that numerical models defined by a discrete set of differential equations would serve our purpose; others wished to consider other modelling techniques including *conceptual* (i.e. box or compartment), *analytical*, and even *intuitive* models, the latter of which are employed routinely by phytoplanktologists in formulating and testing working hypotheses.

Existing models of different types might be helpful for crude estimates for risk assessment, however further research is required to refine the underlying assumptions of such models. All participants would welcome an increased participation of phytoplankton biologists in future modelling exercises. **It was acknowledged that in general the forcing functions determining the hydrodynamic regime in a given system were better defined and thus more amenable to modelling than the biological determinants leading to HAB formation.** At least some of the initial scepticism among biologists towards the utility of numerical modelling in understanding HAB dynamics was due to the belief that biological systems are inherently so complex (involving organismal behaviour, etc.) that the number of functions sufficient to define them could not be successfully incorporated. This was countered by statements that the complexity of a system is not necessarily a fundamental property, hence simple models are not necessarily worse at describing the coupling between physical and biological parameters than more complex ones. In this case, the appropriate level of complexity in the model is that which makes the least number of assumptions while best explaining reality.

One positive outcome of the workshop was the understanding achieved among physical oceanographic modellers and phytoplankton ecologists regarding a common lexicon for their discussions. Thus, physical oceanographers became familiar with the use of terminology associated with growth and primary production (Liebig's Law of the Minimum, cell quota, Michaelis-Menten kinetics, photosynthetic parameters, etc.) while phytoplanktologists were shown the rôle of small-scale turbulence, advective and diffusive flux, barotropic currents, etc., in driving bloom aggregation and dispersion.

The practical examples of extant phytoplankton dynamic models presented to the workshop were essentially oriented towards modelling primary production, biomass, net carbon flux and spring diatom blooms. The implicit assumptions of these models is that there exists a defined suite of first order properties (e.g., nutrient kinetics, photosynthetic rate, etc.) which govern the phytoplankton population growth rate. **There was disagreement regarding the utility of general primary production models for understanding HAB dynamics, since the critical property is the harmful effect of such blooms, rather than a common ecophysiology. Biologists also**

questioned the reductionist approach of the physical modellers towards the biological components; simplifying assumptions such as reducing the primary producer and secondary grazer to single components and fixing the grazing rate as constant in time were considered to be unrealistic. These views did not inmediately deflect the course of the debate, which concerned the mathematical expressions of functional relationships (such as the Michaelis-Menten equation for nutrient kinetics), step functions and truncation procedures, and whether there is a need for feedback between the physical and biological components of models.

Since it is not clear that the biological forcing functions governing HAB population growth are necessarily those of nutrient dynamics, an overemphasis on nutrient kinetics in modelling may be seriously misleading. Some participants expressed the pessimistic view that HABs will prove particularly intractable to modelling since their net population growth may be a function of *secondary* or *tertiary processes* (allelopathy, water conditioning, complex nutrition or behaviour, etc.) which are currently unknown or at best are ill-defined. The fact that HABs may arise in response to catastrophic environmental disruptions which are themselves not predictable contributes additional complications.

A fundamental dichotomy was established between *diagnostic* models, for analyzing and explaining bloom events which have already occurred, and *prognostic* models for forecasting and bloom prediction. **Most participants agreed that given the ecophysiological diversity among HAB species, general prognostic models for harmful bloom dynamics are unlikely to be available in the near future (if ever). In the interim, greater emphasis should be placed on the development of "species of interest" models to focus on specific harmful species. Furthermore, it was pointed out that it is not necessary to model entire ecosystems to provide useful recommendations to public health officials and fisheries and aquaculture managers. Models capable of generating short-term predictions (over a few days or weeks) based upon risk assessment probabilities generated from monitoring data can assist in the implementation of mitigating strategies for HAB effects. The development of *holistic bloom dynamic models* coupling biology with three-dimensional models of circulation and mixing await further definition of the requisite rate processes and parameters.**

Some participants felt that the discussion had not yet succeeded completely in achieving an understanding between physicists and biologists, in part due to the fact that it was being conducted in a language unfamiliar to biologists. Bloom prediction and some other matters already dealt with may belong more properly to a future workshop, while the current session should have addressed fundamental questions about how to begin modelling and the requirements for background information.

Participants felt the workshop was an excellent start towards the goal of strong interaction between biologists, physicists, and modellers on the problems of harmful algal blooms. The multitude of problems associated with the oceanographic complexity of the problem will necessitate many different modelling approaches.

4. CONTINUE THE DEVELOPMENT OF AN UNDERSTANDING OF THE DYNAMICS OF HABs, INCLUDING EXPERIMENTAL ASPECTS

During this session, several presentations were made of ongoing or completed case studies that illustrate physical-biological interactions. The last one is a dynamic study of HABs in the Baltic Sea which the participants would like to see as an additional ICES Pilot Project. These case studies were followed by progress reports on the implementation/execution of HAB Dynamic studies in the pilot areas. Following these presentations, and reflecting the previous week's modelling workshop, several common elements were identified, and comments around them

developed by different participants, that deserve further the attention of the group. These elements were: i) The potential impact of small scale phenomena on HAB Dynamics; ii) Analysis of time and space scales relevant to HABs; iii) The grazing term in HAB dynamics; iv) How to proceed in numerical modelling of HABs.

4.1 Some case studies

4.1.1 PROFILE - Processes in Regions of Freshwater Influence
(J.Joordens, NL)

The project PROFILE (1993-1996) is carried out in the framework of the MAST (Marine Science & Technology) programme, in cooperation with institutes and Universities from the UK, the Netherlands, Italy, Germany, Belgium and Greece. Its objectives are to develop process understanding in ROFIs (Regions of Freshwater Influence) by studying physical and biogeochemical processes, and to develop a fully coupled physical-biological 3D nearshore predictive marine environmental model. Regarding process understanding, measurements are done in the region of the Rhine, Clyde, Po, German Bight and Thermaikos Bay. The different regimes will be compared.
The 1994 Rhine outflow experiments are described in more detail: moorings are deployed from March till October, ongoing 2-weekly measurements are done near the moorings during this period, and cruises took place in April and May. The objective of these experiments is to estimate the relative importance of tides, waves, wind, river discharge rates and irradiance on hydrodynamics and suspended matter (sediment & chl-a) dynamics in the Rhine outflow area.

4.1.2 The Loch Linnhe Project
(E. Macdonald, U.K.)

A fjord ecosystem model was described which integrates tidal flushing with physical and biological processes to simulate the seasonal dynamic behaviour of the system. Results indicate that fjord-like sea lochs cannot be regarded as self-contained biological mesocosms, but have a behaviour analagous to a laboratory chemostat. Turbidity in the surface layer is usually such that light and grazing pressure exert the main controls on phytoplankton biomass except during the spring bloom period. At all other times, tidally driven flushing of dissolved nutrients is easily able to meet the demands of the algal biomass. Hence, anthropogenic nutrient inputs on their own may not have any damaging impact at the scale of the whole fjord. The model was tested initially by comparison with field data drawn from the literature and also with data generated from a comprehensive dedicated field programme to elucidate the major controls on the system dynamics. Whilst the data analysis is not yet complete, it is clear that as predicted by the model, grazing rather than nutrients exert the main control over phytoplankton dynamics within the loch. Model runs perturbating the system using data from the literature suggest that increased anthropogenic nutrient inputs may only affect the whole basin if grazing pressure is reduced.

4.1.3 Physical versus Biological Control of HABs in the Southern Bengala Upwelling Region
(G. Pitcher, South Africa)

Grant Pitcher addressed physical vs biological control of harmful algal blooms (HABs) in the southern Benguela, describing the hierarchy of forcing functions throughout the spectrum of space and time. At the macroscale HABs are generally restricted to the boundaries of the Benguela and are clearly associated with the upwelling ecosystem. The close coupling of seasonal upwelling and the frequency of HABs demostrates the indirect control of seasonal bloom development by wind

driven upwelling. At this scale biological processes such as seeding, differential growth and predation stress are considered important.

The episodic nature of bloom events during the upwelling season occurs in response to the shorter cycles of upwelling and relaxation superimposed on seasonal variation. At this event scale the direct effects of physical forcing in accumulating the seasonal bloom are considered most important; each event associated with wind abatement or reversal is initiated by the passage of a coastal low and maintained by the subsequent merging of low pressure cells off the south west coast. Large-scale weather patterns including the frequency characteristics of Rossby waves, were identified as important in controlling the pulsing of shelf circulation and are therefore instrumental in determining intra-season variation in HAB activity.

The disposition of the South Atlantic anticyclone and belt of westerly winds is considered important in determining interannual variation in HABs. Summers with increased HAB frequency are distinguished by displacement of the South Atlantic high, and increased westerlies, meteorological features which coincide with and follow an El Nino in the Pacific.

At the microscale, physical processes such as internal tides, and species specific vertical migrations were demonstrated to be responsible for bloom accumulations and intense concentration gradients.

It was concluded that wind was a key determinant of variability in the southern Benguela over the entire spectrum of time and space and was therefore the primary force in the generation of HABs.

4.1.4 An Example of a "species of interest" Conceptual Model
(P. Gentien, France)

An example of species of interest conceptual model applied to *Gymnodinium* cf. *nagasakiense* was presented by P. Gentien. The possible relationships this species develops with its environment have been discussed in terms of relations tending to increase or decrease the local concentration of the population. This approach allows us to classify by order of magnitude the importance of the different processes. It appears that, in a first-order approach for this species, due to repression of grazing, allelopathy and possible mixotrophy, the relations between the behaviour of the algae and the physics at different scales (including small scales) are of paramount importance in the understanding of the species dynamics. These physical processes include horizontal confinement, niche separation by turbulence, vertical migration, and concentration or dispersion by advection. In the first approach, it does not appear necessary to consider inorganic nutrient limitation.

4.1.5 Red Tides Generation in Ria de Vigo
(F.G. Figueiras, Spain)

F.G. Figueiras presented some results dealing with red tides generation in the Ría de Vigo (Galicia, NW Spain)(MAST I project on "The Control of Phytoplankton Dominance"). At present, there are conflicting opinions about the red tide generation in the Galician Rías. Some researchers suggest that the appearance of red tide episodes is related to established populations in coastal waters which are advected to the interior of the rías by means of surface water transport induced by upwelling relaxation and/or a poleward surface current. By contrast, other observations indicate that the outer part of the Ría may be a place for active growth of *Gymnodinium catenatum* during periods of weak upwelling. A study in the Ría de Vigo, carried out during late September 1990, showed the development of a red tide assemblage composed of *Alexandrium affinis*, *Ceratium fusus* and *Gymnodinium catenatum*, during a two weeks upwelling-downwelling cycle. Growth occurred at the bottom of the thermocline-top of the nutricline. Above this assemblage, a

diatom assemblage (large diatoms) was blooming. It was suggested that the ratio between velocity of upward water movement and the depth of the stratified upper layer (flushing rate, d-1) is the critical parameter which triggers active phytoplankton growth. It can be concluded that upward water velocities of about 2.5 m d-1 and a stratified upper layer 10 m deep (flushing rate 0.25 d-1) are the main physical constraints for red tide development. A 2-dimensional advection-diffusion model was used to simulate the distribution of *Gymnodinium catenatum* found in Ría de Vigo at that time. The model suggests that horizontal advection is of greater importance in the inner Ría, while vertical advection and vertical diffusion have a stronger influence in the outer Ría. Weak and moderate upwelling events are compatible with growth and cell accumulation in the outermost part of the Ría. Weak downwelling allows patches to form throughout the Ría at rates similar to the growth rate. In these cases it is vertical advection which controls the accumulation or dispersal of cells.

4.1.6 Presence of OA in mussels (M. edulis) in relation to nutrient composition in Swedish coastal waters. (J. Haamer, Sweden)

The seasonal and geographic variation of the concentration of diarrheic shellfish toxin (DST) in mussels (*Mytilus edulis*) has been compared with the variation in the concentrations of the nutrients nitrogen, phosphorus and silica in the Swedish mussel farming district. DST seems to increase in mussels when nutrient conditions favour the growth of toxic dinoflagellates biomass. The ratio between non diatoms and diatoms is mainly regulated by the nutrient ratios and concentrations and therefore we compare DST variations in mussels with nutrient variations.

The lowest DST concentrations were found in a fjord system secluded from the open sea, where the highest concentrations of dissolved inorganic nitrogen (DIN) and phosphorus (DIP) were found. The bottom water there, however, was rich in dissolved reactive silicate (DSi) and supplied the photic zone with enough DSi to support a production dominated by diatoms. Thus the DIN/DSi and DIP/DSi ratios here were the lowest in the whole mussel farming district. Low DIN/DSi and DIP/DSi ratios during the production season coincided with low DST concentrations in mussels in the investigated area. In the winter and spring seasons DSi was supplied by rivers making the growth conditions for diatoms more favorable. The spring bloom has therefore promoted the disappearence of DST in mussels. The DIN/DSi ratio in the winter surface water of the Northern Kattegat (lat 57°15', long 11°50') has changed from 0.5 to 1.1 during the last 30 years which may contribute to inproved growth conditions for toxic dinoflagellates.

4.1.7 Basin-wide Dynamics of Harmful Plankton Blooms in the Baltic Sea (K. Kononen, Finland)

The Baltic Sea is a semi-enclosed sea with a relatively large drainage-area, complicated, shallow coastline, and some periodically anoxic deep areas, the latter determined by large scale water exchange with the North Sea, in the Kattegat.

Late summer blooms of filamentous, diazotrophic cyanobacteria formed by *Aphanizomenon flos-aquae* and *Nodularia spumigena* are recurrent, yearly phenomena in the whole area, except the Gulf of Bothnia. *N. spumigena* is an efficient nitrogen-fixer and all blooms dominated by this species have been found to be hepatotoxic producing nodularin-toxin. Deaths of domestic animals connected to these blooms have been reported from several countries around the Baltic Sea. Due to nitrogen fixation these blooms also increase the nitrogen reserves of the pelagic system thus promoting growth of other, nitrogen limited phytoplankton species.

The long-term studies as well as high-resolution mappings during blooms show that there is a pronounced variability in bloom intensity in different areas and between years. There are several

gaps in our knowledge concerning the blooms on a basin-wide scale. The most important questions, at present based only on speculations are:

- How does a bloom develop, at what depths, at what time scales?
- What is the fate of a bloom?
- Where is the nitrogen fixed by the blooms channelled in the food web?
- Do the blooms increase the nitrogen reserves in the Baltic Sea, thus increasing the potential of other, nitrogen limited blooms to occur?
- What is the fate and accumulation of the cyanobacterial toxins?

Answers to these questions can not be obtained by using traditional research strategies based purely on single sampling stations and experimental laboratory studies. Instead, multidisciplinary studies based on several, complementary strategies, investigating the phenomenon in different spatio-temporal scales, should be conducted. The proposed study is a combination of several strategies, e.g. the use of satellite images, unattended, high-frequency measurements onboard commercial ferry boats, buoys and intensive studies onboard research vessels. Complementary information from processes at the cellular level will be produced by another international research project.

4.2 Review Progress in the Implementation/Execution of physical biological interaction investigations in the Pilot Study Areas

4.2.1 Gulf of Maine

A project on *Alexandrium* population dynamics has begun in the Gulf of Maine supported by NOAA. T. Osborn (on behalf of D.M. Anderson) presented a summary of the ongoing field activities, that can be summarized as follows:

<u>Moored Measurements</u>

- 2 moorings, Year 1; 3 moorings, Year 2
- deployment in mid-March; recovery in mid-June
- Vector-Measuring Current Meter (VMCM) at 5 m (plume flow)
- Vector-Averaging Current Meters (VACM) at 20 m &near bottom
- conductivity and temperature sensors at each depth
- sampling at 7.5-10 min. intervals

<u>Drifter Measurements</u>

- deployed during each large vessel survey near mouth of Kennebec, perhaps from small vessels as well
- will include temperature and conductivity sensors
- 4 drifters are budgeted each year
- recovery will be attempted when possible

<u>Satellite Data</u>

- NOAA Coastwatch, twice daily images of SST, March-June
- perhaps turbidity (AVHRR channels 1 and 2, NOAA-11)
- ocean color in 1994, (SeaWifs)

<u>Shipboard Measurements</u>

- 5 survey cruises (3 days) year 1, R/V ARGO Maine, Cape Cod to Penobscot Bay, 80 stations, April - June 15

- 2 survey cruises (6-9 days) year 2, RV Anderson, R/V ARGO Maine, Cape Cod to Penobscot Bay, 80 stations, plus 3-4 small vessel cruises, April-June 15
- 13 transects (5-8 stations/transect) extending 30 -50 km offshore between Penobscot Bay and Cape Cod Bay (survey cruises)
- continuous vertical profiles of conductivity, temperature
- discrete samples for *Alexandrium* counts, nutrients

Modelling

- 3 dimensional, finite difference circulation model (ECOM-3D,)
- domain to be extended from Mass. Bay north to Penobscot
- simulate transport and water properties in western GOM as functions of wind stress, river discharge, and regional circulation
- incorporate biology (*Alexandrium* populations) first as passive particles, then as particles with behavior (growth, death, vertical migration, nutrient uptake)

4.2.2 *Skagerrak-Kattegat*

The status of the pilot project "Bloom Dynamics in the Kattegat/Skagerrak area" was presented by Lars Edler (Sweden). Comments or amendments had not been received from very many persons which must be interpreted as if people are either not interested or have no time to get involved. Additions to the project that have been discussed are:

- A workshop should be held in order to gather people who are interested on working in this project. During the WS a strategy for the funding should also be discussed, as well as a more definite time table.

- The study should start with an evaluation of existing data (very much data exist from this area).

- A model should be set up to establish the interaction between observation and theory.

4.2.3 Iberia

B. Reguera (Spain) and A. Jorge da Silva (Portugal) commented on "Iberia". During the intersessional period two one-day meetings (15 June, 18 November) were held in Aveiro (half-way between Vigo and Lisboa) with participants from several Portuguese and Galician institutions. The objectives of these meetings were to reconcile divergences between the Portuguese and Galician interpretations of regional observations of phytoplankton and toxicity information, as well as oceanographic results. It has now been decided that a two-pronged approach will be adopted, with emphasis on the one hand on DSP episodes caused by *Dinophysis acuminata* group in the early and middle parts of the upwelling season (May- July), and on the other hand on DSP and PSP episodes due to *Dinophysis acuta* and *Gymnodinium catenatum* respectively (both belonging to the same "large dinoflagellate assemblage" during the late upwelling season and early autumn (August- October).

In the case of *D. acuminata*, it was decided to concentrate on the behavioural responses of this species to environmental conditions. *D. acuminata* is usually found very close to the coast and inside the rías. Studies will be based on microcosm experiments and observations in the laboratory, short term experiments within the rías, and analysis of the weekly monitoring data at 36 stations in the Rias Bajas, which has now been in operation for 24 months.

In the case of *D. acuta* and *G. catenatum*, it is intended to pursue problems associated with the initiation and proliferation of blooms, and toxin production, and the respective dynamics of cyst germination and vegetative growth in relation to mesoscale hydrographic features. This will involve two major cruises of three weeks each designed to examine population processes during the two typical scenarios that enhance bloom development, namely, summer stratification combined with moderate upwelling, and the decay of upwelling as northerly winds give way to southerly ones during autumn. These cruises, using two research vessels, will take place on the platform in the regions off Aveiro-River Duero (Portugal), and the River Miño-Rías Bajas area (Galicia), with the hope that each grid can be repeated at two to three day intervals. All these activities will be supported with the information from monitoring programmes in Portugal and Galicia, by satellite imagery, hopefully in real time, and by moored instruments.

There is an ongoing programme, MORENA (Mesoscale Oceanographic Research in the Eastern North Atlantic), funded by the CEU (MAST-II, CT93-0065), whose aims are to measure and model shelf-open ocean exchange in the coastal upwelling region of the eastern boundary layer of the subtropical ocean. The MORENA research area coincides geographically with that of interest to the IBERIA project. Thus, since mesoscale oceanographic models of the Iberian region are already in hand with the MORENA project, this is no longer a strong priority of the IBERIA project, and it has been decided to shift emphasis towards these scales at which it is felt the physical-biological interactions of significance to HAB may operate. Advantage has already been taken of MORENA cruises to provide opportunistic sampling of phytoplankton and cyst distributions.

Appropriate *in situ* growth rate measurements are being developed, and will be compared in the ICES/IOC Workshop in July 1994. In addition to studies already underway in Spain and Portugal, support for further international collaboration will be linked principally to future funding provided by the next round of CEU marine programmes.

4.2.4 *New Pilot Study Areas*

The Working Group proposed that the Baltic Sea be included as a fourth project inthe ICES Working Group on Harmful Algal Bloom Dynamics.

4.3 Common elements for further discussion

4.3.1 Potential Impact of Small Scale Phenomena on HAB Dynamics

One or more dimensional mixed layer models may adequately simulate the dynamics of mixed phytoplankton populations, but many harmful algal species and zooplankton too have the ability to choose the depth at which they live and are frequently confined to thin layers a few centimeters thick. These layers may be located at such depths that, for example, flushing is evaded. This means that retention can be achieved by purely biological means, and that physical convergences are not the only processes which lead to accumulation of biomass. It also means that the vertical distributions of grazers are often very different from those of potential prey species. Thus, centimeter scale biological processes, as described in Donaghay, Rines and Sieburth (1992), may have an important impact on the forms of functional relationships used in models to regulate phytoplankton growth and to generate grazing mortality. Fluctuations in vertical movements on short time scales (hours) may also have a significant impact on model results. Physical features of the water column on the same vertical scales may also need to be taken into account, as well as horizontal features on larger scales which form intrusions. These second order processes may dominate the mechanisms leading to the accumulation and dispersion of HABs, and the first order

processes which are prominent components of many simulation models may need to be given less emphasis.

4.3.2 Comments on the grazing term

The grazing term in the population dynamics equation for HAB studies had not been discussed with enough depth in past meetings of the previous study group. H.R. Skjoldal, Chairman of the Study Group on Zooplankton Production agreed to guide an introductory session to present and discuss possible methods for grazing measurements to be applied in species-specific HAB studies, but more urgent committments prevent him from attending. The following comments were prepared that summarize the basic problems.

Grazing is usually oversimplified in the formulation of harmful algal blooms dynamics. The grazers constitute a closure term in most phytoplankton models and therefore, one can imagine that the results of modelling are strongly depending on the formulation of the grazing. At best, grazing is estimated by a constant rate, or by an asymptotic function with a threshold. While such an approach is probably suitable for biomass production models, this is not true any more when considering a single algal species which may be grazed by one single species, or an algal species which may use some strategy to avoid or reduce grazing. Some may themselves be grazers. Any mechanism leading to selective grazing gives to the species which is not grazed, a large advantage over its competitors that are grazed. It is therefore, very important to know if a given species is grazed at all during its development (at different cell densities and at different physiological status). For instance, *Gymnodinium* cf. *nagasakiense* is grazed or not grazed by copepods depending on the physiological status of the alga (production of mucus and/or toxic hemolysins). In this case, the conditions leading to an inhibition of grazing must be determined before any attempt to formulate a realistic model.
It should not be forgotten that losses from grazing may be due to benthic filter feeders as well as zooplankton.

Zooplankton: The confinement of dinoflagellates and other toxic species in very thin horizontal layers leads locally to extremelly high densities of the species of interest. The so-called "realistic" concentrations used in experiments should extend to densities which are observed in the field. In some cases, high degrees of aggregation of potential grazers can be observed. For instance, this is the case of some dense copepods layers lying on top of dinoflagellate layers. These aggregations may be seen sometimes as single species swarms. Detailed observation is required in order to decide if some species specific associations of zoo- and phytoplankton can be found. Not to use these species of concern found in such assemblages in grazing experiments would miss the pertinent point.

Benthic filter feeders: In coastal waters, in some hydrodynamical contexts, the confinement of a dinoflagellate may govern its availability to benthic grazing. Hydrodynamic studies would permit us to decide if grazing by benthic filter-feeders should be taken into account or not in attempts to understand the population dynamics. Such studies would also allow a better understanding of the conditions leading to shellfish contamination. There is some evidence that the relatively low efficiency of mussels leads to concentrations of viable dinoflagellate cells in the faeces and pseudofaeces. Some cysts have been found also in the guts of bivalves. In shellfish farming areas, this additional concentration mechanism could be of importance in providing potential growth factors to concentrated seed populations.

From these considerations, the working group recognizes the importance of grazing on the population dynamics of possible harmful species. Two basic sets of questions have been identified, depending on natural or shellfish farming areas:

Coastal areas

- Is grazing pressure a significant loss factor during all stages of population development of the dinoflagellate of interest ?
- What are the documented cases of dinoflagellate-zooplankton species specific associations?
- What are the documented cases of allelopathy reducing grazing?

Shellfish farms

- What is the influence of benthic filter-feeders in enhancing mixing rates?
- What kinds of hydrodynamical situations prevent the availability of dinoflagellate of interest to benthic filter feeders?
- What is the influence of the low efficiency of bivalves on the population dynamics?

4.3.3 Analysis of Time and Space scales in biological and physical processes relevant to the understanding of HAB Dynamics

Harmful algal bloom dynamics appear to be driven by both biological (e.g. growth, behaviour) and physical processes (e.g. upwelling, transport). In order to gain insight in the mechanisms influencing the occurrence of harmful algal blooms, it is useful to identify how relevant biological and physical processes can interact and magnify each other. To achieve this, analyses of the time scales and the space scales of the processes needs to be made. This will facilitate and structure discussions on modelling of HAB as well. An analysis of time/space scales of physical/biological processes has been carried out and reported on by several authors: J.C.J. Nihoul (1986); K.H. Mann & J.R.N. Lazier (1991); B.J. Rothschild (1988). Such studies can serve as an example of how to set this up specifically for harmful (toxic and nuisance) algal blooms.

4.3.4 How to proceed in Numerical Modelling of Harmful Algae Blooms

In principle a model should be as simple as possible and as complex as necessary. This is strongly dependent on the individual problem to be studied. However, one of the major goals is to be able to realistically predict/simulate (in space and time) harmful blooms, and for most situations this require realistic knowledge of horizontal and vertical transports (including mixing) in addition to the most important chemical-biological processes. This means that in principle one needs a coupled physical chemical biological model with appropriate 3-dimensional resolution in space (sometimes 2-D can be enough) and sufficient resolution in time, together with the most important external forcings.

Clearly it can be useful to use simpler models (often just one dimension in space) to study and quantify the sensitivity to different parameterizations, and this is now increasingly being used by biologists. However, sometimes very complex biological interactions are introduced to compensate for the lack of an important physical process (and vice versa), which normally leads to failure.

Some of the most important biological processes (related to species of interest) which have to be given mathematical expression in a "good" model are:

- Growth rate (or division rate, as a function of temperature and limiting factors such as light and, sometimes, different nutrients)
- Mortality (sometimes due to grazing, lack of oxygen..)
- Vertical behaviour.

The major physical processes which have to be modeled together with the biochemistry are vertical mixing and diffusion, horizontal advection and diffusion, and the temperature and salinity structure to go with it. It is only recently that these physical parameters can be somewhat

realistically modelled and therefore that we can create coupled model systems which might to an extent simulate nature. Due to limited computer resources it is still a problem to achieve optimum spatial resolution, and there are still some open questions related to turbulent mixing.

Clearly one must have available the most important highly varying driving forces such as windstress, air pressure, tides at open boundaries, incoming light intensity and in some areas inputs of freshwater and nutrients. The initial fields of all these variables must also be available.

With the present knowledge of harmful algae blooms, nobody will even try to predict what will happen next year based on numerical models. In some cases one can with knowledge of the development of nutrient supplies during the winter and spring be able to say something about increased or decreased probability for an harmful algae bloom related to a certain watermass. However, with respect to modelling certain harmful species, it might be possible predict to development 5-10 days ahead providing a reliable weather forecast is available.

Another way of using the models in a "predictive" way is by modelling "what if" questions such as: "How much do we have to decrease anthropogenic nutrient inputs to significantly reduce the probability of a certain frequent harmful algae bloom". In any case there is a great demand for "quality assurance" of such models before they can be trusted for management purposes, and at present we do not have good and general systems for such "quality assurance".

To awaken the interest in such modelling activity, the best available and quantifiable knowledge of the processes above mentioned for different harmful species must be collected and simplified to a level where it becomes "realistic" to model. Descriptions of some major and monitored harmful algae blooms in different regions should be made available as test cases for model simulations.

ICES should advice national and international funding agencies to put priority to such multidisciplinary activities, that will then lead to the demand for better and useful "hydrobiochemical" knowledge, which again will lead to better models.

5. RECOMMENDATIONS

1. The Working Group should seek advice from the ICES Study Group on Zooplankton Production about: i) techniques for grazing measurements and their limitations, ii) documented observations on specific predator-prey links of planktonic organisms, and iii) effects of algae mucilages and/or algal taste on grazing, and from the WG on Environmental Interactions of Mariculture on the influence of benthic bivalves on local hydrodynamics.

2. ICES should recommend that funds be provided for the development of models more appropriate to the **management** of harmful algal blooms than those presently being developed.

3. Recognizing the importance of achieving a better understanding of HAB's and improving managerial measures against the harmful effects of these blooms, it is recommended that ICES takes an active part in the work of the IOC-FAO ad hoc Intergovernmental Panel on Harmful Algal Blooms.

4. The ICES/IOC Working Group on Harmful Algal Bloom Dynamics will meet during the spring of 1995 in Helsinki (Finland) to:

a) review the results of the Workshop on Intercomparison of *in situ* Growth Rate Measurements;

b) review ongoing activities in the pilot study areas, and other ICES areas, on physical-biological interactions investigations;

c) develop plans for a future practical Workshop on Modelling using real data obtained in monitoring and projects related with HAB Dynamics;

d) assemble and compile, intersessionally, descriptive information about ongoing monitoring programmes on phytoplankton and phycotoxin monitoring, with a view to its presentation in the Intergovernmental Panel on HABs;

e) define the time and space scales of the physical and biological processes relevant to studies of physical-biological interactions in HAB dynamics;

f) review present knowledge of the abilities of certain harmful algal species to **adapt to** and **modify** the microscale physical environment by means for example of vertical migration, mucilage secretion, colony formation, etc.

A Joint session of the WGHABD and the WGSSO is again recommended.

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REPORT OF THE ICES/IOC WORKING GROUP ON HARMFUL ALGAL BLOOM DYNAMICS

Vigo, Spain, 11-12 May 1994

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1. OPENING OF THE MEETING

The ICES/IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD) met in the Instituto Español de Oceanografía (Vigo) from 11-12 May 1994, following two days of joint session with the ICES Working Group on Shelf Seas Oceanography (WGSSO). Thirty four scientists from eighteen countries, including five observers, took part and are listed in Annex I. The meeting was chaired by Beatriz Reguera (Spain), who explained and gave her comments about the terms of reference, some of them too broad and extensive as it is usually the case when a new group is set up. Therefore, it was important to identify relevant issues to plan future activities of the group.

2. TERMS OF REFERENCE

At the 81st Statutory meeting in Dublin the Council resolved (C.Res. 1993/2:47) that:
The ICES/IOC Study Group on the Dynamics of Algal Blooms will be re-established as the ICES/IOC Working group on Harmful Algal Bloom Dynamics (Chairman: Ms Beatriz Reguera, Spain) and will meet in Vigo, Spain from 9-12 May to:

a) continue the development of an understanding of the dynamics of harmful algal blooms, including experimental aspects of harmful algal bloom dynamics;

b) review progress in the implementation and/or execution of physical-biological interaction investigations in the pilot study areas (Gulf of Maine, Skagerrak-Kattegat, Iberia);

c) review the results of the Workshop on Modelling the Population Dynamics of Harmful Algal Blooms, and propose further steps to improve the dialogue between physicists and biologists;

d) finalize planning of the Workshop on Intercomparison of *in situ* Growth Rate Measurements;

e) consider the integration of ongoing research activities on harmful algae phenomena in the ICES area into the existing global international programme on harmful algal blooms (IOC-FAO /OSLR/HAB).

f) evaluate strategies useful in investigating HABs and in mitigating their detrimental effects on marine ecosystems, e.g. the efficacy of regional HAB monitoring systems;

g) consider the development of a HAB database;

h) collate and discuss national reports on harmful algal blooms (HABs).

Terms of reference *a*, *b*, and *c* were dealt with during the joint session of the WGHABD with the WGSSO (see report ICES C.M. 1994/L:11, Ref.C).

3. INTEGRATION OF ONGOING RESEARCH ACTIVITIES ON HARMFUL ALGAE PHENOMENA IN THE ICES AREA INTO THE EXISTING GLOBAL INTERNATIONAL PROGRAMME ON HAB (IOC-FAO/OSLR/HAB)

3.1 IOC-FAO ad hoc Interguvernmental Panel on Harmful Algal Blooms (IPHAB)

B.I. Dybern, Chairman of the IPHAB, reported on the activities of the Panel. The Panel has a comprehensive programme with information, training, scientific and management components. The success of the programme depends very much on cooperative assistance from national institutes and

regional and international organizations. Through the knowledge network (especially on scientific and management matters) which exists within ICES, this organization can assist the IPHAB in several ways. One way is through the current invitation to IOC to co-sponsor the Working Group on Harmful Algal Bloom Dynamics. Other ways include sending ICES representatives to meetings of the IPHAB to take an active rôle in the Panel's activities and to place reports and other written information from different ICES bodies (e.g., the Advisory Committee on the Marine Environment and the Working Groups on Phytoplankton Ecology, Shelf Seas Oceanography and Introduction and Transfers of Marine Organisms) at the disposition of the Panel. Further efforts could involve the right of the IOC/IPHAB to use this information for improving institute-libraries in less developed countries. Details on this co-operation may be discussed among representatives for ICES and IOC.

Recognizing the importance of achieving a better understanding of HAB's and improving managerial measures against the harmful effects of these blooms, and following term of reference e, it is recommended that ICES takes an active part in the work of the IOC-FAO ad hoc Intergovernmental Panel on Harmful Algal Blooms (IPHAB).

3.2 Report of the First Meeting of the SCOR/IOC Working Group # 97 on the Physiological Ecology of Harmful Algal Blooms.

This report was presented as an item of information to the ICES Working Group by H. Enevoldsen, IOC representative in this meeting. There has been a good comunication by correspondence between D.M. Anderson, Chairman of the SCOR/IOC working group, and B. Reguera, Chairman of the WGHABD. They agreed that far from considering their terms of reference an overlapping of subjects, the activities developed and results achieved in the SCOR/IOC group will be very useful for a better understanding of the biological processes relevant to the HAB dynamic studies.

To meet their terms of reference, the SCOR/IOC group has recommended in the report that a workshop be held in 1996 at a venue yet to be decided. The timing and structure of this workshop were planned so as to conflict as little as possible with the meeting of the Seventh International Symposium on Toxic Marine Phytoplankton in Sendai, Japan in the summer of 1995. An application for funding from NATO for this workshop has been prepared but funding is not yet assured. The workshop will comprise of a group of 80 to 90 participants, including experts in the relevant fields. A report in the form of a book will be produced as a result, which will summarize the status of current understanding on the topics covered, in direct response to the terms of reference mandated by SCOR. The draft programme, prepared at La Rochelle, France (23-24 October, 1993) in accordance with the policy for a NATO-ASI application, was presented.

The proposed workshop will consist of plenary and key lectures, round table discussions, poster displays and technical demonstrations. Two main themes will be addressed: **Autecology** (including culture, isolation and physiology of various dinoflagellate species) and **Ecophysiological Processes and Mechanisms** (including toxin production, mixotrophic nutrition, small-scale physical processes, bacterial interactions and genetic variation). The discussions will be relevant to modelling and population dynamics of harmful algal species. There will also be a session for assessing emerging issues, including UV irradiation effects, extracellular products, fungi, viruses and other parasites.

The participants aknowledged the scientific interest of the subjects to be treated during the proposed workshop, and considered it would in the future be useful information for the WGHABD activities relating population dynamics with biological processes.

4. WORKSHOP ON INTERCOMPARISON OF *in situ* GROWTH RATE MEASUREMENTS.

4.1 Introduction

Plans for this forthcoming workshop were presented by M. Sampayo. The aim of the workshop is to undertake an intercomparison of *in situ* growth rate measurements of dinoflagellates to be used in support of studies of harmful algal bloom dynamics. The workshop is being organised by the Instituto Portugués para la Investigación del Mar (IPIMAR) at the Regional Center of Aveiro with co-operation from the Instituto Español de Oceanografía (Spain) and the assistance of the invited participants.

4.2 Objective

To use different techniques for measuring *in situ* growth rates of dinoflagellates, mainly the toxic species *Dinophysis* spp, *Gymnodinium catenatum* and *Alexandrium* spp and compare results in order to asses the best approach for the study of the dynamics of harmful algal blooms.

4.3 Study Area

The Ria de Aveiro (8°44' W, 40°38.5' N) is a shallow lagoon with an area of 43-47 km^2. The lagoon has a complex topography with three main channels, several branches, islands and mudflats. Organic pollution levels are high. Various bivalve mollusc species are exploited and PSP and DSP intoxications are regularly recorded.

4.4 Logistics

There is a laboratory with the necessary analytical equipment and two small research vessels will be moored at fixed stations for sampling and incubation studies. A small boat will be available for transfer between the laboratory and the vessels (journey time 20 minutes). Two current meters will be operational during the study period. Accommodation has been booked in an hotel in Aveiro, close to the laboratory, and a draft programme has been prepared. A draft summary of discussions, conclusions and recommendations will be prepared during the workshop.

4.5 Techniques for Comparison

The proposed methods, listed below, were discussed.

(i) *Enclosed water column measurements*
The construction of the plastic bag system was described. It was suggested that the bags should be filled by opening them at the required depth rather than pumping water into them as the latter method may damage some organisms. The problem of sedimentation and stratification in the bags was discussed. It was suggested that dye experiments be carried out in advance of the workshop to evaluate this. A simple and inexpensive device for taking samples at discrete depths without mixing the water column was described. Problems of obtaining representative samples were discussed. It was recommended that light measurements be made at the beginning and end of the experiments and the values obtained compared with field measurements. It was recommended that water samples be screened for cyst formation and that no nutrients should be added to the bags.

(ii) *14 C Method*
Some information was given on the designs of the ICES incubator and the incubator developed and constructed by O. Lindahl. It was suggested that a comparison be made of division rates obtained by cell counts and from the 14 C Method.

(iii) *RNA/DNA and DNA/PCNA Methods*
It was noted that knowledge of the phasing of the division cycle is essential for these methods. Also, that use of flow cytometry may be affected by the expected lower cell numbers of toxic species in the system, compared with other species present. Results may be different from those obtained using monocultures or monospecific blooms.

(iv) *Diffusion Chamber Method*
There were no comments made on this method.

(v) *Mitotic index and Morphological Methods*
Knowledge of phasing of the division cycle will also be required for these methods. This will determine the frequency of sampling. The methods will not be suitable for some species as nuclear and cellular division are complete in less than one hour and the phasing is not precise enough. It was noted that in earlier studies with *Ceratium* it was necessary to examine 1000 cells to give accurate results, and that although the method apparently avoids inaccuracies due to grazing, recently divided cells may be more vulnerable to grazing, so that this assumption cannot necessarily be taken for granted.

(vi) *Single Cell 14 C uptake Method*
The problems involved in comparing results from single cells and up to 1000 cells in obtaining a mean doubling time of the population were noted.

5. STRATEGIES USEFUL IN INVESTIGATING HABs AND IN MITIGATING THEIR DETRIMENTAL EFFECTS

Presently, monitoring programmes provide the basic information required for making management decisions, and are thus therapeutic in character. But with better models, based on the same monitoring data, it should be possible to obtain prognoses which would facilitate more flexible management decisions. An example of this approach was presented by A. Cembella, and is explained in section 5.2.

5.1 Monitoring programmes

Details of some national monitoring programmes, and national reports on toxic/harmful events were presented by representatives and are attached as Annex IV. It was noted that monitoring strategies for toxic phytoplankton had been discussed by the Working Group on "Phytoplankton and the Management of their Effects" and recommended methods had been published in the ICES Co-operative Research Report no. 181. In addition to the national programmes presented, an international programme for Phytoplankton and Environmental Monitoring in the Baltic was presented by K. Kononen. The sampling frequency has been reviewed in relation to the value of the information obtained, which is collected using transects from ships of opportunity. A system for dissemination of the data collected has been initiated.

The national monitoring strategies described can be grouped into three types:

(i) Detailed programmes which include not only identification and enumeration of phytoplankton species but also associated physical and chemical data (e.g. temperature, salinity, nutrients, pigments, etc.)

(ii) Monitoring of water samples for determination of (harmful) algal species only. The effort put into these programmes varies between countries.

(iii) Programmes where most of the monitoring effort is put into the analysis of shellfish flesh samples for toxins and very few data are collected on phytoplankton. This can however be a useful monitoring tool, as described below.

A sub-group was convened to elaborate a draft format to guide a full description of monitoring programmes, which will be compiled during the intersessional period, and presented to the next meeting of the Working Group. The draft format is in Annex II.

5.2 Modelling phycotoxin kinetics using bivalve molluscs

A. Cembella presented a paper putting forward the proposal that mussels can be used as integrators of toxic phytoplankton. The advantages of using mussels are that they have a low sensitivity to the toxins; they are widely distributed; they have a high filtration rate which leads to a rapid build up of toxin; they detoxify rapidly; they have a low rate of toxin transfer from the digestive gland to other tissues; they acclimate quickly and they have a high rate of retention of particles in the size range of interest. One or two compartment models may be applied, in which the rate of change of toxin concentration is a function of ingestion, filtration rate, algal cell concentration, cellular toxin content and excretion. Examples were presented for PSP intoxication, using a standard size of mussel and assuming a filtration rate of 32 litres per day, which gave a good fit to experimental results. The model has not yet been evaluated for DSP intoxication but there is no reason why it should not be applied and experiments are in progress to evaluate rate constants for *P. lima* cells. An example was given by J. Haamer of the use of mussels to monitor DSP on the Swedish coast. Bags of mussels suspended from ropes fixed vertically in the water column are placed strategically in order to give advance warning of the influx of toxic algae to the main growing areas.

In the discussion which followed it was recognised that these methods, which model or measure toxin transfer rather than populations, will only work for certain harmful species. It was further recognised that these methods enhance the value of the monitoring data in that they are not only useful for public health reasons but can also help to give a better understanding of population dynamics in the prediction of potential levels of intoxication. The monitoring data can also be helpful in the design of experimental programmes and as a source of secondary information.

Further discussion dealt with the fate of toxins from cells in mussel faecal pellets or in senescent algal cells. These toxins have been detected in the water column and in the surface of the benthic layer, where they may be grazed, causing intoxication of, for example, abalones. It was recognised however that very little information is available on this aspect.

6. CREATION OF A DATABASE

H. Dooley provided a provocative account (appended in Annex III) of previous efforts within ICES to establish a database of HAB events. Attempts to establish a database within ICES go back as far as 1982 and the issue has been discussed by various groups. There exists an event information database, set up by Dr. Mommaerts, which includes data from 1962-1984. This kind of database is limited by the recording and monitoring inputs from particular areas and at particular times.

It was recommended that attention should be paid to the art of the possible, without making stringent requirements on formatting and data content.

7. NATIONAL REPORTS

National reports were presented for Sweden, Norway, England and Wales, Portugal, Germany, Canada, Iceland, Scotland, The Netherlands, France, Chile, Finland, Spain, Denmark, U.S.A., Mexico, Argentina and Cuba. A summary of the items of greatest interest in the reports presented is given below. The reports are attached as Annex IV.

7.1 Sweden

There were blooms of a variety of species in 1993, although none were exceptional. Cyanobacterial cells in the Northern Baltic were tested to be toxic but no harmful effects were noted. Mussel harvesting was suspended at certain periods, as usual.

7.2 Norway

There were exceptionally high cell concentrations of *Dinophysis norvegica* which, in a mixture with other species, caused small bands of reddish water in some places. DSP was above action levels along the South and mid Norway coast. PSP was above action levels in mid Norway. *Prymnesium parvum* occurs annually in a brackish water fjord system. Fish kills in fjords in West Norway were associated with low cell concentrations of a *Chrysochromulina* species.

7.3 England and Wales

A non-toxic bloom of *Alexandrium tamarense* was detected on the South coast.

7.4 Portugal

Reports were presented for 1992 and 1993. New areas were affected by PSP and at action levels for the first time following no recorded intoxications in 1991. In 1993 a spread in the distribution of the species responsible (*G.catenatum*) from South to North was noticed. There were fewer records of lower intoxication of DSP in 1992 and none in 1993.

7.5 Germany

Blooms of various species were reported, including the annual *Phaeocystis* event. Cysts of *Gymnodinium catenatum* were detected over a wide area, although no vegetative cells were found. This represents a discontinuity in the distribution of this species and stimulated a discussion on where the cysts came from. It was felt that ballast water transport was unlikely to be the cause and that the Shelf Seas Oceanography Group shoud study and comment on the forthcoming paper on this finding.

7.6 Canada

About 60% to 70% of the British Columbia coastline remains closed for shellfish harvesting due to chronic PSP intoxication. PSP in other areas was also at normal levels. There was no record of domoic acid intoxication although *Pseudonitzchia* was detected. Two other toxic incidents are under further investigation, but have not as yet been associated with toxic phytoplankton.

7.7 Iceland

No harmful blooms were detected. Exported scallops, fished in 1992 and stored frozen until 1993, were found to contain PSP above action levels.

7.8 Scotland

No fish kills or exceptional blooms were reported. PSP above action levels were detected in mussel flesh in the Firth of Forth, parts of the West coast and Moray Firth (in scallops) in the Spring and throughout the year in the Orkney Islands.

7.9 The Netherlands

Data were presented for 1992 and 1993, with incomplete analysis of the latter. Various species were recorded including first records for *Chattonella marina* and *Pseudonitszchia* sp.

7.10 France

Toxicity of mussel and oyster flesh was associated with discoloration of the water by *Alexandrium minutum*. DSP was above action levels in fewer instances than previous years. Neuro-toxins in shellfish flesh, which have not as yet been associated with toxic phytoplankton, continued to be reported throughout the Winter from the Atlantic coast and in the Spring from the Mediterranean coast.

7.11 Chile

Blooms of *Leptocylindricus minimus* were associated with low level fish kills although the cause was not clear. PSP is recorded and outbreaks appear to be more frequent. DSP is also recorded from fjord areas.

7.12 Finland

No exceptional blooms were recorded.

7.13 Spain

PSP (*G.catenatum* and *A.minutum*) and DSP (*Dinopyhsis* spp) toxicity causing shellfishery closures occured in the rias of Galicia in the last two years. The most prolonged closure were caused by persistent low concentrations of the *Dinophysis acuminata* complex. No toxic incidents are reported from the Mediterranean coast. Blooms of a non-toxic dinoflagellate, at one time thought to be *G.catenatum*, were recorded in this area.

7.14 Denmark

A small non-toxic bloom of *Chrysochromulina* was recorded.

7.15 U.S.A.

The overall pattern of harmful algal blooms in the United States throughout 1993 did not differ substantially from temporal and spatial patterns that have been recognized in previous years. Blooms of *Alexandrium* occurred in the Northeast, Southwest, and Northwest regions of the country. Blooms of the brown tide organism, *Aureococcus anophagefferens*, occurred in Long Island, New York. Blooms of the ambush predator, *Pfiesteria piscimorte*, occurred in the estuarine waters of North Carolina. Domoic acid contamination on razor clams (*Siliqua patula*) occurred along the coasts of Oregon and Washington.

7.16 Mexico

A range of red tide species occur along various parts of the coast.

7.17 Argentina

There has been an increase in PSP intoxication since 1992. The relationship between this and increased UV-B irradiation is being studied.

7.18 Cuba

There were no exceptional blooms reported, except the chronic cases of Ciguatera.

8. RECOMMENDATIONS

1. The Working Group should seek advice from the ICES Study Group on Zooplankton Production about: i) techniques for grazing measurements and their limitations, ii) documented observations on specific predator-prey links of planktonic organisms, and iii) effects of algae mucilages and/or algal taste on grazing, and from the WG on Environmental Interactions of Mariculture on the influence of benthic bivalves on local hydrodynamics.

2. ICES should recommend that funds be provided for the development of models more appropriate to the management of harmful algal blooms than those presently being developed.

3. Recognizing the importance of achieving a better understanding of HAB's and improving managerial measures against the harmful effects of these blooms, it is recommended that ICES takes an active part in the work of the IOC-FAO ad hoc Intergovernmental Panel on Harmful Algal Blooms.

4. The ICES/IOC Working Group on Harmful Algal Bloom Dynamics will meet during the spring of 1995 in Helsinki (Finland) to:

a) review the results of the Workshop on Intercomparison of *in situ* Growth Rate Measurements;

b) review ongoing activities in the pilot study areas, and other ICES areas, on physical-biological interactions investigations;

c) develop plans for a future practical Workshop on Modelling using real data obtained in monitoring and projects related with HAB Dynamics;

d) assemble and compile, intersessionally, descriptive information about ongoing monitoring programmes on phytoplankton and phycotoxin monitoring, with a view to its presentation in the Intergovernmental Panel on HABs;

e) define the time and space scales of the physical and biological processes relevant to studies of physical-biological interactions in HAB dynamics;

f) review present knowledge of the abilities of certain harmful algal species to **adapt to** and **modify** the microscale physical environment by means for example of vertical migration, mucilage secretion, colony formation, etc.

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ANNEX II: FORMAT FOR THE DESCRIPTION OF NATIONAL MONITORING PROGRAMMES

COUNTRY X MONITORING PROGRAMME

1. REGION

2. HISTORY OF REGION'S HAB PROBLEMS

3. SPECIFIC OBJECTIVES OF MONITORING PROGRAMME

   e.g.: to prevent/minimize economic losses due to fish kills or harvesting bans; human health concerns from algal toxins; long term changes in the environment...

4. MONITORING ACTIVITIES

4.1 Causative organisms (dinoflagellate, diatom, etc)
4.2 Groups/species of concern (shellfish, fish)
4.3 Other factors involved

5. PARAMETERS MEASURED

5.1 Cell counts; cell toxicity; other
5.2 Toxicity in shellfish; effects on fish (mortality, etc)
5.3 Meteorological conditions, hydrography, chemistry, species composition.

6. SAMPLING LOCATIONS (for each parameter)

7. SAMPLING FREQUENCY (for each parameter)

ANNEX III: COMMENTS ON ESTABLISHMENT OF HAB DATA BASE

WG on HAB Dynamics
Vigo, May 1994

Agenda 7 - Comments on Establishment of HAB Data Base.

Background

Attempts to establish an Algal Bloom database within ICES go back many years, in fact to 1982. It is a topic that has been on the agenda of the Biological Oceanography Committee, the Harmful Effects Working Group, the Working Group on Marine Data Management, the Working Group on Phytoplankton and the Management of their Effects, the ACMP, and now this Working Group. I wish the HAB WG every success in coming finally to a happy resolution of this apparently complex and difficult issue!

Recent History

When ACMP dealt with this issue at its 1991 meeting it recommended that the Working Group on Phytoplankton and the Management of their Effects explore at its 1993 meeting the development of the Mommaert's directory and the possibility of the statistical analyses of appropriate time series (see Annex 1). However this Working Group came to no particular conclusion, partly because they did not know about the Mommaerts directory. Also, they only addressed the issue from the point of view of a primary production "data" database.

What do we want now?

The important thing the Working Group has to decide at the outset is to clearly state what it is that is actually required. It is in my opinion that you have to very carefully define what you mean by a database, because one man's database is another man's list is another man's descriptive catalogue is another man's dataset..... To some data means information as well as numbers, to others data means numbers only. I think what you want is a searchable catalogue of information (to some a database!), and if so, say so.

When the issue was first put to the Working Group on Marine Data Management in 1990 (following years of discussion), it was clearly seen as an event information database. Following that discussion I prepared a document which I submitted to ACMP in 1991. This summarised the position at that time, and drew specific attention to the efforts of Dr Mommaerts. His database has no numbers, just searchable and extractable information describing events. Such a "database" was, I think, along the lines envisaged by the "Harmful Effects" group too. However ACMP concluded that such lists were basically devalued by what I call the "Loch Ness Monster Syndrome", as their contents could not be validated by statistical means, and relied very much on chance observations with no knowledge of the "effort" required for each observation. For this reason one possible explanation for the observed trend in HAB events this century may be the increase in the effort of observation.

Databases containing numbers, whether this be chlorophyll, primary production, or phytoplankton numbers, are also vulnerable to such distortion, but in such cases distortions can often be remedied by statistical means. Whether a trend will ever be discernible from such a data set, given all the various competing variables such as spatial and temporal variability, varying standards (both human and instrumental), and varying observational effort, is however a question that has to be addressed too. Maybe the answer lies in both approaches, perhaps capitalising on the capabilities of remote sensing techniques, a capability that was still in its infancy when Mommaerts first set up his database.

Harry Dooley
ICES Oceanography Secretary
2 May 1994

ANNEX IV: NATIONAL REPORTS

HARMFUL ALGAL BLOOMS IN 1993 - FINLAND

1. **Locations:** Large areas in the open western Gulf of Finland and the Bothnian Sea. Some miner areas in the northern parts of the eastern Gulf of Finland.
2. **Date of occurrence:** July - September
3. **Effects:** Intensive cyanobacterial bloom forming flocks in the open sea. In some areas the flocks were also drifted to the shore. In northern parts of eastern Gulf of Finland an intoxication of a dog was suspected to have been caused by a cyanobacterial bloom at the end of September.
4. **Management decision:** Media informed
5. **Causative species:** *Nodularia spumigena* (hepatotoxic) and *Aphanizomenon flos-aquae* were the dominant species.
6. **Environment:**
7. **Advected population or *in situ* growth:** *In situ* population in the sea area.
8. **Previous occurrence:** Extensive cyanobacterial blooms were previously observed in the area in 1992.
9. **Additional comments:** The monitoring of the area is intensified by using unattended flow-through analyzer (chlorophyll *a*, temperature, salinity and water samples for species determination) on board merchant ship which has a frequent connection between Helsinki and Travemünde. The system has been started in 1992.
10. **Individuals to contact:** Kaisa Kononen

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Eija Rantajärvi

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29.04.94

The Baltic Alga Fax

Peridiniella catenata

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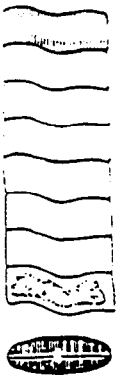

Achnantes taeniata
(orig. T. Tikkanen)

Eija Rantajärvi
Seija Hällfors
Juha-Markku Leppänen

Dear colleagues,

This is the second Baltic Alga Fax in 1994.

The data is based on unattended recordings onboard the merchant ship 'Antares'. The recorded variables are *in vivo* fluorescence of chlorophyll *a*, temperature and salinity. The water for the sensors is pumped constantly from a depth of ca. 5 m while the ship is moving and the spatial resolution is ca. 200 m. The figures are based on the average values counted for one nautical mile. At least once a week 24 water samples are taken automatically during the transect across the Baltic Proper from Lübeck to Helsinki. The microscopic determination of the phytoplankton species composition is done weekly. The analyses of nutrients (total-P, total-N, NH_4-N, NO_2+NO_3-N, SiO_4-Si) are made fortnightly.

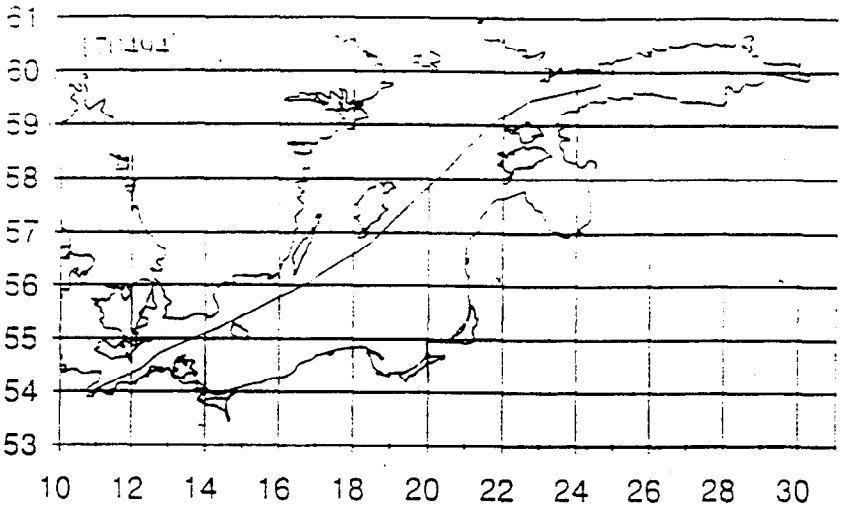

Figure 1. The route map of the merchant ship 'Antares' in 17-19 April 1994.

Results

The results of chlophyll *a* recordings for four subsequent transects are presented below.

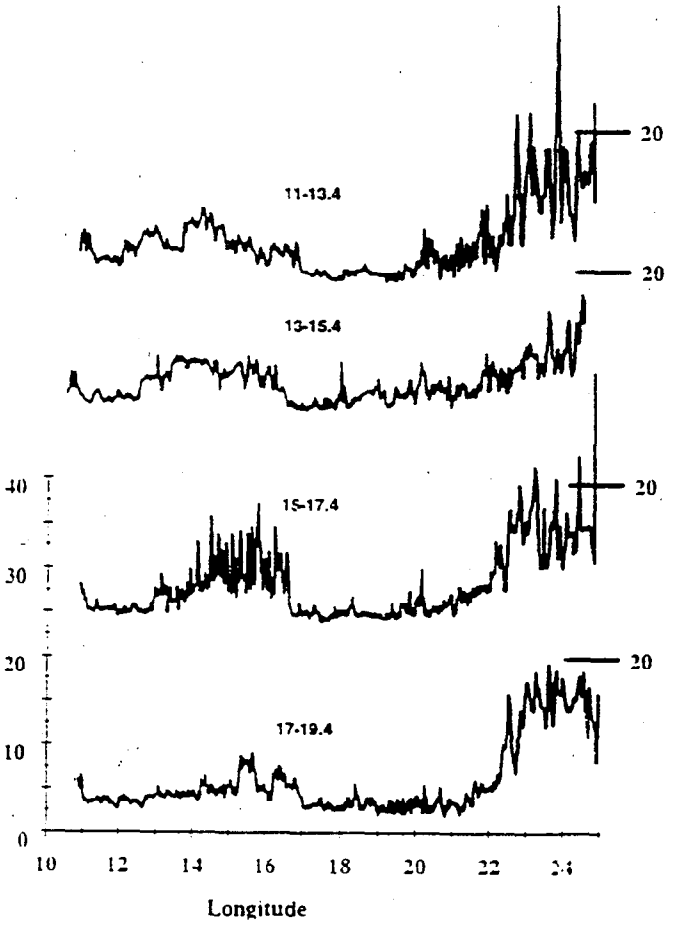

Figure 2.The concentrations of chlorophyll *a* (mg m^{-3}) in 11-19 April along the route.

The phytoplankton species composition

Diatoms and dinoflagellates are still predominating in the whole area.
In the Gulf of Finland the diatoms (*Chaetoceros* spp., *Achnanthes taeniata*) and dinoflagellates (*Peridiniella catenata*, *Peridinium hangoei*) are the dominant groups. In addition to them species of *Pyramimonas* and cryptomonads are present. In the Northern Baltic Proper down to the southern areas of the Gotland Sea the dominant species are dinoflagellates (*Peridiniella catenata*, *Peridinium hangoei*). The amount of diatoms (*Achnanthes taeniata*, *Chaetoceros* spp.) is high as well. Along the Swedish coast and in the Arkona Sea the diatom *Skeletonema costatum* is the most dominant species. The diatoms *Chaetoceros wighamii*, *C. holsaticus*, *Thalassiosira baltica*, *T. levanderi* and small flagellates (*Chrysochromulina* spp., *Pyramimonas* spp., *Cryptomonadales*) occurred in large numbers as well.

The oxygen situation in the Baltic Sea

The research vessel Aranda has made two cruises to the Gotland Deep during this year.

During the cruise of Aranda in February this year the new hydrogen sulfide formation, which was observed already in November 1993, was still ongoing.
In April this year the situation in the **Gotland Deep** was changed. In the Eastern Gotland Basin only a couple of pockets containing hydrogen sulfide were found, one in the Fårö Deep and the other in the southwestern areas of the Basin. Even there the concentrations of hydrogen sulfide were extremely low. Otherwise the entire watermass of the Basin was oxygenated. In the deepest area of Gotland Deep the oxygen concentration was as high as 2 ml/l. The last time this high oxygen concentrations have been observed there, was in1977 and before this only in 1950's.
In the **Gulf of Finland** in November 1993 a weak halocline was observed. However, in April this year it had almost completely disappeared. Consequently, the oxygen concentrations in the bottom waters of the Gulf of Finland had clearly increased. The bottom fauna in the area had survived well the period of low oxygen concentrations in 1993.

The additional information from all of you is highly appreciated. The concentrations of chlorophyll *a* at the depth of ca. 5 m at the monitoring stations of the various institutes would be valuable in order to compile maps on the algal concentrations. All information on bloom events is welcome.

Looking forward to hear from you.

THE ALGAL TEAM

Finnish Institute of Marine Research

To be continued in the near future...

MONITORING OF HARMFUL ALGAL BLOOMS
FRANCE - 1993

The French Phytoplankton Monitoring Network (REPHY), consists of 35 to 40 routine stations sampled all year long (water samples), twice a month in winter, once a week in summer. Systematic cell count of all phytoplankton species is carried out, and a few physico-chemical parameters are measured (temperature, salinity, turbidity and chlorophyll a + phaeopigments).
Many other warning stations may be sampled, once a week, in the event of a growth of a toxic species ; water samples are collected for cell count of toxic or doubtful species, and shellfish samples are collected for mouse-tests (DSP or PSP).
In 1993, shellfish samples were also collected all winter over about 25 stations, once a week, for the detection of an unknown toxin present in mussels (see results below).

Discolored waters were recorded especially along the Brittany coast and the Mediterranean coast (Fig. 1). The responsible species were primarily *Mesodinium rubrum*, *Prorocentrum micans* and different species of *Thalassiosira*, *Chaetoceros* and *Rhizosolenia*.

DSP toxicity affected a few areas, especially in Brittany (Fig. 2). It was always linked with the presence of species of *Dinophysis*.

PSP toxicity was recorded in one area of northwestern Brittany, linked with the presence of *Alexandrium minutum* (Fig. 2).

Fish mortalities were recorded in a pond of Corsica. The responsible species was *Gymnodinium sp.*, very close to *Gymnodinium* cf. *nagasakiense* (Fig. 2).

An **"unknown toxin"** was found in winter in shellfish of many areas of the Atlantic coast (Fig. 2). This toxin was nor DSP neither PSP,but killed mice in few minutes.

Such a toxicity episode began again in spring along the Mediterranean coast, with PSP traces, not enough to explain mice mortality. Then a new toxic event was recorded in November in a little bay of Mediterranean, despite of the absence of DSP and PSP toxins.

No toxic or doubtful phytoplankton species could be linked to this toxicity.

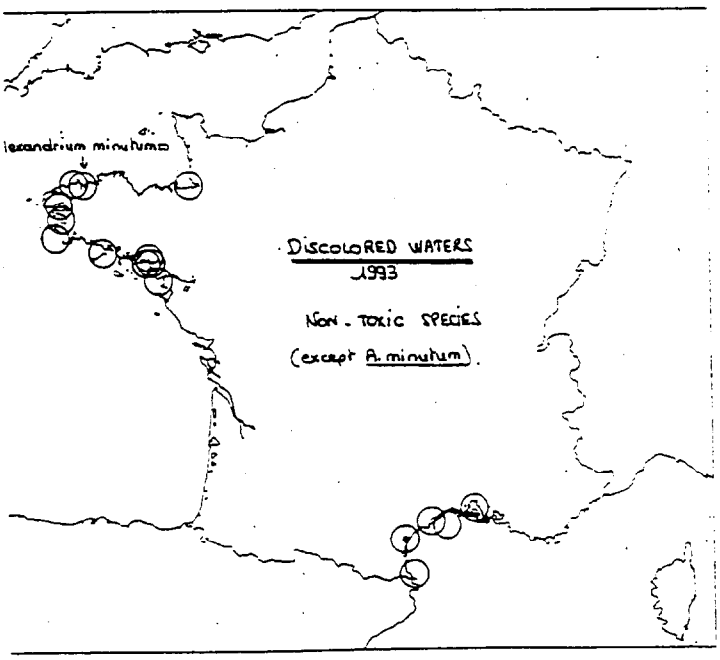

Fig. 1

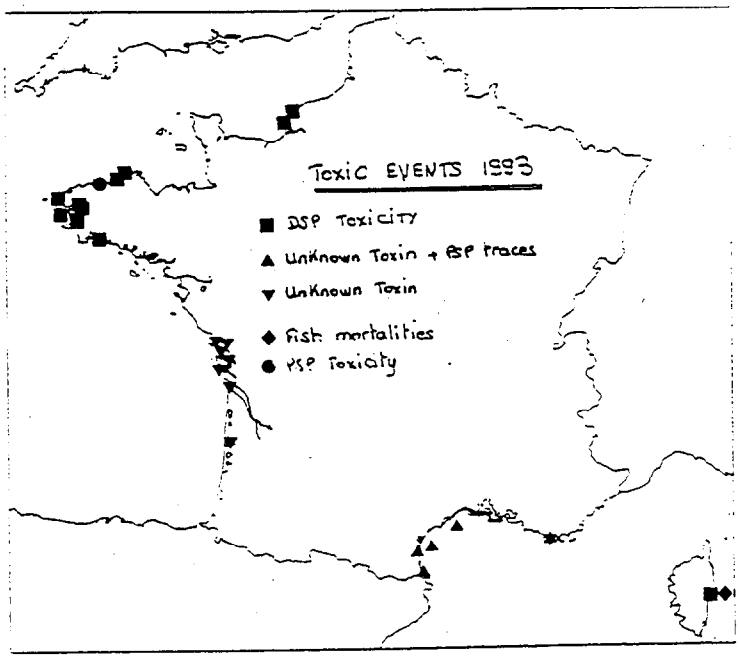

Fig. 2

FRANCE
ALGAL BLOOM REPORT
1993

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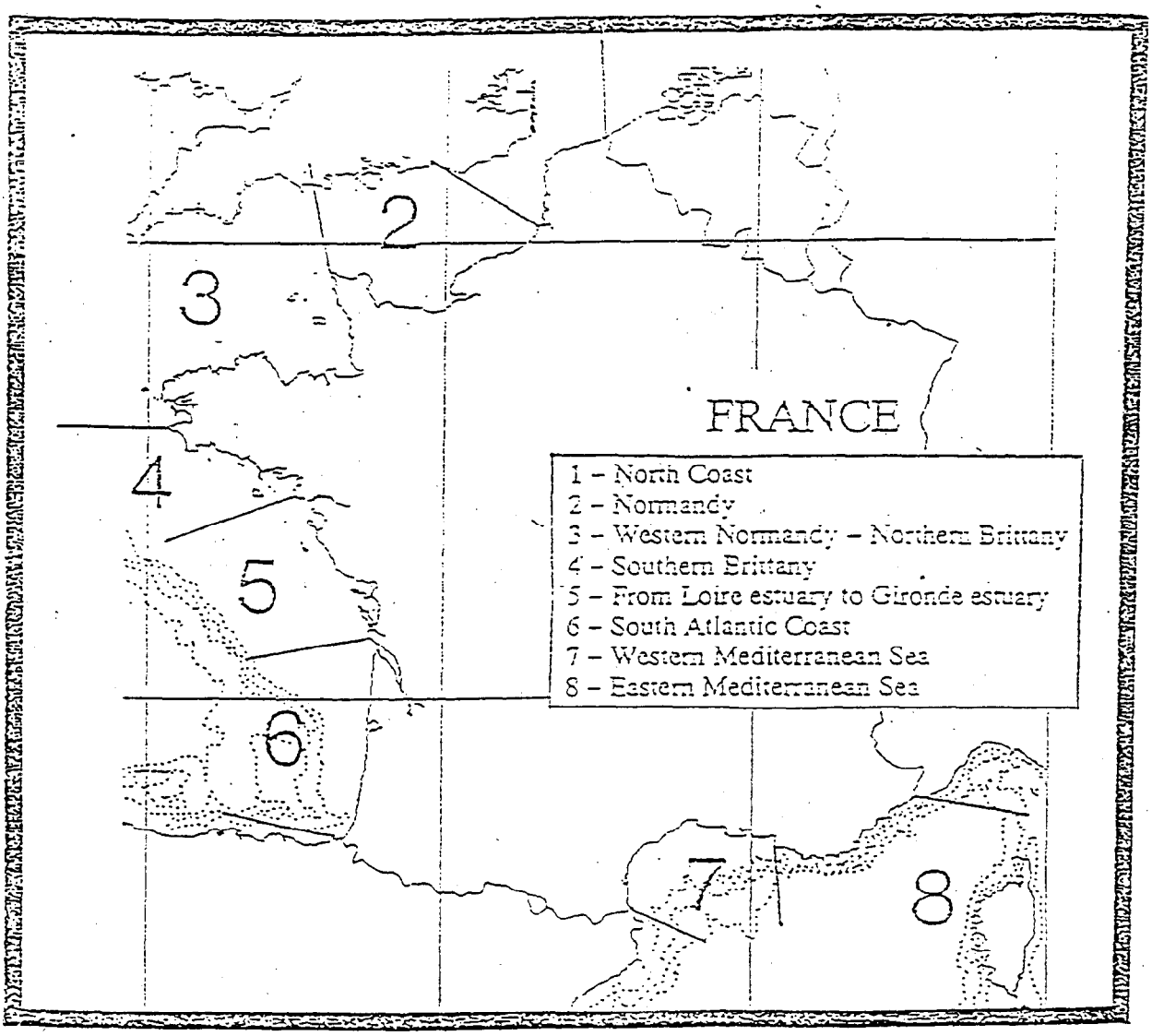

The French coast is divided into 8 areas for description of Harmful Algal Blooms

ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
NORMANDY (area 2)
North of Seine estuary : sites of Fécamp (009) and Antifer (010)

DATE OF OCCURRENCE
August to early September

EFFECTS
DSP toxicity above safety level

MANAGEMENT DECISIONS
Ban of shellfish marketing, from August 19 to September 3

CAUSATIVE SPECIES
Dinophysis spp. (dominant *Dinophysis* cf. *acuminata*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH
Advected population from Seine plume

PREVIOUS OCCURRENCES
Fécamp : 1989, 1992
Antifer : 1983, 1984, 1986, 1988, 1989, 1990, 1992

ADDITIONNAL COMMENTS
The largest *Dinophysis* cell counts of the whole French coast are recorded every year in this zone

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

NORTHERN BRITTANY (area 3)
Mont St Michel bay (site 023)

DATE OF OCCURRENCE

March 22

EFFECTS

Discolored water

MANAGEMENT DECISIONS

Continued surveillance

CAUSATIVE SPECIES

Thalassiosira rotula / gravida (98 100 cells.l-1)
and *Skeletonema costatum* (72 000 cells.l-1)

ENVIRONMENT

Temperature : 9.1°C
Salinity : 34.8.10-3
Turbidity : 4 NTU
A-Chlorophyll : 3.11 mg.m-3 Phaeopigments : 0.84 mg.m-3

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

NORTHERN BRITTANY (area 3)
Perros-Guirrec (site 031) and Lannion-Locquirec (site 032)

DATE OF OCCURRENCE

July

EFFECTS

DSP toxicity above safety level

MANAGEMENT DECISIONS

Ban of shellfish marketing, from July 2 to July 15

CAUSATIVE SPECIES

Dinophysis spp. (dominant *Dinophysis* cf. *sacculus*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
NORTHERN BRITTANY (area 3)
Morlaix river (site 033)

DATE OF OCCURRENCE
July 12 to 15

EFFECTS
Reddish water
No PSP toxicity

MANAGEMENT DECISIONS
Ban of shellfish marketing (preventive, because of the presence of PSP toxicity in Penzé river, nearby) from July 7 to 28

CAUSATIVE SPECIES
Alexandrium minutum (max : 2 912 000 cells.l^{-1})

ENVIRONMENT
Temperature : 16 to 18.9°C
Salinity : 31 to 35.10^{-3}
Turbidity : 2.5 to 7 NTU

ADVECTED POPULATION OR IN SITU GROWTH
In situ growth (presence of cysts in the sediment)

PREVIOUS OCCURRENCES
1989, 1990, 1992 in Morlaix bay

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
NORTHERN BRITTANY (area 3)
Morlaix river (site 033)

DATE OF OCCURRENCE
July 05

EFFECTS
Reddish to brown water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Kryptoperidinium foliaceum (4 136 000 cells.l-1)

ENVIRONMENT
Temperature : 16.8°C
Salinity : 16.10^{-3}
Turbidity : 7 NTU

ADVECTED POPULATION OR IN SITU GROWTH
Probably in situ growth

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

NORTHERN BRITTANY (area 3)
Penzé river (site 033)

DATE OF OCCURRENCE

June 21 to July 12

EFFECTS

Pink to reddish colored water
PSP toxicity level above safety level : - up to 474 µg per 100 g of flesh in oysters
- up to 112 µg per 100 g of flesh in mussels

MANAGEMENT DECISIONS

Ban of shellfish marketing from June 24 to July 28

CAUSATIVE SPECIES

Alexandrium minutum (max : 5 012 000 cells.l-1)

ENVIRONMENT

Temperature : 16 to 20°C
Salinity : 23 to 35.10^{-3}
Turbidity : 1.25 to 60 NTU

ADVECTED POPULATION OR IN SITU GROWTH

In situ growth (presence of cysts in the sediment)

PREVIOUS OCCURRENCES

1989, 1990, 1992 in Morlaix bay

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

NORTHERN BRITTANY (area 3)
Ouessant island (site 035)

DATE OF OCCURRENCE

June to July

EFFECTS

DSP toxicity above safety level

MANAGEMENT DECISIONS

Ban of shellfish marketing, from June 10 to July 23

CAUSATIVE SPECIES

Dinophysis spp. (dominant *Dinophysis cf. sacculus*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE – 1993

LOCATION

NORTHERN BRITTANY (area 3)
Iroise sea (site 036), Elorn river (site 037), Aulne river (site 038) and Douarnenez bay (site 039)

DATE OF OCCURRENCE

May to August

EFFECTS

DSP toxicity above safety level

MANAGEMENT DECISIONS

Ban of shellfish marketing, from :
- May 10 to September 2 (Iroise sea)
- May 27 to July 23 (Elorn and Aulne rivers)
- May 5 to September 2 (Douarnenez bay)

CAUSATIVE SPECIES

Dinophysis spp. (dominant *Dinophysis* cf. *sacculus*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

Iroise sea : 1986, 1989, 1990, 1992
Elorn and Aulne river : no
Douarnenez bay : every year since 1983

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE – 1993

LOCATION
NORTHERN BRITTANY (area 3)
Elorn river (site 037)

DATE OF OCCURRENCE
July 26 to August 30

EFFECTS
Red water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Prorocentrum micans (max : 70 000 000 cells.l^{-1})

ENVIRONMENT
Temperature : 17 to 18.5°C
Salinity : 26 to 35.10^{-3}
Turbidity : 1.4 to 42 NTU
A–Chlorophyll : up to 1008.2 $mg.m^{-3}$

ADVECTED POPULATION OR IN SITU GROWTH
No data available

PREVIOUS OCCURRENCES
1987, 1988, 1990

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
NORTHERN BRITTANY (area 3)
Douarnenez harbour (site 039)

DATE OF OCCURRENCE
March 24 - 25

EFFECTS
Very red water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Mesodinium rubrum (2 500 000 cells.l-1)
(+ *Gymnodinium, Gonyaulax* as dominant species, and little cell counts of *Alexandrium minutum*)

ENVIRONMENT
Temperature : 11°C
Salinity : 35.10^{-3}
Turbidity : 6.5 NTU

ADVECTED POPULATION OR IN SITU GROWTH
No data available

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE – 1993

LOCATION
SOUTHERN BRITTANY (area 4)
Audierne bay (site 040)

DATE OF OCCURRENCE
January 4 to February 1

EFFECTS
Brown–greenish water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Chaetoceros armatum (max : 29 400 000 cells.l–1)

ENVIRONMENT
Temperature : 8.5 to 10.5°C
Salinity : 33 to 35.10^{-3}
Turbidity : 4.5 to 20 NTU
A–Chlorophyll : up to 275 mg.m^{-3}

ADVECTED POPULATION OR IN SITU GROWTH
Probably in situ growth

PREVIOUS OCCURRENCES
1989, 1990, 1991, 1992

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

SOUTHERN BRITTANY (area 4)
Concarneau bay (site 043)

DATE OF OCCURRENCE

July to September

EFFECTS

DSP toxicity above safety level

MANAGEMENT DECISIONS

Ban of shellfish marketing, from July 6 to July 30, then from August 11 to October 8

CAUSATIVE SPECIES

Dinophysis spp. (dominant *Dinophysis* cf. *sacculus*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

1985, 1986, 1987, 1988, 1990, 1992

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
SOUTHERN BRITTANY (area 4)
Groix island (site 045)

DATE OF OCCURRENCE
April 20

EFFECTS
Red water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Prasinophyceae

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
SOUTHERN BRITTANY (area 4)
Vilaine bay (site 057)

DATE OF OCCURRENCE
April 9 to 13

EFFECTS
Red water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Mesodinium rubrum (max : 680 000 cells.l^{-1})

ENVIRONMENT
Temperature : 12.2°C

ADVECTED POPULATION OR IN SITU GROWTH
No data available

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

SOUTHERN BRITTANY (area 4) and FROM LOIRE TO GIRONDE (area 5)
Vilaine bay (site 057) and Loire estuary (site 060)

DATE OF OCCURRENCE

May 2 to 10

EFFECTS

Green to brown water

MANAGEMENT DECISIONS

Continued surveillance

CAUSATIVE SPECIES

Rhizosolenia delicatula (2 900 000 cells.l-1 in Vilaine, 1 564 000 in Loire)
(and *Rhizosolenia setigera* (280 000 cells.l-1 in Vilaine, 400 000 in Loire))

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
SOUTHERN BRITTANY (area 4)
Vilaine bay (site 057)

DATE OF OCCURRENCE
June 7

EFFECTS
Discolored water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Chaetoceros sp (2 500 000 cells.l-1)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH
No data available

PREVIOUS OCCURRENCES
1988

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

FROM LOIRE TO GIRONDE (area 5) and SOUTH ATLANTIC COAST (area 6)
All sites from Pertuis Breton (065) to Arcachon basin (077)

DATE OF OCCURRENCE

February

EFFECTS

Very rapid mortalities of mice with acetone extract of shellfish digestive gland, despite of the absence of toxic phytoplankton species. No DSP, and no PSP toxins were found by HPLC analysis. The event was very short

MANAGEMENT DECISIONS

Ban of shellfish marketing, from February 2 to February 17

CAUSATIVE SPECIES

No toxic or harmful species, and no very abundant species

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES

Such a toxicity episode was recorded in November and December 1992, in Pertuis Breton (site 065)

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

WESTERN MEDITERRANEAN SEA (area 7)
Argelès, Catalan coast (site 080)

DATE OF OCCURRENCE

August 19 to 21

EFFECTS

Red brown water

MANAGEMENT DECISIONS

Continued surveillance

CAUSATIVE SPECIES

Gymnodinium sp. (1 200 000 cells.l-1)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

No data available

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
WESTERN MEDITERRANEAN SEA (area 7)
Roussillon coast (sites 080 and 081) and Languedoc coast (site 088)

DATE OF OCCURRENCE
April

EFFECTS
Very rapid mortalities of mice with acetone extract of mussel digestive gland. The HPLC analysis showed the absence of DSP toxins, and the presence of very small quantities of PSP toxins, not sufficient to explain the mortality of mice.

MANAGEMENT DECISIONS
Ban of shellfish marketing, from April 8 to April 22

CAUSATIVE SPECIES
Presence of *Dinophysis spp.*, *Alexandrium minutum*, and *Prorocentrum minimum*, all these species in very small concentrations

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
WESTERN MEDITERRANEAN SEA (area 7)
Salses-Leucate lake (site 083)

DATE OF OCCURRENCE
May to July

EFFECTS
Very rapid mortalities of mice with acetone extract of mussel digestive gland. The HPLC analysis showed the absence of DSP toxins, and the presence of very small quantities of PSP toxins, not sufficient to explain the mortality of mice.

MANAGEMENT DECISIONS
Ban of shellfish marketing, from

CAUSATIVE SPECIES
Presence of *Dinophysis spp.*, *Alexandrium minutum*, and *Prorocentrum minimum*, all these species in very small concentrations

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
WESTERN MEDITERRANEAN SEA (area 7)
Bages pond (site 085)

DATE OF OCCURRENCE
January 12

EFFECTS
Red water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Prorocentrum micans (230 000 cells.l^{-1})

ENVIRONMENT
Salinity : 18.5.10^{-3}
Turbidity : 1.7 NTU

ADVECTED POPULATION OR IN SITU GROWTH
In situ growth

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
WESTERN MEDITERRANEAN SEA (area 7)
Thau lake (site 087)

DATE OF OCCURRENCE
February 15 - 16

EFFECTS
Brown water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Heterocapsa triquetra (10 000 000 cells.l-1)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH
In situ growth

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
WESTERN MEDITERRANEAN SEA (area 7)
Languedoc coast (site 088)

DATE OF OCCURRENCE
June 16

EFFECTS
Red brown water

MANAGEMENT DECISIONS
Continued surveillance

CAUSATIVE SPECIES
Mesodinium rubrum (2 500 000 cells.l-1)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH
No data available

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

WESTERN MEDITERRANEAN SEA (area 7)
Berre – Vaine lake (site 095)

DATE OF OCCURRENCE

September 20

EFFECTS

Discolored water

MANAGEMENT DECISIONS

Continued surveillance

CAUSATIVE SPECIES

Thalassionema nitzschioïdes (267 200 cells.l^{-1})
(and *Prorocentrum minimum* 17 800 cells.l^{-1})

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
EASTERN MEDITERRANEAN SEA (area 8)
Toulon roads (site 100)

DATE OF OCCURRENCE
March to May then again in November and December

EFFECTS
Very rapid mortalities of mice with acetone extract of mussel digestive gland. The HPLC analysis showed the absence of DSP toxins, and the presence in April of very small quantities of PSP toxins, not sufficient to explain the mortality of mice. In December, no DSP and no PSP toxins were found in samples.

MANAGEMENT DECISIONS
Ban of shellfish marketing, from March 30 to June 4 and from November 25 to ?? (the toxicity is still present in April 94)

CAUSATIVE SPECIES
No toxic or harmful phytoplankton species

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH

PREVIOUS OCCURRENCES
No

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION
EASTERN MEDITERRANEAN SEA (area 8)
Urbino pond (site 114) in Corsica

DATE OF OCCURRENCE
March to May

EFFECTS
DSP toxicity above safety level

MANAGEMENT DECISIONS
Ban of shellfish marketing, from March 2 to May 18

CAUSATIVE SPECIES
Dinophysis spp. (dominant *Dinophysis* cf. *sacculus*)

ENVIRONMENT

ADVECTED POPULATION OR IN SITU GROWTH
In situ growth

PREVIOUS OCCURRENCES
1988, 1992

ADDITIONNAL COMMENTS

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ALGAL BLOOM REPORTS
FRANCE - 1993

LOCATION

EASTERN MEDITERRANEAN SEA (area 8)
Diana pond (site 114) in Corsica

DATE OF OCCURRENCE

September and October

EFFECTS

Fish mortalities (about 3 tons of sea perchs and gilthead breams)

MANAGEMENT DECISIONS

Reinforced surveillance

CAUSATIVE SPECIES

Gymnodinium sp., very close to *Gymnodinium* cf. *nagasakiense* (max : 2 720 000 cells.l^{-1})

ENVIRONMENT

Temperature : 19 to 25°C
Salinity : 36.2 to 37.1.10^{-3}

ADVECTED POPULATION OR IN SITU GROWTH

In situ growth

PREVIOUS OCCURRENCES

No

ADDITIONNAL COMMENTS

A first bloom was recorded in February - March

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NATIONAL REPORT : GERMANY 1993

North Sea :

The annual recurrent bloom of ***Phaeocystis globosa*** showed high colony numbers in the East Frisian Waddensee, up to 10^5 colonies dm^{-1}. In late july, there was a bloom of ***Ceratium furca*** around Helgoland with cell numbers as high as 2×10^5 dm^{-1}. ***Prorocentrum redfieldii*** was not so abundant as in 1992. ***Gyrodinium*** cf ***aureolum*** was abundant from June to August, but no fish kill has been reported. ***Dinophysis*** species were present only in low cell numbers, 3000 dm^{-1}. For the first time, cysts identified as those from the toxic species ***Gymnodinium catenatum*** had been found over large areas of the German Bight. Vegetative stages have not been reported so far. The same applies for ***Alexandrium minutum***, see also report for the Baltic Sea.

Baltic Sea :

In Kiel Bight, ***Chrysochromulina*** species showed cell densities up to several million cells per liter, toxic events were not reported. Blue greens were not so abundant as in 1992, were surface discoloration have been reported, but nevertheless high abundancy was reported end of june and in july. For the first time, cysts identified as those from the toxic species ***Gymnodinium catenatum*** and ***Alexandrium minutum*** have been found at the sediment surface over large areas.

In the Arkona Basin in june, july high densities of the pontially toxic ***Nodularia spumigena*** was reported, other genera present were ***Aphanizomenon*** and ***Anabaena***. Very early in the year, already in april started a dense bloom of ***Nodularia***, ***Aphanizomenon***, and ***Anabaena*** in the "Bodden" of Rügen, but no toxic effect has been reported. In addition, there was no bad smell and no negative influence on the taste of fish as in earlier years.

Summary on **Longterm observations** and **Monitoring** of **Harmful Algal Blooms** in Germany

1) **Longterm Observations**

The BIOLOGISCHE ANSTALT HELGOLAND continues with Longterm observations of phytoplankton in coastal waters of Germany at Helgoland and Sylt.

a) Helgoland : each working day : phytoplankton; salinity, temperature, pH, nitrite, nitrate, ammonium, phosphate, silicate

b) List/Sylt : once a weak : phytoplankton; salinity, temperature, pH, nitrite, nitrate, ammonium, phosphate, silicate

2) **Monitoring** of **Harmful Algae**

a) STATE of NIEDERSACHSEN :

North Sea coastal waters from the Dutch Boarder to river Elbe : 10 stations, every second week from march to october : harmful algal species; phytoplankton, salinity, temperature, pH, oxygen, nitrite, nitrate, ammonium, phosphate, silicium

b) STATE of SCHLESWIG- HOLSTEIN :

North Sea : from river Elbe to Danish Boarder : from 19. april to 13. october every second week, 15 stations : harmful algae, temperature, salinity, pH, nitrite, nitrate, ammonium, phosphate, silicate

c) STATE of SCHLESWIG-HOLSTEIN :

Baltic Sea : from Danish Boarder to Fehmarn : from 26. april to 10 october, once a week, 14 stations : harmful algae

d) STATE of MECKLENBURG-VORPOMMERN

Baltic Sea : from Fehmarn to Polish Boarder : 50 stations 1 x per month : phytoplankton, salinity, temperature, pH, oxygen, nitrite, nitrate, ammonium, phosphate, chlor. a,

Algal bloom report - Iceland

To our best of knowlegde there were no harmful algal blooms in Icelandic waters during 1993.

However, with respect to last years report on harmful algal blooms in Icelandic waters, we want to add some recently gathered information. We have learned that a cargo of frozen scallopmuscles with gonads exported from Iceland in 1993 was found to contain PSP when checked by Danish authorities. The poisonous scallop was caught in Southern Breiðafjörður in June 1992.

Mouse tests made by the Industry Control of the Fishery Ministry in Denmark showed 1534 Mu pr. 100 g sample, i.e. 306 µg PSP pr. 100 g. This was verified by HPLC analyses. Further sampling of the same cargo showed quite a variation in PSP content and in 13 samples the range was from 24 to 176 µg saxotoxin equivalents pr. 100 g. These results therefore show that there was in fact a harmful blooming of PSP containing species in Southern Breiðafjörður in early summer 1992.

As far as we know there are two species commonly found in Icelandic waters which may contain PSP, *Alexandrium tamarense* and *A. ostenfeldi*. This is, however, the first time a harmful event caused by PSP is recorded in Icelandic waters.

Contribution of The Netherlands to the ICES Working Group on Harmful Algal Bloom Dynamics. Vigo, Spain, May 9-12 1994.

Communicated by J.C.A. Joordens. National Institute for Coastal and Marine Management/*RIKZ* (Rijkswaterstaat).
P.O. Box 20907, 2500 EX The Hague, The Netherlands.

NUISANCE AND POTENTIALLY TOXIC PHYTOPLANKTON IN DUTCH COASTAL WATERS (1992-1993)

INTRODUCTION

Since 1990 phytoplankton monitoring forms part of the monitoring programme of the National Institute for Coastal and Marine Management (till January 1994 called Tidal Waters Division), in close cooperation with the North Sea Directorate. A total number of 31 sampling stations cover the Dutch coastal and off-shore zones (fig. 1), the Dutch Wadden Sea including the Ems-Dollard estuary (Fig. 2) and the Dutch Delta area including the Westerschelde estuary, the Oosterschelde tidal basin, the brackish Lake Veere and the saltwater Lake Grevelingen (Fig. 3). Results from 1992 are reported in Koeman et al. (in press) and in Rademaker & Koeman (1993). Results from 1993 will be reported by end 1994, and are presented in a preliminary way in this document.

SAMPLING AND ANALYTICAL PROCEDURES

Sampling frequencies at all stations are once a month during the period October-March, and (mostly) twice monthly during April-September. At all stations surface samples are taken. In stratified areas CTD- and fluorescence profiling guide sampling at more depths: surface, thermocline, bottom.
Samples of 1 l are preserved with 4 ml Lugol. At regular intervals fresh samples are taken for convnient analysis and also for comparison of microscopic with flowcytometric counts. Storage and transport take place under cool and dark conditions.
Species determination and cell counts are made using inverted microscopes. Sometimes samples are treated with Fluorescent Brightener for an easier identification of thecate dinoflagellates. Also other microscopial techniques (phase-contrast, differential interference contrast and fluorescence microscopy with green, blue and UV filters) are used. Sample analysis always takes place with the same standard procedures.

RESULTS 1992

In this contribution only results from the year 1992, and in a preliminary way results from 1993 will be presented with respect to potentially toxic phytoplankton and Phaeocystis sp. The results from the Delta area in 1992 have not yet been analyzed, and will therefore not be reported here.
Results on the following potentially toxic species are reported: Dinophysis acuminata, D. acuta, D. rotundata, Alexandrium spp., Gyrodinium aureolum, Prorocentrum redfieldii, P. minimum, P. micans, P. balticum, Gonuaulax spinifera, Noctiluca scintillans and Chatonella sp..

NORTH SEA:

Dinophysis acuminata:
D. acuminata occurred at offshore station R70 at the Rottum transect in July, with cell numbers of 5.10^3 cells/l at the surface and near the thermococline. In October 27 cells/l

were counted at T235.

Dinophysis acuta:
In October at T235 265 cells/l of this species were found.

Dinophysis rotundata:
In July this species was found at N10 (1065 cells/l) and at N2 (252 cells/l). D. rotundata occurred in September at the Terschelling coastal station T4 with 481 cells/l.

Alexandrium spp.:
The following species could be distinguished by using Fluorescence Brightener: A. tamarense (Lebour)Balech, A. ostenfeldii (Paulsen)Balech & Tangen, A. leei (Balech)Balech, A. minutum Halim, A. cohorticula (Balech)Balech, A. affine (Inoue et Fukuyo)Balech. These species were found in 1992 at the offshore station T135 of the Terschelling transect in cell numbers generally less than 100 cell/l. Alexandrium cysts have been found at the bottom of T235 in 1992. Following this, bottom samples have been taken at this station from January 1992 till January 1994 along the Terscelling transect. These samples have not been analyzed yet.

Gyrodinium aureolum:
Contrary to the situation in 1991, in 1992 no bloom of G. aureolum was found at T135. Further off-shore at T235 concentrations of 16.10^3 cells/l were counted in October.

Prorocentrum redfieldii:
This species reached densities of 3.10^4 cells/l in August along the Rottum transect. Also in August, at coastal stations along the Terschelling transect densities of 5.10^4 cells/l were found. Along the Noordwijk transect in August P. redfieldii was encountered as well: N2 (3.10^4 cells/l), N10 (4.10^4 cells/l) and N20 (3.10^4 cells/l). At the off-shore station N70 some Prorocentrum species were counted, but not as many (3.10^3 cells/l). At the coastal stations along the Walcheren transect blooms were noted in summer and late summer, with a maximum cell number of 7.10^4 cells/l on W20. In late summer at station G6 (Goeree) cell numbers of 7400 cells/l were counted.

Prorocentrum minimum:
This Prorocentrum species has been noted in September samples from the Rottum transect: at R70 around 1000 cells/l, at R50 600 cells/l and at R3 around 1000 cells/l. In equal numbers the species was found in autumn samples from the Walcheren transect: 1000 cells/l at W2. The species was also encountered at T235 in June: 2000-2500 cells/l.

Prorocentrum micans:
Along the Rottum transect P. micans was found in June-August, in numbers around 500-1500 cells/l at the off-shore stations. In the same period this species was found along the Terschelling transect (10^3-10^4 cells/l), both at the off-shore and on-shore stations.

Prorocentrum balticum:
About 10^3 cells/l were counted at T235 in June. At the same time, 2.10^4 cells/l of this species were found at the coastal station T10.

Gonyaulax spinifera:
Gonyaulax was identified at the Rottum transect (R50) in August, in a concentration of 1230 cells/l. Also in August this species was found at T235 (80 cells/l), and in September at T4 250 cells/l were counted. In June at T4 522 cells/l were found, at T10 130 cells/l and at N2 760 cells/l.

Noctiluca scintillans:
This heterotrophic organism was found along the Noordwijk transect in June and July, especially at the coastal stations in cell numbers ranging from 500 to 3.10^3 cells/l. The species also occurred at the coastal stations G6 and W2 in July (200-500 cells/l).

Phaeocystis sp.:
In spring this species bloomed with 6.10° cells/l at coastal stations on the Terschelling transect; offshore numbers were lower, with a maximum of 10^5 cells/l. A second bloom of Phaeocystis occurred in summer, with cell numbers above 10^6 cells/l only at the coastal station T4. Phaeocystis bloomed a third time in August, this time with cell numbers above 10^6 cells/l at T4 and T10.
Along the Noordwijk transect Phaeocystis was the dominant species, especially in spring. Maximum cell numbers were found at N20 (in April 3.10^7 colonial cells/l and 3.10^6 flagellate cells/l); in offshore direction numbers decreased.
At the Goeree station Phaeocystis bloomed in April, with colonial cell numbers amounting to 10.10^6 cells/l and flagellate cells amounting to 2.10^5 cells/l.
Along the Walcheren transect the bloom started in April with maximum concen-trations at coastal stations, reaching 15.10^6 cells/l at W20 and 3.10^6 cells/l at the offshore station W70. In late summer a second bloom was found with maximum cell numbers of 10^6 cells/l.

WADDEN SEA:

Dinophysis rotundata:
A concentration of 124 cells/l was found at the Western inlet of the Wadden Sea (W30) in September.

Prorocentrum redfieldii:
In August at the station W420 concentrations of 24.10^3 cells/l occurred. At the Western inlet of the Wadden Sea (W30) 8.10^3 cells/l were counted in July, 23.10^3 cells/l in August and 2600 cells/l in September.

Prorocentrum minimum:
At W590 15.10^3 cells/l of this species occurred by the end of July. In September 785 cells/l were counted at this station. At the western inlet of the Wadden Sea (W30) around 10^3 cells/l were found in August-Sepember.

Prorocentrum micans:
P. micans was encountered at W420, with cell numbers varying from 46.10^3 cells/l in July to 1300 cells/l in September-October. Also at W590 the species was found from end June till August, with concentrations of 4.10^3 cells/l in June, 14.10^3 cells/l in July and 1200 cells/l in August. At the Western inlet of the Wadden Sea (W30) concentrations varying between 10^3 and 20.10^3 cells/l were counted in the period July sepember, with the maximum cell numbers occurring in July.

Gonyaulax spinifera:
By the end of May at W420 G. spinifera was encountered at a concentration of 1051 cells/l, and at W30 (the Western inlet of the Wadden Sea) 1238 cells/l. In the Ems-Dollard estuary (E250) 168 cells/l were counted in September.

Noctiluca scintillans:
In April Noctiluca occurred at W590 (1400 cells/l), in May at W420 (1050 cells/l) and in the Ems-Dollard estuary (E250) with 1330 cells/l.

Phaeocystis pouchetii:
Throughout the period end March till half October Phaeocystis was present at W420, in cell numbers generally varying between 16.10^4 cells/l and 77.10^4 cells/l. The maximum concentration was found in June: 15.10^6 cells/l! The same pattern was encountered at W590, though without the June bloom. At the Western inlet of the Wadden Sea (W30) Phaeocystis abounded in the period March till November, with cell numbers ranging from 16.10^4 cell/l 14.10^6. The maximum was found at the end of May: 5.10^7 cells/. In the Ems-Dollard estuary (E250) Phaeocystis occurred from March till the end of september, with concentrations generally ranging from 6.10^3 cells/l to 13.10^5 cells/l. The maximum

concentration was measured by the end of May: 18.10^5 cells/l.

PRELIMINARY RESULTS 1993

In spring 1993 Phaeocystis was found at all coastal sampling stations with cell numbers around 5.10^7 cells/l.
In May 1993 Alexandrium spp. (A. tamarense, A. ostenfeldii, A. minitum) were encountered at T135 with cell numbers varying between 200-500 cells/l. Also closer to the coast Alexandrium was present, but not in high numbers.
In May Chatonella marina was found along the Terschelling transect at T100 (3.10^5 cells/l), and along the Rottum transect at R70 (2.10^5 cells/l).
Chrysochromulina polylepis occurred in 1993 at coastal stations in concentrations of 5.10^5 cells/l.
Gyrodinium aureolum was found at T175 (9.10^3 cells/l).
In August 1993 a Ceratium furca bloom was encounterd at the Rottum off-shore station R70 (4.10^4 cells/l).

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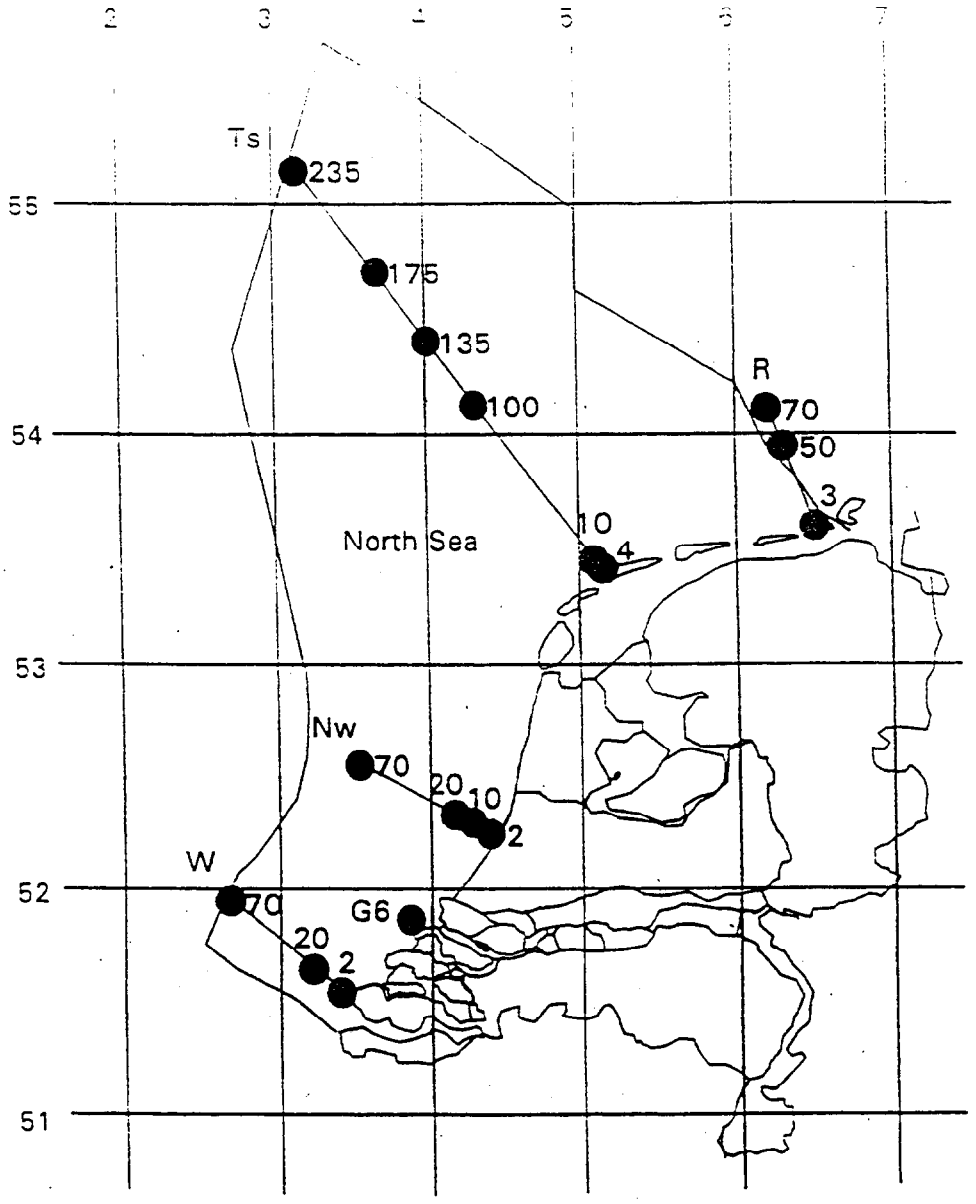


Figure 1. Map of the Dutch Continental Shelf with sampling stations in the North Sea. R = Rottum transect; Ts = Terschelling transect; Nw = Noordwijk transect; W = Walcheren transect. Numbers indicate distance (km) offshore.

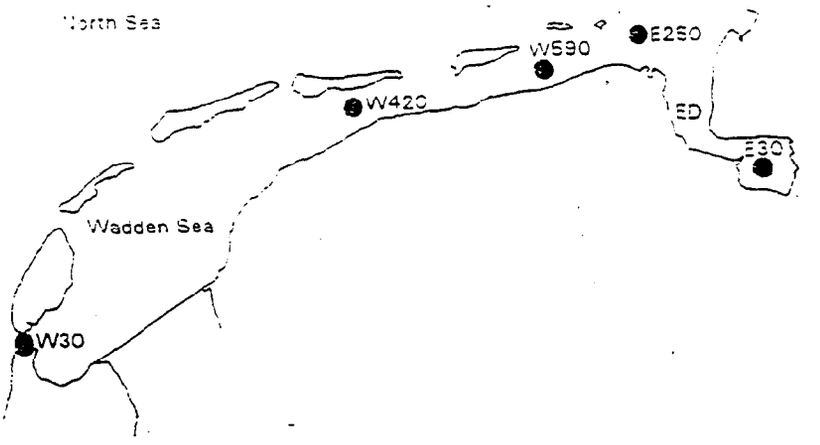


Figure 2. Sampling stations in the Dutch Wadden Sea. ED = Eems-Dollard estuary.

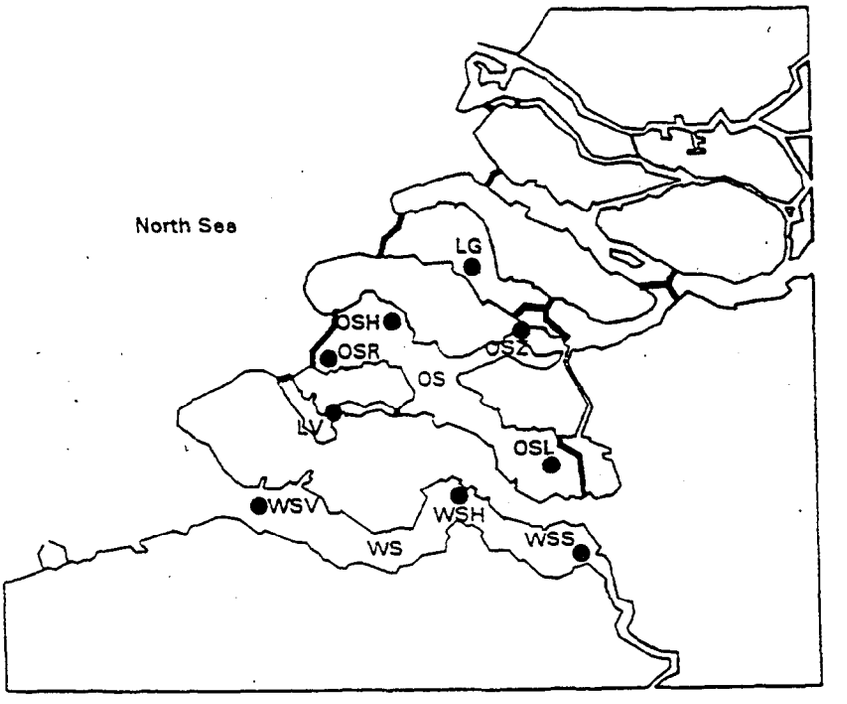


Figure 3. Sampling stations in the Dutch Delta area. LG = Lake Grevelingen; OS = Oosterschelde; LV = Lake Veere; WS = Westerschelde estuary.

HARMFUL ALGAL BLOOM IN NORWAY 1993

Prymnesium cf. parvum

LOCATION	Ryfylkefjordene (near Stavanger), South-west Coast of Norway.
DATES	Late June throughout August, 1993.
EFFECTS	About 6 tons of salmon were killed.
MANAGEMENT DECISIONS	Fish farms in the danger zones escaped the area.
CAUSATIVE SPECIES	*Prymnesium cf. parvum*, up to 2,5 million cells per liter were recorded.
ENVIRONMENT	The temperature range was 10-15 °C. In the most intensive bloom period 13-15 °C. The Secchi depth varied between 4.5- 6 m.
ADVECTED POPULATION	The bloom was first located in the inner parts of the fjord system. Some advection of algae and especially toxic flakes are observed throughout the fjord system.
PREVIOUS OCCURRENCE	Bloom occurred in 1989, 1990, 1991 and 1992.
ADDITIONAL COMMENTS	To verify toxicity of the algae, test-cages of salmon were placed on different locations in the fjord-system. To detect floating toxic flakes an open well-boat with salmon was tracked in the fjord system. When entering toxic water the fish biked over. Mostly they recovered when entering clean water.
INDIVIDUAL TO CONTACT	Ingrid Martinussen, HOV-center, DNMI, Allegt. 70, N-5007 Bergen. Tel +47 55 23 66 60, Fax +47 55 23 66 61, or Einar Dahl, Institute of Marine Research Station N-4817 HIS, Tel+47 37 00 580, Fax +4737052515

HARMFUL ALGAL BLOOM IN NORWAY 1993
Chrysochromulina sp. (unknown)

LOCATION	Byfjorden Bergen, on the West Coast of Norway.
DATES	May 1993.
EFFECTS	Some few tons of salmon were killed.
MANAGEMENT DECISIONS	
CAUSATIVE SPECIES	*Chrysochromulina sp.*, so far unknown species. Identified in electron microscopy by Wenche Eikrem, University of Oslo.
ENVIRONMENT	Secchi depth 3 m, temperature 12-13 °C and salinity 15-18 PSU. *Chrysochromulina* sp. was mixed up with *Chaetoceros wighamii* and *Skeletonema costatum*. A mixed bloom of *Emiliana huxleyi* and diatoms was going on in adjacent fjords, which were under the influence of the Norwegian Coastal current.
ADVECTED POPULATION	*In situ* growth. The bloom probably started in a cove with some advection into the fjord.
PREVIOUS OCCURRENCE	
ADDITIONAL COMMENTS	The water showed positive synaptosome test when tested for toxicity. Anne Sophie Meldahl, Norwegian Defence Research Establishment, division for Environmental Toxicology.
INDIVIDUAL TO CONTACT	Ingrid Martinussen, HOV-center, DNMI, Allegt. 70, N- 5007 Bergen. Tel +47 55 23 66 60, Fax +47 55 23 66 61, or Einar Dahl, Institute of Marine Research Station N-4817 HIS, Phone +47 37 01 05 80, Fax +47 37 05 2515

HARMFUL ALGAL BLOOM IN NORWAY 1993

Dinophysis spp. **Diarrhoeic Shellfish Toxins**

In 1992 regular monitoring of algae and control of shellfish toxicity by mouse bioassy along the Norwegian Coast were established. The 1993 results from this program concerning Diarrhoeic Toxins are summarized below.

LOCATION	Dinophysis spp. were recorded all along the Norwegian Coast, but most numerous along the South-west Coast.
DATES	From March and throughout the year.
EFFECTS	Toxins recorded above the action level according to mouse bioassy at one or another station from March on. Harvesting and consumption banned.
MANAGEMENT DECISIONS	Harvesting was locally banned. The public was warned against collecting toxic mussels.
CAUSATIVE SPECIES	Most probably *Dinophysis* spp..
ENVIRONMENT	The problem occurred over a wide range of temperature and salinities.
ADVECTED POPULATION	Along the South Coast there are some evidence that algae and toxin problems are spread by advection. Along theWest Coast the "hot spots" seem to be rather patchy, which indicate local concentration of the algae and/or *in situ* growth.
PREVIOUS OCCURRENCE	A few more dubious historical records. A yearly more or less large scale and long lasting phenomenon since 1984 according to mouse bioassay. The phenomenon was not so extensively monitored before 1992.
ADDITIONAL COMMENTS	Concentrations of some few hundred cells/l or more were recorded at some stations. In September-October even small patches of reddish water due to mass occurrence of *Dinophysis norvegica* were seen along the South Coast of Norway.
INDIVIDUAL TO CONTACT	Einar Dahl, Institute of Marine Research Station N-4817 HIS, Tel +47 37 0105 80, Fax +47 37 05 2 15 or Ingrid Martinussen, HOV-center, DNMI, Allegt. 70, N- 5007 Bergen. Tel +47 55 23 66 60, Fax +47 55 23 66 61.

HARMFUL ALGAL BLOOM IN NORWAY 1993

Paralytic Shellfish Toxins

In 1992 regular monitoring of algae and control of shellfish toxicity by mouse bioassy along the Norwegian Coast were established. The 1993 results from this program concerning Paralytic Shellfish Toxins in 1993 are summarized below.

LOCATION	Toxicity were recorded in mussseis along the South-west Coast of Norway.
DATES	March - June 1993.
EFFECTS	Toxins recorded above the action level (400 ME/100 g) according to mouse bioassy.
MANAGEMENT DECISIONS	Harvesting was locally banned. The public was warned against collecting (picking) toxic mussels.
CAUSATIVE SPECIES	*Alexandrium* spp.
ENVIRONMENT	No information.
ADVECTED POPULATION	Mainly due to *in situ* growth ?
PREVIOUS OCCURRENCE	A few historical records. More or less regular occurrence in the area during the recent years. However, the spatial and temporal extent may vary significantly from one year to another.
ADDITIONAL COMMENTS	Extensively monitored in 1992 and 1993.
INDIVIDUAL TO CONTACT	Einar Dahl, Institute of Marine Research Station N-4817 HIS, Tel +47 37 01 05 80, Fax +47 37 05 2 15 or Ingrid Martinussen, HOV-center, DNMI, Allegt. 70,. N- 5007 Bergen. Tel +47 55 23 66 60, Fax +47 55 23 66 61

ALGAE MONITORING ALONG THE COAST OF NORWAY

For the last three years HOV has coordinated algae data in Norway. Weekly we receive 'real time data' which are sampled and analyzed from Monday through Wednesday. The data are organized in one report which is distributed on Thursdays. To get an idea about the geographical pattern Satellite data from AVHRR imagery giving SST-data (sea surface temperature) are used in combination with a mathematical model giving a 48 hours prognoses.

The algae data are collected by other institutions for different purposes. The Directorate of Fisheries collect data to survey the fish farming industry, The Norwegian Food Control Authority collect algae data to give information about DSP and PSP producing algae. Some algae data are collected for purely scientific reasons. Our goal is to produce a nowcast of the algal situation at different areas along the coast of Norway and give an early warning to the fish farming industry in case of occurrence of harmful algal bloom.

■ Stations run by The Norwegian Food Control Authority, ● Stations run by The Directorate of Fisheries, HOV, and the Institute of Marine Research. ○ Anchored buoys for optical recording of phytoplankton growth.

Tromsø
Trondheim
Oslo
Bergen
UTC 00 1991:60:30 (01)

PSP

After one year break (1991) the problem appeared again at the portuguese coast but in areas never before affected.
For the first time values over 80ug/100g were detected in the coast south from Lisbon and at the Algarve coast. The responsible species was as since 1986 *Gymnodinium catenatum.*

1. and 2 -**Location and areas of occurrences:**

- Algarve coast - June - July and September - October (500ug/100g).
- Setúbal coast - July - August (125ug/100g)
- Albufeira Lagoon - June - December (110ug/100g).

3. **Effects:**

Most of the bivalve molluscs from these regions presented PSP toxins however some of them did not reach the 80ug/100g threshold, the most affected were:

- Algarve coast: -*Spisula solida*, *Venus gallina*, *Mytilus edulis* and *Ostrea edulis*
-Setúbal coast: -*Callista chione*
- Albufeira Lagoon: -*Mytilus edulis* .

4. **Management decisions** :

Bivalve species with PSP values over 80ug/100g closed to harvest.

5. **Causative species** :

The causative organism was *Gymnodinium catenatum* .
Highest detected concentrations :- Off Algarve July 21 - 13600 cells/L.
-Off Setúbal July 23 - 2000 cells/L.
-At Albufeira Lagoon June 12 - 7000 cells/L.

6. **Environment :**

Temperature range : 15 - 20 °C
Salinity range: 34 - 36‰.

7. **Advected population or *in situ* growth :**

Most probably a combination of both.

8. **Previous occurrences :**

At this southern part of the country this year was the first with values of PSP over 80 ug/100g in bivalves.

10. **Individual to contact :**

Maria Antónia de M. Sampayo and Maria da Graça Vilarinho
IPIMAR
Av. Brasilia 1400 LISBON PORTUGAL

PORTUGAL 1992

DSP

DSP toxinas were only found in bivalves from the northern coast including Aveiro Ria and Modêgo Estuary.

1 and 2. **Location and data of occurrences:**
...-Minho Estuary 20 October - 3 November
...-Mondêgo Estuary (Figueira da Foz) 3 - 24 August
... Aveiro Ria 15 - 30 June -and 8 August - 12 October

3. **Effects:**
-Most of the bivalves from these regions presented DSP toxins.
-At Minho Estuary - *Mytilus edulis*
...-At Mondêgo Estuary - *Mytilus edulis* and *Scrobicularia plana* .
-At Aveiro Ria - *Mytilus edulis* and *Cerastoderma edule.*

The Mouse bioassay ,following Yasumoto method,1984, was used to determine toxification.

4. **Management Decisions:**
...Harvest of affected species closed during toxification.

5. **Causative species:** -*Dinophysis* cf *acuminata* and *D. acuta.*
-Minho estuary- *D.* cf *acuminatas* (400 cells/L).
-Mondêgo Estuary- *D. acuta* (200 cells/L) and *D.* cf *acuminata* (600 cells/L)
-Aveiro Ria- *D. acuta* (6300 cell/L) and *D.* cf *acuminata* (1100 cells/L).

6. **Environment:**
-Temperature range: 15 - 18°
-Salinity range : 24 - 35‰.

7. **Adevected population or *in situ* growth:**
- Most probably a combination of both.

8. **Previous occurrences:**
-In Portugal since 1987 ,the year of the first confirmed occurrence. every year until 1992 we are having the problem this year the affected areas were reduced not only in space but also in the duration of toxication .Aveiro Ria is always the most affected area.

10. **Individual to contact:**
Maria Antónia de M. Sampayo and Maria da Graça Vilarinho
IPIMAR
Av. Brasilia 1400 LISBON PORTUGAL

PORTUGAL 1993

PSP

This year all the portuguese coast was affected starting at Albufeira Lagoon .Algarve coast and Setúbal litoral in January followed by Lisbon litoral in February, Obidos Lagoon in March, São Martinho do Porto in April, Figueira da Foz (Mondêgo Estuary) in June as well as Aveiro Ria and litoral ,and all the northern coast.

1. and 2 -**Location and areas of occurrences:**

- Algarve coast (Sagres) -January - October (3497 ug/100g)
- Sines coast March - December (525 ug/100g)
- Setúbal coast - January - May (1185 ug/100g) and July - September (1954 ug/100g)
- Albufeira Lagoon - January - March (756 ug/100g) , July - September (520 ug/100g) and October (128 ug/100g).
- Lisbon coast February - March (496 ug/100g) and July - September (9145 ug/100g)
- Obidos Lagoon - March (277ug/100g) and Sptember (145 ug/100g).
- São Martinho do Porto - March (210ug/100g).
- Figueira da Foz (Modêgo Estuary) - June - November (918 ug/100g).
- Litoral Aveiro - July (540 ug/100g).
- Aveiro Ria - June - July (762 ug/100g), August (130 ug/100g) and December (273 ug/100g).
- Espinho and Northern coast - June - July (2870 ug/100g) ,August (129 ug/100g) ,September - October (461 ug/100g) ,November (262 ug/100g) and December (113 ug/100g).

3. **Effects:**

All the exploited bivalve molluscs from these regions presented PSP toxins:

- Algarve coast (Sagres region): *Mytilus edulis* and *Ostrea edulis*
- Sines litoral: *Ensis siliqua* and *Spsisula solida.*
- Setúbal coast: -*Callista chione*,*Ensis siliqua* ,*Donax trunculus*, *Chamalea striatula* and *Venus verrucosa.*
- Albufeira Lagoon: -*Mytilus edulis* .
- Lisbon litoral: -*Ensis siliqua* and *Donax trunculus.*
- Obidos Lagoon: -*Spisula solida* and *Venerupis pullastra.*
-São Martinho do Porto:- *Mytilus edulis.*
- Figueira da Foz (Mondêgo Estuary): -*Scrobicularia plana* and *Mytilus edulis.*
- Litoral Aveiro: -*Spisula solida.*
- Ria de Aveiro: -*Mytilus edulis*, *Cerastoderma edule* and *Venerupis pullastra.*
- Espinho Litoral and Northern coast: *Spisula solida* and *Mytilus edulis.*

4. **Management decisions :**

Bivalve species with PSP values over 80ug/100g closed to harvest.

5. **Causative species :**

The main causative organism was *Gymnodinium catenatum* but at Obidos Lagoon it was what we call *Alexandrium lusitanicum.*

Highest detected concentrations :- Off Algarve (Sagres region) 26200 cells/L. July 20.

-Off Sines. 6500cells/L, July 7.
-Off Setúbal 1400 cells/L, March 12; 2700 cells/L. July 6.
-At Albufeira Lagoon 1800 cells/L, March 21; 1750 cells/L, July 5.
-Off Lisbon 1000 cells/L, March 23; 63500 cells/L, July 20.
-At Obidos Lagoon 14000 cells/L, September 7 (*A.lusitanicum*)
-At São Martinho do Porto Bay 2000 cells/L, March 16.
-At Figueira da Foz (Mondêgo Estuary) 24000 cells/L, August 17.
-At Ria de Aveiro 22000 cells/L, July 6
-Off Aveiro 8500 cells/L, July 13.
-Off Espinho 18500 cells/L, July 14; 4800 cells/L, September 16;

6. **Environment :**

Temperature range : 14 - 20 °C
Salinity range: 20 - 36‰.

7. **Advected population or *in situ* growth :**

Most probably a combination of both.

8. **Previous occurrences :**

Since 1986 and until 1990 *Gymnodinium catenatum* was responsible for PSP. occurrences at the portuguese coast north from Roca cape. In 1991 the problem did not occur and in 1992 it appeared again but displaced from the usual area, now at the south coast of Lisbon and at the Algarve coast.

1993 was the first year with PSP almost all arround the year and covering as well almost all the coast seaming that there was indeed a spreading of the species from south to north.

10. **Individual to contact :**

Maria Antónia de M. Sampayo and Maria da Graça Vilarinho
IPIMAR
Av. Brasilia 1400 LISBON PORTUGAL

DSP

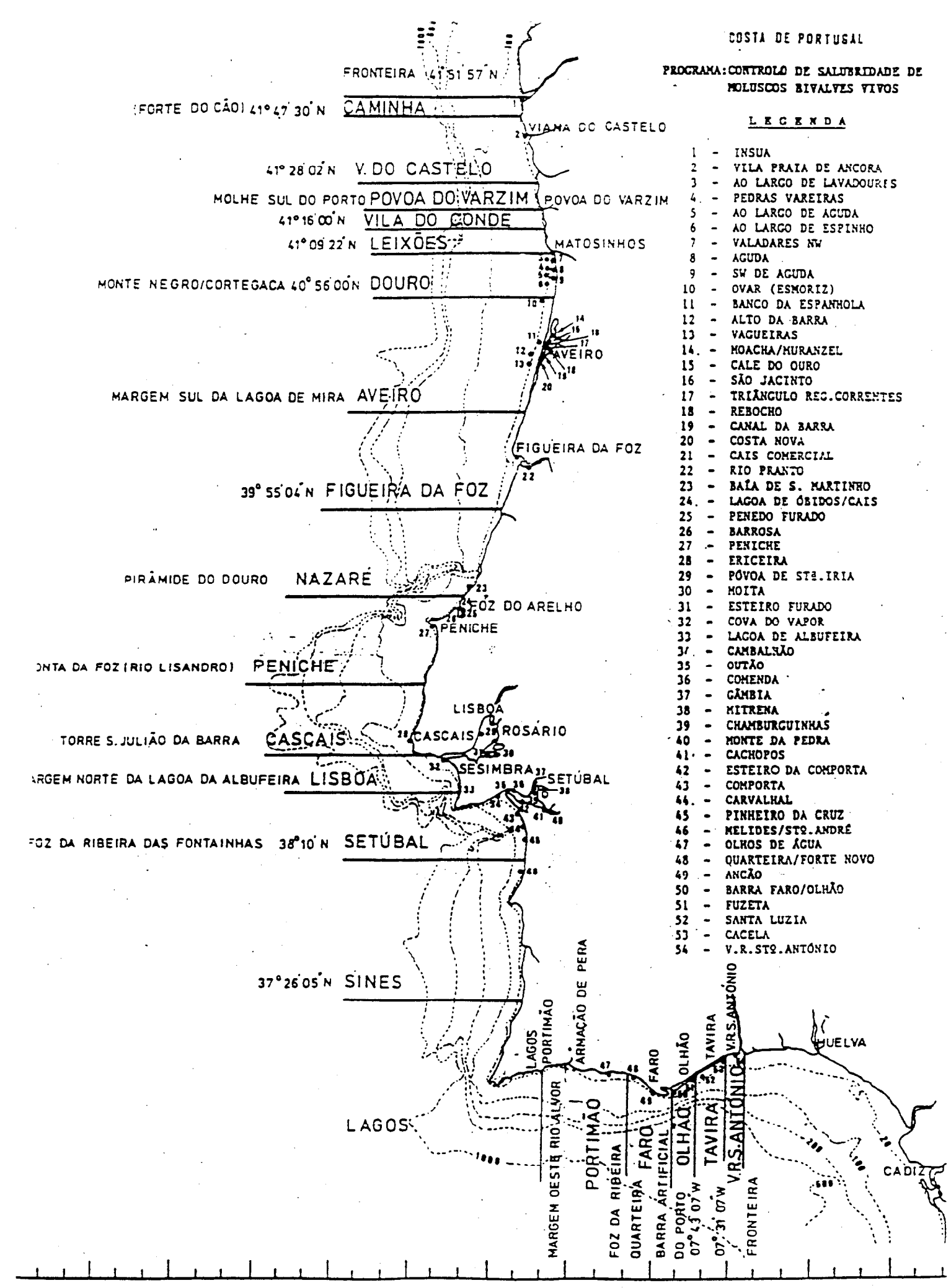
For the first year since 1987 there were any positive results of DSP in the bivalves from the Portuguese coast.

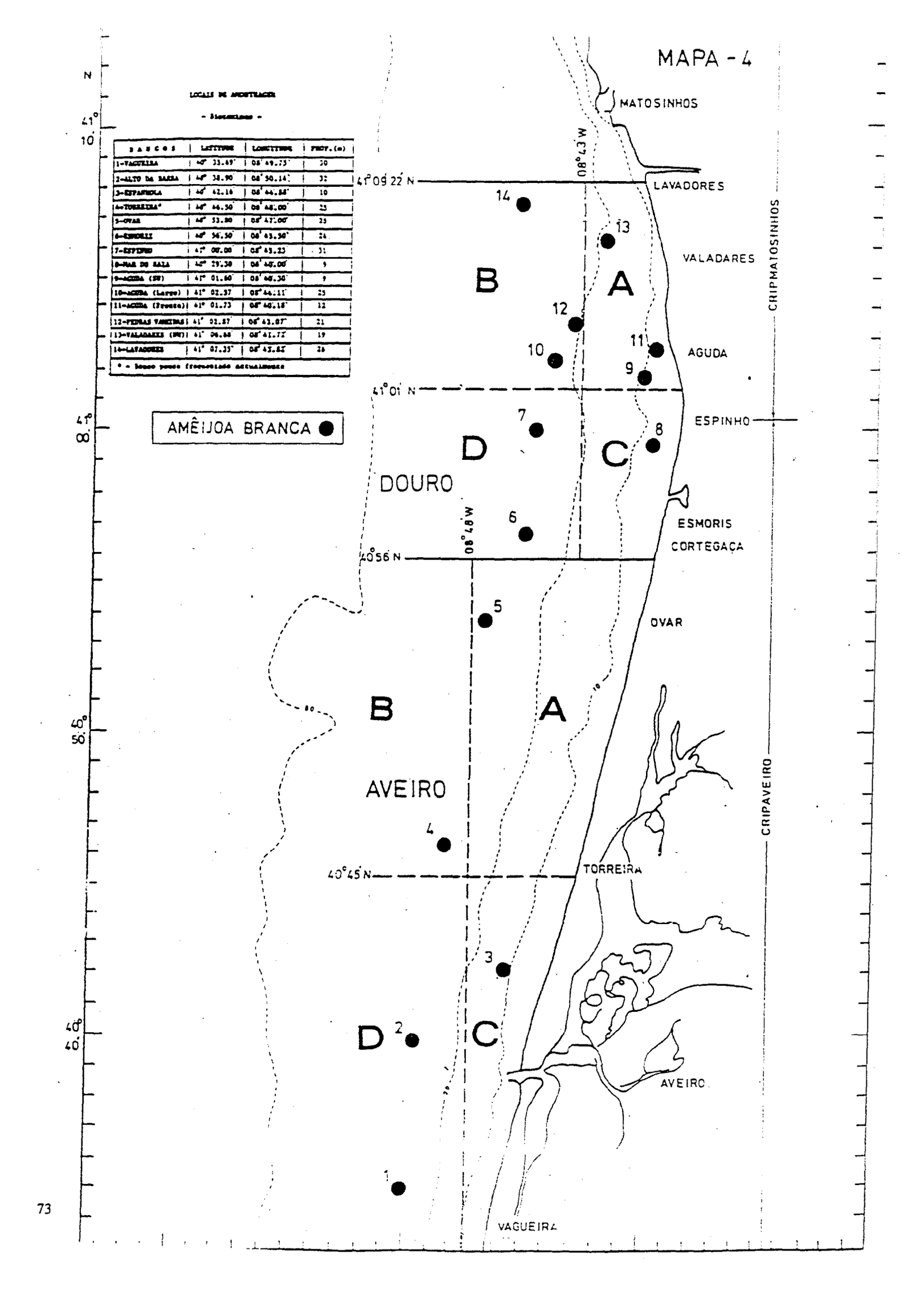
MONITORING IN PORTUDAL

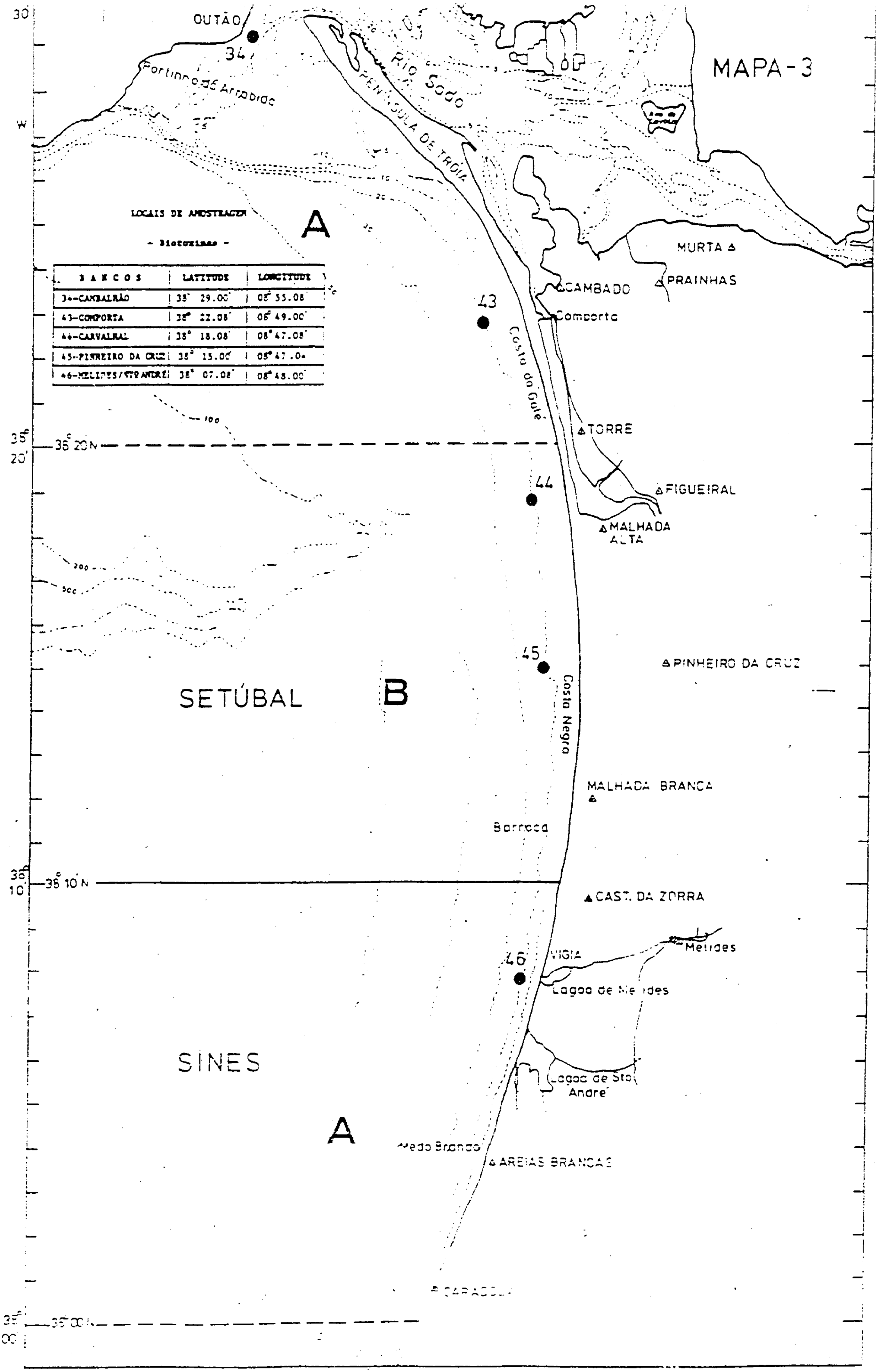
There are 85 sample stations along the coast and inside estuaries and coastal lagoons (maps in annex)

From each station at least once a month and more frequently twice a month water samples are taken from surface or from an integrated 5M water column for phytoplankton studies.
From the same stations bivalves are sampled for PSP and DSP analysis.
In each station salinity and temperature are measured. At the inside stations from Algarve sea lagoons dissolved oxygen and pH are also measured.

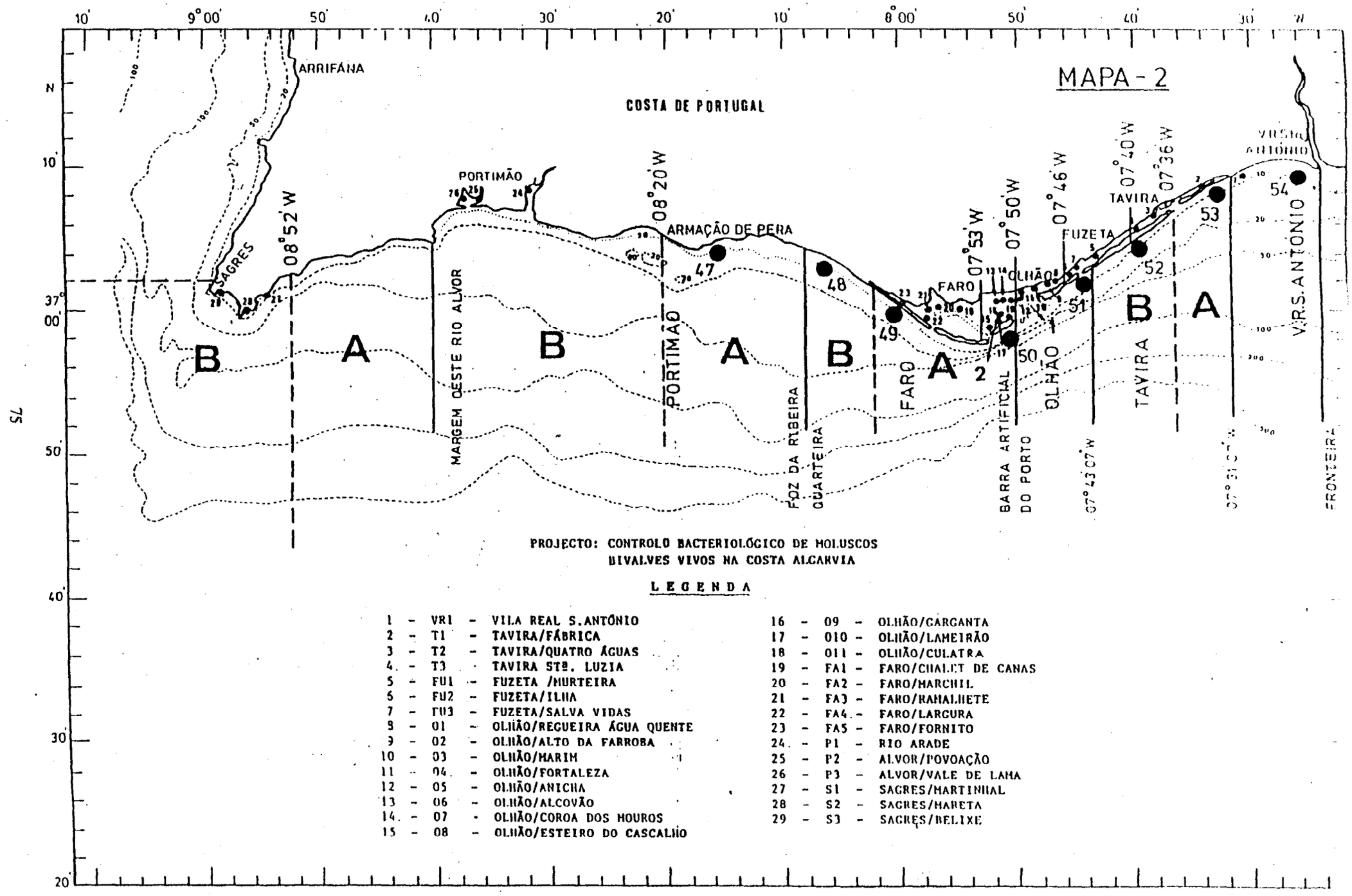
Whenever toxic species are found or there are positive results in biotoxin analysis the sampling is intensified becoming weakly or even twice a weak. until bivalves are cleared from toxins and the toxic species are not found or rare in the water samples. Sampling is made mostly by fishermen and by our Regional Centers.


COSTA DE PORTUGAL
PROGRAMA: CONTROLO DE SALUBRIDADE DE MOLUSCOS BIVALVES VIVOS
LEGENDA
1 - INSUA
2 - VILA PRAIA DE ANCORA
3 - AO LARGO DE LAVADOURES
4 - PEDRAS VAREIRAS
5 - AO LARGO DE AGUDA
6 - AO LARGO DE ESPINHO
7 - VALADARES NW
8 - AGUDA
9 - SW DE AGUDA
10 - OVAR (ESMORIZ)
11 - BANCO DA ESPANHOLA
12 - ALTO DA BARRA
13 - VAGUEIRAS
14 - MOACHA/MURANZEL
15 - CALE DO OURO
16 - SÃO JACINTO
17 - TRIÂNGULO REC.CORRENTES
18 - REBOCHO
19 - CANAL DA BARRA
20 - COSTA NOVA
21 - CAIS COMERCIAL
22 - RIO PRANTO
23 - BAÍA DE S. MARTINHO
24 - LAGOA DE ÓBIDOS/CAIS
25 - PENEDO FURADO
26 - BARROSA
27 - PENICHE
28 - ERICEIRA
29 - PÓVOA DE STª.IRIA
30 - MOITA
31 - ESTEIRO FURADO
32 - COVA DO VAPOR
33 - LAGOA DE ALBUFEIRA
34 - CAMBALHÃO
35 - OUTÃO
36 - COMENDA
37 - GÂMBIA
38 - MITRENA
39 - CHAMBURGUINHAS
40 - MONTE DA PEDRA
41 - CACHOPOS
42 - ESTEIRO DA COMPORTA
43 - COMPORTA
44 - CARVALHAL
45 - PINHEIRO DA CRUZ
46 - MELIDES/STº.ANDRÉ
47 - OLHOS DE ÁGUA
48 - QUARTEIRA/FORTE NOVO
49 - ANCÃO
50 - BARRA FARO/OLHÃO
51 - FUZETA
52 - SANTA LUZIA
53 - CACELA
54 - V.R.STº.ANTÓNIO
FRONTEIRA 41°51'57"N
(FORTE DO CÃO) 41°47'30"N CAMINHA
VIANA DO CASTELO
41°28'02"N V. DO CASTELO
MOLHE SUL DO PORTO POVOA DO VARZIM
POVOA DO VARZIM
41°16'00"N VILA DO CONDE
41°09'22"N LEIXÕES
MATOSINHOS
MONTE NEGRO/CORTEGACA 40°56'00"N DOURO
AVEIRO
MARGEM SUL DA LAGOA DE MIRA AVEIRO
FIGUEIRA DA FOZ
39°55'04"N FIGUEIRA DA FOZ
PIRÂMIDE DO DOURO NAZARÉ
FOZ DO ARELHO
PENICHE
ONTA DA FOZ (RIO LISANDRO) PENICHE
LISBOA
TORRE S. JULIÃO DA BARRA CASCAIS
CASCAIS
ROSÁRIO
SESIMBRA
SETÚBAL
ARGEM NORTE DA LAGOA DA ALBUFEIRA LISBOA
FOZ DA RIBEIRA DAS FONTAINHAS 38°10'N SETÚBAL
37°26'05"N SINES
LAGOS
PORTIMÃO
ARMAÇÃO DE PERA
FARO
OLHÃO
TAVIRA
V.R.S.ANTÓNIO
HUELVA
CADIZ
MARGEM OESTE RIO ALVOR
FOZ DA RIBEIRA
QUARTEIRA
BARRA ARTIFICIAL
DO PORTO
07°43'07"W
07°31'07"W
FRONTEIRA
PORTIMÃO
FARO
OLHÃO
TAVIRA
V.R.S.ANTÓNIO
LAGOS


MAPA - 4
LOCAIS DE AMOSTRAGEM
- Sistemáticos -
BANCOS | LATITUDE | LONGITUDE | PROF.(m)
1-VAGUEIRA | 40° 33.69' | 08° 49.75' | 30
2-ALTO DA BARRA | 40° 38.90 | 08° 50.14' | 32
3-ESPANHOLA | 40° 42.16 | 08° 44.84' | 10
4-TORREIRA* | 40° 46.50 | 08° 48.00' | 25
5-OVAR | 40° 53.80 | 08° 47.00' | 23
6-ESMORIZ | 40° 56.50' | 08° 43.50' | 24
7-ESPINHO | 41° 00.00 | 08° 43.25 | 31
8-MAR DE BAIA | 40° 29.50 | 08° 48.00' | 9
9-AGUDA (SW) | 41° 01.60' | 08° 48.30' | 9
10-AGUDA (Largo) | 41° 02.37 | 08° 44.11' | 25
11-AGUDA (Frente) | 41° 01.73 | 08° 48.18' | 12
12-PEDRAS VAMEIRAS | 41° 02.87 | 08° 43.87' | 21
13-VALADARES (NW) | 41° 06.88 | 08° 41.72' | 19
14-LAVADORES | 41° 07.35' | 08° 43.82' | 28
* - Banco pouco frequentado actualmente
AMÊIJOA BRANCA
41°09 22 N
41°01 N
40°56 N
40°45 N
08°43 W
08°48 W
LAVADORES
MATOSINHOS
VALADARES
AGUDA
ESPINHO
ESMORIS
CORTEGAÇA
OVAR
TORREIRA
AVEIRO
VAGUEIRA
CRIPMATOSINHOS
CRIPAVEIRO
DOURO
A
B
C
D
1
2
3
4
5
6
7
8
9
10
11
12
13
14
N
41°10'
40°50'
40°40'



BANCOS	LATITUDE	LONGITUDE
34-CAMBALHÃO	38° 29.00'	08° 55.08'
43-COMPORTA	38° 22.08'	08° 49.00'
44-CARVALHAL	38° 18.08'	08° 47.08'
45-PINHEIRO DA CRUZ	38° 15.00'	08° 47.04
46-MELIDES/STº ANDRÉ	38° 07.08'	08° 45.00'



PROJECTO: CONTROLO BACTERIOLÓGICO DE MOLUSCOS BIVALVES VIVOS NA COSTA ALGARVIA

LEGENDA

1	VR1	VILA REAL S.ANTÓNIO	
2	T1	TAVIRA/FÁBRICA	
3	T2	TAVIRA/QUATRO ÁGUAS	
4	T3	TAVIRA STª. LUZIA	
5	FU1	FUZETA /MURTEIRA	
6	FU2	FUZETA/ILHA	
7	FU3	FUZETA/SALVA VIDAS	
8	01	OLHÃO/REGUEIRA ÁGUA QUENTE	
9	02	OLHÃO/ALTO DA FARROBA	
10	03	OLHÃO/MARIM	
11	04	OLHÃO/FORTALEZA	
12	05	OLHÃO/ANICHA	
13	06	OLHÃO/ALCOVÃO	
14	07	OLHÃO/COROA DOS MOUROS	
15	08	OLHÃO/ESTEIRO DO CASCALHO	
16	09	OLHÃO/GARGANTA	
17	010	OLHÃO/LAMEIRÃO	
18	011	OLHÃO/CULATRA	
19	FA1	FARO/CHALET DE CANAS	
20	FA2	FARO/MARCHIL	
21	FA3	FARO/RAMALHETE	
22	FA4	FARO/LARGURA	
23	FA5	FARO/FORNITO	
24	P1	RIO ARADE	
25	P2	ALVOR/POVOAÇÃO	
26	P3	ALVOR/VALE DE LAMA	
27	S1	SAGRES/MARTINHAL	
28	S2	SAGRES/MARETA	
29	S3	SAGRES/BELIXE	

HARMFUL ALGAL BLOOMS IN 1991 - SPAIN

1. Location: Rías Bajas Gallegas (Vigo, Pontevedra, Arosa and Muros).

2. Date of Occurrence: From June to November 1991.

3. Effects: DSP was detected in mussel cultivated on rafts from June until September or December depending on the area.

4. Management Decision: Areas where DSP was detected were closed to the harvesting of mussels.

5. Causative Species: *Dinophysis acuminata* and *Dinophysis sacculus* were the causative species. In ría de Pontevedra two main peaks were observed: one of *Dinophysis acuminata* from 23 June to 1 July, the second of *D. sacculus* on 23 September (both with maximum concentrations of 8.10^3 cells.l in integrated samples).

6. Environment: Summer bloom developed during upwelling time with surface temperatures of 15-17° C and 13°C at 10 m. The second peak developed following strong stratification and temperatures of 17-21°C.

7. Advected Population or In Situ Growth: On some occasions *Dinophysis acuminata* appears in the outer parts of the rías because of advection from the shelf not far off the coast, and increases in number due probably to *in situ* growth. On the contrary *D. sacculus* is observed mainly in the inner parts of the rías.

8. Previous Occurrences: *D. acuminata* has been found in the Rías Bajas since the beginning of the monitoring programme in 1977. *D. sacculus* is rare in the area, and more common in the Rías Altas.

9. Additional Comments:

10. Individual to Contact:

Isabel Bravo
Instituto Español de Oceanografía
Centro Oceanográfico de Vigo
Aptdo. 1552
36280 VIGO
34 86 492111 (Voice)
34 86 492351 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - SPAIN

1. Location: Rías Bajas Gallegas (Vigo, Pontevedra, Arosa and Muros).

2. Date of Occurrence: 23 September 1991.

3. Effects: No effects detected.

4. Management Decision

5. Causative Species: *Heterosigma carterae* (Hada) Taylor reached 759,000 cells l^{-1}.

6. Environment: Surface temperature of 19-20°C and stratification in water column (17°C at 7 m).

7. Advected Population or *In Situ* Growth: Probably in situ growth was the most important factor.

8. Previous Occurrences: In 1980 up to 8,000 cells ml^{-1}.
In 1986 until 1700 cells ml^{-1}.

9. Additional Comments:

10. Individual to Contact:

Isabel Bravo
Instituto Español de Oceanografía
Centro Oceanográfico de Vigo
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34 86 492111 (Voice)
34 86 492351 (Fax)

HARFMUL ALGAL BLOOMS IN GALICIA IN 1992

1.- Location: Ría of Ares-Betanzos

2.- Date of Occurrence: From the end of April to the end of May 1992.

3.- Effects: PSP bivalve toxicity.

4.- Management Decision: Harvesting was closed when PSP toxin was equal to or above 80 μg equiv. STX /100 g meat.

5.- Causative Species: *Alexandrium lusitanicum*. Maximum cells concentrations: 446,900 cells l^{-1} in the inner part of the ría in mid-May.

6.- Environment: Bloom associated with high runoff, low salinity and water column stratified (14°C at bottom and 19°C at surface).

7.- Advected Population or *In Situ* Growth: Most probably, the population grew *in situ*.

8.- Previous Occurrences: Up to 10^7 cells l^{-1} in the same month and ría in 1984 (Blanco et al., 1985). In that bloom they found salinities between 22 and 27 UPS and a temperature of 15°C in the same month.

9.- Additional Comments:

10.- Individual to Contact:

J. Mariño; J. Maneiro; Y. Pazos
Condicions Oceanográficas e Fitoplancton
Centro para o Control da Calidade do Medio Mariño
Peirao de Vilaxoán. D. P. 36600
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Fax. +34 86 51 23 00

HARFMUL ALGAL BLOOMS IN GALICIA IN 1992

1.- Location: Rías of Pontevedra, Arousa, Muros and Ares-Betanzos

2.- Date of Occurrence: 1992.

3.- Effects: DSP bivalve toxicity.

4.- Management Decision: Harvesting was closed when DSP toxin was detected.

5.- Causative Species: *Dinophysis acuminata*. Maximum cells concentrations were:

- 2320 cells l^{-1} in mid-March in Pontevedra.
- 16240 cells l^{-1} in Muros and values higher than 2000 cells l^{-1} in Arosa, Muros and Pontevedra from the end of May to the beginning of June.
- 3900 cells l^{-1} in the mouth of Ares- Betanzos and high values in the mouth of Pontevedra and Muros in mid-July.
- 3720 cells l^{-1} in Muros in the middle of August.
- 3280 cells l^{-1} in Ares-Betanzos in mid-September.
- 6120 cells l^{-1} in Pontevedra at the end of November.

6.- Environment: D. acuminata was found within the whole range of temperature and salinity values common in the region.

7.- Advected Population or In Situ Growth: Increases of *D. acuminata* populations in the Rías were not associated with shelf waters Probably they represent *in situ* growth.

8.- Previous Occurrences: Very frequently recorded since the phytoplankton monitoring programme started in 1977.

9.- Additional Comments:

10.- Individual to Contact:

J. Mariño; J. Maneiro; Y. Pazos
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HARFMUL ALGAL BLOOMS IN GALICIA IN 1993

1.- Location: Rías of Vigo, Pontevedra, Arousa and Muros.

2.- Date of Occurrence: 1993.

3.- Effects: DSP bivalve toxicity.

4.- Management Decision: Harvesting was closed when DSP toxin was detected.

5.- Causative Species: *Dinophysis acuminata*. Maximum concentrations:
- 3920 cells l^{-1} in the mouth of Arosa with values more than 2000 cell/l in Pontevedra, Arosa and Muros in mid-May.
- 5120 cells l^{-1} in the mouth of Vigo in mid-August.
- 10640 cells l^{-1} in the inner part of Pontevedra with values of more than 2000 cells l^{-1} in Pontevedra, Vigo and mouths of Arosa and Muros in mid-September.

6.- Environment: D. acuminata did not show any salinity or temperature preferences while occuring within the whole range of salinity and temperature values for the region.

7.- Advected Population or *In Situ* Growth: The increases of *D. acuminata* populations in the Rías were not associated with shelf waters. Probably they represent *in situ* growth.

8.- Previous Occurrences: It has been very frequently recorded since the phytoplankton monitoring programme started.

9.- Additional Comments:

10.- Individual to Contact:

J. Mariño; J. Maneiro; Y. Pazos
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HARFMUL ALGAL BLOOMS IN GALICIA IN 1993

1.- Location: Rías of Vigo, Pontevedra, Arosa, Muros and Camariñas.

2.- Date of Occurrence: From mid-September to mid-November.

3.- Effects: PSP bivalve toxicity reaching a maximum concentration of 6175 STX eq. g/100 g meat.

4.- Management Decision: Harvesting was closed when PSP toxin content was equal or higher than reached 80 µg equiv. STX /100 g meat.

5.- Causative Species: *Gymnodinium catenatum*. The maximum cell concentration was 140,080 cells l^{-1} .

6.- Environment: During maximum cell numbers the temperatures ranged from 14°C to 17°C and the salinity from 30 to 36 USP.

7.- Advected Population or *In Situ* Growth: The initial population was clearly advected. The initial (and largest) population increase was very sudden and coincided with a downwelling episode. The population was maintained in the Rías for two months period of stratification, and persisted during moderate donwnwelling and upwelling pulses, disappearing when a strong upwelling period started.

8.- Previous Occurrences: Blooms of this species were recorded in the Rías Bajas in autumn 1981, 1985, 1986, 1987, 1988 and 1990. In these two latter years, small populations were also found during summer.

9.- Additional Comments:

10.- Individual to Contact:

J. Mariño; J. Maneiro; Y. Pazos
Condicions Oceanográficas e Fitoplancton
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HARFMUL ALGAL BLOOMS IN GALICIA IN 1993

1.- Location: Rías of Pontevedra, Arosa, Muros and Vigo.

2.- Date of Occurrence: From the beginning of July to mid-August 1993.

3.- Effects: PSP bivalve toxicity reaching a maximum concentration of 1550 µg equiv. STX /100 g meat.

4.- Management Decision: Harvesting was closed when PSP toxin was equal to or above 80 µg equiv. STX /100 g meat.

5.- Causative Species: *Gymnodinium catenatum*. The maximum cell concentration was 10,280 cells l^{-1}.

6.- Environment: During the bloom, the water column was stratified (14°C at bottom and 19°C at surface).

7.- Advected Population or *In Situ* Growth: The initial increase of the population followed a downwelling episode characterized by homogeneous vertical temperature and salinity distributions in the water column (18-20°C and about 34 UPS in the stations at the mouths of the Rías). The population was maintained in the Rías for a month while thermal stratification persisted, disappearing when a strong upwelling period started. Both, advection and *in situ* growth were possible mechanisms to maintain the population.

8.- Previous Occurrences: Blooms of this species were recorded in the Rías Baixas in autumn 1981, 1985, 1986, 1987, 1988 and 1990. In these two latter years, low abundance populations were also found during the summer.

9.- Additional Comments: This species was also recorded in very low concentrations in the Ría of Ares-Bentanzos.

10.- Individual to Contact:

J. Mariño; J. Maneiro; Y. Pazos
Condicions Oceanográficas e Fitoplancton
Centro para o Control da Calidade do Medio Mariño
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HARMFUL ALGAL BLOOMS IN 1993 - SPAIN

1. Location: Coast of Cataluña .

2. Date of Occurrence: From 27 July to middle of August .

3. Effects: The high concentration of cells and the associated mucus made large patchs in the sea causing a nuisance to tourism. No toxicity detected.

4. Management Decision:

5. Causative Species: *Gyrodinium impudicum* Fraga (in press). Maximum concentration of 5.10^6 cells l^{-1}.

6. Environment: The salinity of the water was 37.7 and the temperature 23-24°C.

7. Advected Population or In Situ Growth:

8. Previous Occurrences: This species was also observed reaching very high concentrations on the Valencia coast during summer 1992.

9. Additional Comments: The morphology of this organism is very similar to *Gymnodinium catenatum*. The differences were described in a paper presented in the "Sixth International Conference on Toxic Marine Phytoplankton" (Nantes, 1993) by Fraga et al.

10. Individual to Contact:

Maximino Delgado
Instituto de Ciencias del Mar
Paseo Nacional s/n
08039 Barcelona
Telf: 3106450
Fax : 3199842

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION: Skagerrak
Kristineberg

DATE: May xx

CAUSATIVE SPECIES: Eutreptiella gymnastica
Halosphaera viridis

CONCENTRATION: xx

EFFECTS: No

MANAGEMENT DECISIONS: –

ENVIRONMENT: xx

ADVECTED POPULATION OR IN SITU GROWTH: In situ growth

PREVIOUS OCCRUENCE: xx

ADDITIONAL COMMENTS: xx

CONTACT PERSONS:

Odd Lindahl
Kristineberg Marine Biological Station
450 34 Fiskebäckskil, Sweden
tel 46 523 18512
fax 46 523 18502

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION: Skagerrak coast
Kattegat

DATE: September xx

CAUSATIVE SPECIES: Ceratium xx

CONCENTRATION: xx

EFFECTS: No

MANAGEMENT DECISIONS: –

ENVIRONMENT: xx

ADVECTED POPULATION OR IN SITU GROWTH: In situ growth ??

PREVIOUS OCCRUENCE: Nearly every year

ADDITIONAL COMMENTS: xx

CONTACT PERSONS:

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Kristineberg Marine Biological Station
450 34 Fiskebäckskil. Sweden
tel 46 523 18512
fax 46 523 18502

Lars Edler
SMHI
Doktorsgatan 9
262 52 Ängelh
tel 46 431 808
fax 46 431 83

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION: Baltic Sea

DATE: April xx

CAUSATIVE SPECIES: Peridinella catenata
Dinophysis acuminata
Dinophysis norvegica

CONCENTRATION: xx

EFFECTS: No

MANAGEMENT DECISIONS: –

ENVIRONMENT: xx

ADVECTED POPULATION OR IN SITU GROWTH: In situ growth

PREVIOUS OCCRUENCE: Occur every year but usually in lower concentrations

ADDITIONAL COMMENTS: xx

CONTACT PERSONS:

Lars Edler
SMHI
Doktorsgatan 9D
262 52 Ängelholm. Sweden
tel 46 431 80854
fax 46 431 83167

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION:	North west Baltic Sea	Askö area
DATE:	June and August	
CAUSATIVE SPECIES:	Mesodinium rubrum	
CONCENTRATION:	XX	
EFFECTS:	No	
MANAGEMENT DECISIONS:	–	
ENVIRONMENT:	XX	
ADVECTED POPULATION OR IN SITU GROWTH:	In situ growth and advection	
PREVIOUS OCCRUENCE:	91, 92,	???
ADDITIONAL COMMENTS:	XX	

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION: North west Baltic Sea Askö area

DATE: June and August

CAUSATIVE SPECIES: Mesodinium rubrum

CONCENTRATION: xx

EFFECTS: No

MANAGEMENT DECISIONS: –

ENVIRONMENT: xx

ADVECTED POPULATION OR IN SITU GROWTH: In situ growth and advection

PREVIOUS OCCRUENCE: 91, 92, ???

ADDITIONAL COMMENTS: xx

CONTACT PERSONS:

Susanna Hajdu
Dept. of System Ecology, Univ. of Stockholm
Box 7050, 750 07 Uppsala, Sweden
tel 46 18 673155
fax 46 18 673156

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION: Baltic Sea Bothnian Sea

DATE: July - August

CAUSATIVE SPECIES: Aphanizomenon flos aquae
Nodularia spumigena
Chrysochromulina spp.

CONCENTRATION: xx

EFFECTS: No

MANAGEMENT DECISIONS: –

ENVIRONMENT: xx

ADVECTED POPULATION OR IN SITU GROWTH: In situ growth and advection

PREVIOUS OCCRUENCE: Every year

ADDITIONAL COMMENTS: xx

CONTACT PERSONS:

Susanna Hajdu
Dept. of System Ecology, Univ. of Stockholm
Box 7050. 750 07 Uppsala. Sweden
tel 46 18 673155
fax 46 18 673156

NATIONAL REPORT OF PHYTOPLANKTON BLOOMS 1993

SWEDEN

LOCATION:	Bothnian Sea
DATE:	November
CAUSATIVE SPECIES:	Aphanizomenon flos aquae Nodularia spumigena
CONCENTRATION:	xx
EFFECTS:	Hepatotoxin found No effects reported
MANAGEMENT DECISIONS:	–
ENVIRONMENT:	xx
ADVECTED POPULATION OR IN SITU GROWTH:	Advected
PREVIOUS OCCRUENCE:	??
ADDITIONAL COMMENTS:	xx
CONTACT PERSONS:	Susanna Hajdu Dept. of System Ecology, Univ. of Stockholm Box 7050, 750 07 Uppsala, Sweden tel 46 18 673155 fax 46 18 673156

NATIONAL REPORT OF HARMFUL ALGAL EFFECTS 1993

SWEDEN

LOCATION: Swedish Skagerrak coast

1	Tjärnö
2	Stridsfjord
3	Björnsund
4	Nösund
5	Styrsö

DATE:

1	August. 12	–	April. 25. 1994
2	September. 3	–	April. 25. 1994
3	October. 12	–	November. 2
4	August. 27	–	April. 25. 1994
5	August. 28	–	April. 25. 1994

CAUSATIVE SPECIES: Dinophysis spp ?????

CONCENTRATION:

EFFECTS: DSP

MANAGEMENT DECISIONS: Harvest ban

ENVIRONMENT:

ADVECTED POPULATION OR IN SITU GROWTH:

PREVIOUS OCCRUENCE: Nearly every year

ADDITIONAL COMMENTS:

CONTACT PERSONS:

Joel Haamer
Dept. of Oceanography, Univ. of Göteborg
Box 4038, 400 40 Göteborg, Sweden
tel 46 31 131893
fax 46 31


BERWICK-UPON-TWEED 13
BUDLE BAY 12
CRASTER 6
TROW ROCKS 10
SOLWAY FIRTH 10
REDCAR 8
CORNELIAN BAY 7
MENAI STRAIT 7
THE WASH 5
UNITED KINGDOM
BURRY INLET 11
THE THAMES 9
THE EXE 5
POOLE HARBOUR 11
THE TEIGN 5
PORTLAND HARBOUR 10
THE AVON 10
FAL ESTUARY 8

SOAFD PSP/DSP MONITORING PROGRAMME

Sampling of bivalves for phycotoxins is carried out at 65 stations covering the Scottish mainland and island coasts, usually starting in early April and continuing until September. In areas where PSP has been previously detected, sampling is carried out weekly and fortnightly at all other locations. When toxins are detected, sampling frequency is increased and if levels exceed 1000 mu, commercially exploited crustaceans are also sampled. Monitoring continues beyond September in areas where toxicity is still being detected.

DSP monitoring is also carried out, but to date on a smaller scale.

No routine water sampling is carried out for phytoplankton species analysis.

HARMFUL ALGAL BLOOMS 1994 - SCOTLAND

1. **Location:** East coast of Scotland

2. **Date of Occurrence:** Late April to July 1994

3. **Effects:** PSP was first detected in Moray Firth shellfish in late April and on 10th May levels in mussels from Firth of Forth had reached 6751 mu, before falling below 400 mu by early June. Wild scallop stocks were also affected with samples from the Moray Firth in early June recording levels of 2734 mu in gonads and 1210 mu in muscle.

4. **Management Decision:** A closure order was placed on the Moray Firth on 23rd June and was lifted on 28th July.

5. **Causative Species:** Low concentrations of Alexandrium cf. tamarense were detected in water samples from the Forth area.

6. **Environment:** Water column in the Firth of Forth was well stratified in late April with a thermocline at around 10m. By late May this stratification had broken down. Summer weather was cool and wet.

7. **In situ Population or Advected Growth:** Firth of Forth is a known site of Alexandrium cyst abundance, so could be in-situ population.

8. **Previous Occurrences:** Regular occurrence every year since 1968 in Forth.

9. **Additional Comments:** PSP toxins were also detected in brown crab and Nephrops hepatopancreas, but only twice did levels exceed 400 mu.

10. **Individual to Contact:**

G Howard/E Macdonald
SOAFD Marine Laboratory
PO Box 101
Victoria Road
Aberdeen AB1 6HQ
UK

HARMFUL ALGAL BLOOMS 1994 - SCOTLAND

1. **Location:** Orkney Islands, Scotland

2. **Date of Occurrence:** Early May until September

3. **Effects:** PSP toxins detected in pectinids, mussels and razor fish from many sites in the area. Maximum toxicity (5040 mu) was recorded in early June and although levels then declined, they did not drop below 400 mu until early September.

4. **Management Decision:** Six closure orders were enforced beginning on 21st May and finally lifted on 17th September.

5. **Causative Species:** Low concentrations of Alexandrium cf. tamarense (< 1000 cells l^{-1}) were detected in water samples from Waulkmill Bay.

6. **Environment:** No detailed information. Summer weather was generally cool and wet.

7. **In situ Population or Advected Growth:** There is a small population of Alexandrium cysts in parts of Scapa Flow, so in some cases, toxicity could be caused by in-situ populations.

8. **Previous Occurrences:** Regular occurrence since 1990.

9. **Additional Comments:** PSP toxins were also detected in brown crab and lobsters but were found to be mainly <400 mu. Velvet crabs had toxin levels up to 1924 mu. No action necessary, as fisherman imposed a voluntary closed season.

10. **Individual to Contact:**

G Howard/E Macdonald
SOAFD Marine Laboratory
PO Box 101
Victoria Road
Aberdeen AB1 6HQ
UK

HARMFUL ALGAL BLOOMS 1994 - SCOTLAND

1. **Location:** West coast of Scotland

2. **Date of Occurrence:** Early May to July.

3. **Effects:** PSP was first detected in Loch Hourn in early May and then declined before a second peak in early June, lasting six weeks. Maximum toxicity (1716 mu) was detected in late June. Toxicity was also detected in the Clyde (August) and Solway (June) areas, with levels reaching 1680 mu in the Clyde.

4. **Management Decision:** Voluntary closures of all shellfish farms in the affected areas.

5. **Causative Species:** Low concentrations of Alexandrium cf. tamarense were detected in water samples from Loch Hourn (<1000 cells l^{-1}).

6. **Environment:** No detailed information. Generally, summer was cool and wet.

7. **In situ Population or Advected Growth:** Not known.

8. **Previous Occurrences:** Outbreaks of PSP have been previously recorded around Skye and the Inner Sound, but 1994 was the first year toxins were detected in the Clyde.

9. **Additional Comments:**

10. **Individual to Contact:**

G Howard/E Macdonald
SOAFD Marine Laboratory
PO Box 101
Victoria Road
Aberdeen AB1 6HQ
UK

ALGAL BLOOM REPORTS - ENGLAND AND WALES

1. Location: Estuary of River Avon. South Devon

2. Date of occurence: 9 June to 2 Sept 1993

3. Effects: None

4. Management decision: Increase sampling frequency. Take samples of mussel flesh for PSP analysis

5. Causative species: *Alexandrium tamarense*, > 1.7 million cells l^{-1} on 6/8/93.

6. Environment: No data

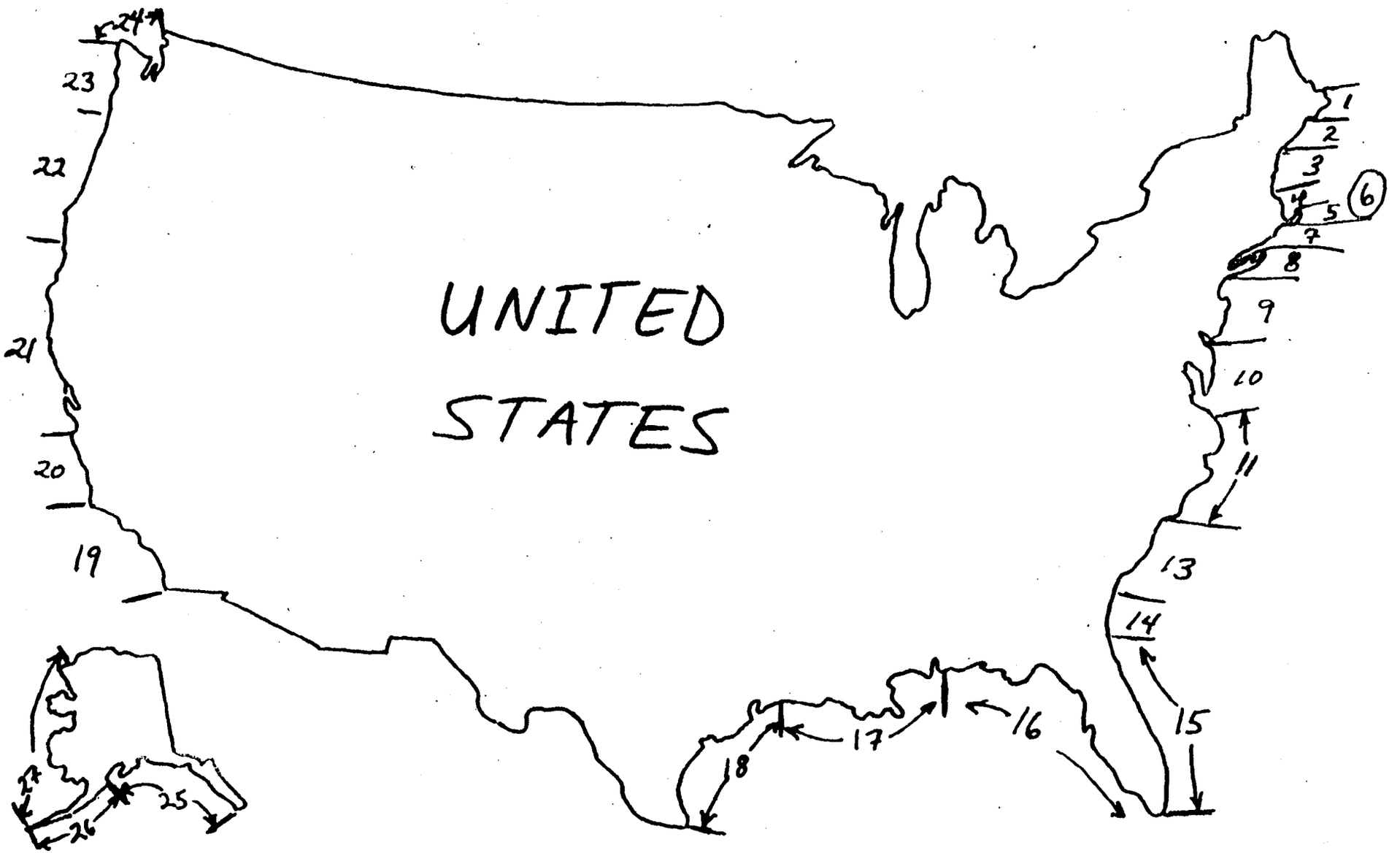
7. Advected population or in situ growth: no data.

8. Previous occurrences: no data

9. Additional comments: No toxins detected.

10. Individual to contact:

I.Laing
M.A.F.F.
Fisheries Laboratory
Benarth Road
Conwy
Gwynedd LL32 8UB



CODE DESIGNATIONS FOR

BLOOM REPORTING

Harmful Algal Blooms in the United States - 1993

1. Location: Kittery - Stonington, Maine

2. Date of Occurrence: May - September

3. Effects: PSP in shellfish (Mytilus edulis, Mya arenaria, Spisula solidissima, Modiolus modiolus, Euspira heros)

4. Management Action: Affected areas closed to the harvest of specific species

5. Causative Species: Alexandrium tamarensis

6. Environment:

7. Advected Population or In Situ Growth:

8. Previous Occurrences:

9. Additional Comments:

10. Individual to Contact: John W. Hurst, Jr.
Department of Marine Resources
W. Boothbay Harbor, ME 04575

Harmful Algal Blooms in the United States - 1993

1. Location: Tremont, Maine to the Canadian border

2. Date of Occurrence: January - August (Arctica remained closed throughout the winter)

3. Effects: PSP in shellfish (Mytilus edulis, Mya arenaria, Modiolus modiolus, Arctica islandica, Placopecten magellanicus)

4. Management Action: Affected areas closed to the harvest of specific species

5. Causative Species: Alexandrium tamarensis

6. Environment:

7. Advected Population or In Situ Growth:

8. Previous Occurrences:

9. Additional Comments:

10. Individual to Contact:

John W. Hurst, Jr.
Department of Marine Resources
W. Boothbay Harbor, ME 04575

HARMFUL ALGAL BLOOMS IN THE UNITED STATES---1993

1. **Location:** "North Shore" of Massachusetts- Cape Ann to the northern MA border
"South Shore" of Massachusetts - communities directly south of Boston
Cape Cod salt ponds

2. **Date of Occurence:** mid-May through early July

3. **Effects:**
   - Shellfish toxicity on both North and South Shores (100-400ug/100g shellfish) - *Mytilis edulis*, *Mya arenaria*, and others
   - Longer shellfish toxicity event than usual near the South Shore (see additional comments)
   - Shellfish toxicity barely detectable in several Cape Cod salt ponds; ponds already closed due to high coliform
   - No known human or marine mammal illnesses

4. **Management Action:**
   - Closure of shellfish beds (>80ug toxin/ 100g shellfish) - May
   - reopened shellfish beds when toxins in shellfish were not detectable for 3 consecutive weeks detection limit (40 ug toxin/ 100g shellfish) - June and July

5. **Causative Species:** *Alexandrium fundyense*

6. **Environment:**
   - Temperature: 8-10 degrees C
   - Salinity: 25-30 PSU
   - Stratification: Yes, mostly due to spring run off, not local heating
   - Cell numbers: 100-1000 cells/liter
   - Nutrients: Data not yet available

7. **Advected Population or *In Situ* Growth:**

Source-most likely southern Maine coastal waters; cells were presumably advected southward and alongshore into Massachusetts coastal waters via a buoyant coastal plume or surface current formed from spring run-off. *In situ* growth may have occurred during transit and within Massachusetts Bay as the run off subsided and the southward-flowing coastal current appeared to slow down. Within the restricted salt ponds *in situ* growth dominates.

8. **Previous Occurences:**

Annual event in most years since Sept. 1972, usually in May/June, but may also occur later in summer and early autumn. Outbreaks on the "South Shore" are more sporadic than the "North Shore". For instance, in 1991 and 1992 there was no occurence of shellfish toxicity on the "South Shore", while in 1993, there was a rather large protracted bloom probably due to increased spring runoff compared to the previous two years.

9. **Additional Comments:**

The bloom in Massachusetts Bay was particularly long in 1993. It lasted for about 2 months and extended further south within Mass Bay/Cape Cod Bay than previously recorded. This was probably due to the subsidence of earlier strong run off and the slow transport that followed which enabled the cells to maintain themselves within the Bays. If this event had been recorded after the controversial offshore Boston Harbor sewage outfall was operational, the potential conclusion would have been that the new outfall caused an increase in the red tide. However, 1993 documents that this event was part of the "normal" interannual variability during pre-existing conditions within the region. Preliminary data now suggests that the pre-existing conditions (i.e. the current outfall) may have contributed to the stimulation of the bloom near the "South Shore".

The lack of development of a major bloom on the "North Shore" may have been due to upwelling which pushed the toxic dinoflagellates offshore away from the shellfish beds and dissipated the bloom north of Cape Ann. Therefore, the dynamics on the "North Shore" and "South Shore" became decoupled when wind conditions changed to upwelling favorable.

10. **Individual to Contact:**

Donald M. Anderson
Woods Hole Oceanographic Institution
Woods Hole, MA USA 02543
508-548-1400 x2351
E-mail: Danderson@whoi.edu

HARMFUL ALGAL BLOOMS IN THE UNITED STATES -- 1993

1. Location: Georges Bank (offshore, Area 6)

2. Date of Occurrence:

3. Effects:

4. Management Decision: The closure of Georges Bank to the harvesting of molluscan shellfish with the exception of sea scallop adductor muscles was continued throughout 1993 because of the risk of paralytic shellfish poisoning.

5. Causative Species: Alexandrium fundyense and/or A. tamarense (variety not yet determined)

6. Environment: Georges Bank is an open ocean environment, 100-200 miles from the nearest land (Cape Cod). Much of the Georges Bank area is very shallow (10-15 m). The region is a rich fishing grounds for shellfish and finfish. Stratification of the waters overlying Georges Bank starts to occur in May, at which time the surface waters are about 10-12° C.

7. Advected Population or In Situ Growth: The origin of the offshore toxicity and its relationship with inshore toxicity remain unknown.

8. Previous Occurrences: High levels of paralytic shellfish toxins were first observed in Georges Bank shellfish in 1989. Toxin levels increased in 1990. Despite the apparent absence of Alexandrium blooms in the Georges Bank region since 1990, the persistence of the toxins in surf clams has resulted in a continuing closure of the Georges Bank surf clam fishery.

9. Additional Comments:

10. Individual to Contact:

Dr. Alan White
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, MA, USA 02543
Tel: 508-548-5123 Fax: 508-548-5124

Algal Bloom Reports - United States-1993

1. **Locations**: West Neck Bay and Coecles Harbor, Shelter Island, N.Y., on the eastern end of the Peconic Bay system. Densities of up to 6.5×10^3 cells/ml occurred in West Neck Bay, and up to 1.3×10^4 cells/ml in Coecles Harbor.

2. **Dates of Occurrence**: May through July, with peak concentrations occurring during late May and early June.

3. **Effects**: None apparent - the aesthetic effects typically associated with this bloom (water discoloration (brown) and reduced transparency) are generally not visible until concentrations approach 2.0×10^5 cells/ml. Effects on various shellfish species have previously been reported, but again occurred when cell numbers were higher than those seen during 1993.

4. **Management Decisions**: Continue weekly monitoring program.

5. **Causative Species**: ***Aureococcus anophagefferens***

6. **Environment**: Temperature: 15.3 - 26.6 degrees C
   Salinity: 26.13 - 29.40 ppt
   Dissolved Oxygen: 5.6 - 8.4 mg/l
   Water column stability: mixed

7. **Advected population or in-situ growth**: in-situ growth.

8. **Previous occurrences**: The bloom was present throughout the entire Peconic Bay system from 1985 through 1987, with densities occasionally exceeding 10^6 cells/ml. Cell numbers declined through 1988 and 1989, and were generally undetectable during 1990 with the exception of those from the West Neck Bay station. During 1991, densities of up to 2×10^6 cells/ml occurred in Flanders Bay (on the western end of the system) and West Neck Bay. During 1992, numbers approached 8.5×10^5 cells/ml in Coecles Harbor and 10^6 cells/ml in West Neck Bay.

9. **Additional Comments**:

10. **Individual to Contact**: Dr. Robert Nuzzi
Bureau of Marine Resources
Suffolk County Department of Health Services
Riverhead, New York 11901
516-852-2082

Algal Bloom Reports - United States - 1993

1. **Locations**: Great South Bay (N.Y.). The bloom was present throughout the bay from January through March, with highest concentrations occurring in the eastern bay area between Bayshore and Bellport. Concentrations ranged from $< 10^3$ to 2.6×10^5 cells/ml. A secondary bloom occurred in the fall from August through November, when counts ranged from $<10^3$ to 6.5×10^3 cells/ml.

2. **Dates of Occurrence**: January through March, and August through November.

3. **Effects**: Its effects are primarily aesthetic - water column discoloration (brownish), and reduced transparency. Secchi depth readings were less than 0.5 meters during peak bloom periods.
Effects on various shellfish species have previously been reported.

4. **Management Decisions**: To increase the frequency of monitoring activities.

5. **Causative Species**: **Aureococcus anophagefferens**

6. **Environment**: Temperature: -0.6 - 23.8 degrees C.
Salinity: 22.26 - 30.04 ppt.
Dissolved Oxygen: 6.0 - 12.9 mg/l.
Water column stability - mixed

7. **Advected population or in-situ growth**: Probably in-situ growth

8. **Previous occurrences**: 1985, 1986: $> 10^6$ cells/ml
1988: $10^3 - 5 \times 10^5$ cells/ml (June - August)
1989: $< 2.5 \times 10^4$ cells/ml (April - September)
1990: $< 1 \times 10^4$ cells/ml (May - December)
1991: $< 10^4$ cells/ml (January - June)
1992: $10^3 - 10^6$ cells/ml (January - December)

9. **Additional Comments**:

10. **Individual to Contact**: Dr. Robert Nuzzi
Bureau of Marine Resources
Suffolk County Department of Health Services
Riverhead, New York 11901
516-852-2082

Algal Bloom Reports - United States - 1993

1. **Locations**: Moriches and Shinnecock Bays (N.Y.). The bloom was mainly concentrated in eastern Moriches Bay, Quantuck Bay, and western Shinnecock Bay, where peak cell densities of > $2x10^5$ cells/ml occurred.

2. **Dates of Occurrence**: January through February, and May through November.

3. **Effects**: Its effects are primarily aesthetic - water column discoloration (brownish), and reduced transparency. Secchi depth readings were less than 0.5 meters during peak bloom periods.
Effects on various shellfish species have previously been reported.

4. **Management Decisions**: To increase the frequency of monitoring activities.

5. **Causative Species**: **Aureococcus anophagefferens**

6. **Environment**: Temperature: -0.3 - 25.3 degrees C.
Salinity: 26.51 - 31.50 ppt.
Dissolved Oxygen: 4.9 - 12.3 mg/l.
Water column stability - mixed

7. **Advected population or in-situ growth**: Probably in-situ growth in Quantuck Bay, eastern Moriches Bay, and western Shinnecock Bay, with other areas containing advected populations. Both bays are subject to significant tidal flow through ocean inlets.

8. **Previous occurrences**: 1989: < 1.3×10^5 cells/ml in Moriches Bay
< 2.3×10^4 cells/ml in Shinnecock Bay
1990: < 10^3 to $9.6x10^5$ cells/ml
1991: < 10^3 to > 10^6 cells/ml

1992: >10^6 cells/ml

9. **Additional Comments**:

10. **Individual to Contact**: Dr. Robert Nuzzi
Bureau of Marine Resources
Suffolk County Department of Health Services
Riverhead, New York 11901
516-852-2082

HARMFUL ALGAL BLOOMS IN THE UNITED STATES -- 1993

1. Location: North Carolina coast

2. Date of Occurrence: June and July, 1993

3. Effects: In June, the Bear Creek Clam Hatchery lost $7,500 worth of Mercenaria mercenaria seed clams maintained in static culture with water from Bogue Sound. Planozygotes (50-100 μm) similar to the ones described by Burkholder (1994) were observed. In July, at the Duke University Marine Laboratory in Beaufort, NC, sea urchins held overnight in seawater tanks died suddenly; dinospores (2/ml) and cysts of Pfiesteria piscimorte were observed upon backwashing the seawater filters.

4. Management Decision: None

5. Causative Species: Pfiesteria piscimorte

6. Environment: Estuarine and near coastal

7. Advected Population or In Situ Growth: Probably in situ

8. Previous Occurrences: Similar occurrences in previous years involving fish and shellfish

9. Additional Comments: These are incidents that I know of. Dr. JoAnn Burkholder (NC State University) is the main contact for NC State workers when they see fish kills.

10. Individual to Contact:

Dr. Patricia A. Tester
Southeast Fisheries Science Center
National Marine Fisheries Service
101 Pivers Island Road
Beaufort, NC 28516

HARMFUL ALGAL BLOOMS IN 1993 - UNITED STATES

1. Locations: MARIN COUNTY, CALIFORNIA areas and shellfish affected. Drakes Bay (SSM, SBM), Drakes Estero (SSM, SBM, WBM, CPO), Keho Beach (WSM), Stinson Beach (WSM), Tomales Bay (SSM, SBM, WBM, CBM, CPO, WC)

2. Date of Occurrence: March, April, May, June, October PSP concentration above alert level. In November PSP levels were in the high detectable range below the alert.

3. Effects: Sentinel sea mussels (SSM) assayed at 1900 ug/100 g meat in March but decreased through June to 320 micrograms and through September to non detectable levels. Again in November the level increased to 220 ug. In March the WSM's PSP level elevated to 1300 ug, in SBM to 1700 ug and in CPO's to 1400 ug. A sample of GC reached 81 ug/100g tissue.

4. Management Decisions: A special quarantine was established on March 12 on all species of mussels taken for human consumption. The annual quarantine on sport harvested mussels goes into effect on May 1, 1993 and continues through October 31,1993. Closure of the growers harvest areas was instituted and harvesting resumed on a batch release basis. The quarantine was lifted on October 31.

5. Causative Species: Alexandrium catenellum

6. Environment: No data available

7. Advected Population or In Situ Growth: In situ growth. Sea water samples collected March 9 contained an abundance of the dinoflagellate A. catenellum but the shellfish collected contained low detectable toxin levels however the concentration increased to very high throughout the month of March. In April a secondary bloom seemed to occur.

8. Previous Occurrences: 1927, '29, '32, '54, '62, '63, '64, '65, '66, '70, '71, '76, '80, '81, '82, '84, '86, '87, '88, '89, '90, '91, '92, '93.

9. Additional Comments: This is the area of the shellfish aquaculture industry. All the beds are monitored continuously for toxin levels. The new phytoplankton monitoring program initiated in 1993 will certainly alert the industry to increase shellfish monitoring efforts and insure consumer safety.

10. Individual to Contact:
Dr. Maria R. Ross
Biology Department
University of California at Los Angeles
405 Hilgard Avenue
Los Angeles, California 90024
(310) 206-3528

Ref:State of California Department of Health Services (SCDHS)
Shellfish Monitoring Program

CALIFORNIA COUNTIES 1993 PSP CONCENTRATION

DEL NORTE - In March, April, Aug., Sep. the wild sea mussels (WSM) exhibited high measurable levels of PSP. In Oct. the concentration in the shellfish exceeded the alert level reaching 170 ug/100g meat. Special quarantine on sports harvested mussels was lifted on Dec. 15. Previous occurrences: 1981, '91, '92, '93

HUMBOLDT - In May, Aug., Sep. the sentinel sea mussels (SSM) contained high measurable concentrations of PSP which in Oct. elevated to 220 ug. Also, the WSM concentrations during April, May, Sep., Oct. although below alert levels were in the measurable range. Special quarantine was extended to December 15. Previous occurrences: 1969, '71, '73, '89, '92, '93

MENDOCINO - In March the PSP concentration in WSM assayed at 980 ug/100g meat. Special quarantine was instituted for all species of mussels which was lifted on October 31. Previous occurrences: 1932, '62, '66, '67, '69, '75, '82, '84, '89, '90, '91, '92, '93

SONOMA - In March WSM PSP level was just above the alert at 82 ug/100g. The Washington clam (WC) contained high measurable PSP content below the alert concentration in both the siphon and viscera. Special quarantine was issued on March 23 for all species of mussels and continued for sport harvested WC. Previous occurrences: 1927, '29, '30, '32, '37, '54, '62, '68, '69, 70, '71, '76, '80, '81, '82, '87, '89, '90, '91, '92, '93

SAN MATEO - In April and May the level of PSP in WSM was below the alert but in the measurable range. Previous occurrences: 1970, '71, '82, '83, '84, '86, '87, '89, '90, '91, '92, '93

SANTA CRUZ - In April measurable low PSP levels found in WSM and in Oct. 74 ug per 100g of wild rock scollop tissue . Ptrevious occurrences: 1971, '84, '89, '91, '92, '93

LOS ANGELES - In April the WSM sample contained 74 ug/100g meat Previous occurrences: 1970, '71, '72, '83, '85, '86, '87, '89, '91, '92, '93

SAN FRANCISCO, MONTEREY, SAN LOUIS OBISPO, SANTA BARBARA, VENTURA, ORANGE, SAN DIEGO
No detectable levels of PSP in shellfish samples submitted

INDIVIDUAL TO CONTACT: Dr. Maria R. Ross
Biology Department
University of California at Los Angeles
405 Hilgard Avenue
Los Angeles, California 90024
(310) 206-3528

Ref:State of California Department of Health Services, Shellfish Monitoring Program

1993

CALIFORNIA COUNTIES

TOXIC EPISODES AND SHELLFISH AFFECTED

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max PSP ug/100g tissue
DEL NORTE	<43	<40	57	41	<41	<39	<38	36	77	170	<35	<35	170 WSM
HUMBOLDT	<40	<39	<36	<32	46	<39	<37	42	76	220	<35	<36	220 SSM
	ns	ns	<37	35	44	<41	<40	<38	46	55	<36	ns	55 WSM
MENDOCINO	<41	<41	980	<36	<40	<42	<38	<41	<41	<35	<36	<38	980 WSM
SONOMA	ns	ns	ns	34	ns	ns	ns	ns	ns	ns	ns	ns	34 SSM
	ns	ns	82	<41	<41	<44	<38	ns	ns	ns	ns	ns	82 WSM
	ns	ns	68	78	ns	49	ns	ns	ns	ns	ns	ns	78 WCS
	ns	ns	51	62	ns	51	ns	ns	ns	ns	ns	ns	62 WCV
MARIN	<41	<41	1900	400	640	320	<37	<41	<36	220	65	54	1900 SSM
	ns	ns	1300	ns	<42	41	<40	<38	<35	55	ns	ns	1300 WSM
	<38	<40	1700	44	530	<42	<38	<39	<40	ns	40	64	1700 SBM
	ns	ns	ns	36	ns	ns	ns	ns	<38	ns	ns	ns	36 WBM
	<42	<40	44	36	<40	<36	<37	<38	<36	ns	<36	<35	44 CBM
	<39	<39	1400	43	92	41	<38	<39	<38	<35	34	43	1400 CPO
	<43	ns	ns	ns	<43	ns	ns	ns	ns	ns	ns	ns	nd WCS
	<43	ns	ns	ns	<43	ns	ns	ns	ns	ns	ns	ns	nd WCV
	ns	ns	81	ns	ns	ns	ns	ns	ns	ns	ns	ns	81 GC
SAN FRANCISCO	<40	<41	ns	ns	ns	<38	<42	<38	<35	<38	<36	ns	nd SSM/WSM
SAN MATEO	ns	ns	<38	41	54	<39	<36	<37	<37	38	<34	<34	54 WSM
SANTA CRUZ	<37	ns	<36	44	<41	<35	<38	ns	ns	<38	<38	ns	44 WSM
	ns	ns	ns	ns	ns	ns	<40	ns	ns	74	ns	ns	74 WRS
MONTEREY	ns	<39	<36	<42	<43	<36	ns	ns	ns	ns	<37	ns	nd WSM
SAN LOUIS OBISPO	<39	<37	ns	<42	<38	<36	<40	ns	<38	<35	<38	<36	nd WSM
	<44	ns	ns	<42	ns	ns	ns	ns	ns	ns	ns	ns	nd WBM
	<42	<38	<38	<42	ns	<38	<37	<39	<35	<37	<37	<36	nd CBM
	<41	<40	<38	<36	<39	<37	<36	<38	<37	<37	<35	<36	nd CPO
	ns	<40	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	nd PC
SANTA BARBARA	ns	ns	<34	<41	<41	<38	<37	<38	<37	<35	<36	<37	nd WSM
	<41	<41	46	<36	<40	<36	<38	<40	<37	<35	<36	<34	46 WBM
VENTURA	ns	<40	<42	<42	<43	<42	<37	<40	ns	<34	<38	ns	nd WSM
LOS ANGELES	<42	ns	<36	75	<43	<40	<37	<35	<40	<37	ns	<34	75 WSM
	<42	<40	ns	ns	ns	ns	ns	ns	ns	<38	ns	ns	nd WBM
ORANGE	<42	<39	<38	<40	<40	<36	<39	<40	<38	<36	<37	<36	nd WSM
SAN DIEGO	ns	<38	ns	<41	ns	<44	<40	ns	<37	ns	ns	ns	nd WSM
	ns	ns	<36	<35	<41	<35	<38	<38	<37	<35	<34	<36	nd CBM
	ns	ns	ns	ns	ns	ns	ns	ns	<35	ns	ns	ns	nd SBM

Sentinel Sea Mussel (SSM)
Wild Sea Mussel (WSM)
Wild Rock Scallop (WRS)
Cultured Pacific Oyster (CPO)
Washington Clam Siphon (WCS)
Gaper Clam (GC)
Not Detectable (nd)

Sentinel Bay Mussel (SBM)
Wild Bay Mussel (WBM)
Cultured Bay Mussel (CBM)
Sentinel Pacific Oyster (SPO)
Washington Clam Viscera (WCV)
Pismo Clam (PC)
No Sample (ns)

Ref: State of California Department of Health Services (SCDHS)
Shellfish Monitoring Program

1993

DURATION OF TOXIC EPISODES

PARALYTIC SHELLFISH TOXIN (PSP)

COUNTIES	AREA	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	[Max Toxin] ug/100g
DEL NORTE	21			57	41				36	77	170			170 WSM
HUMBOLDT	21				35	46			42	76	220			220 SSM
MENDOCINO	21			980										980 WSM
SONOMA	21			82	78		51							82 WSM
MARIN	21			1900	406	240	320				220		64	1900 SSM
SAN FRANCISCO	21													
SAN MATEO	20				42	54								54 WSM
SANTA CRUZ	20				44						74			74 WRS
MONTEREY	20													
SAN LOUIS OBISPO	20													
SANTA BARBARA	19													
VENTURA	19													
LOS ANGELES	19				75									75 WSM
ORANGE	19													
SAN DIEGO	19													

PSP concentration below alert level

PSP concentration above alert level

Ref: State of California Department of Health Services (SCDHS)
Shellfish Monitoring Program

Harmful Algal Blooms in the United States – 1993

1. **Location:** Domoic acid occurred in razor clams on Pacific coast beaches.

2. **Date of Occurrence:** April through December

3. **Effects:** Toxicity in Pacific razor clams, Siliqua patula

4. **Management Action:** Partial closure of recreational razor clam fishery during scheduled spring and fall harvest seasons.

5. **Causative Species:** Unknown, but Pseudonitzschia pungens, P. australis, and P. pseudodelicatissima were found in coastal waters in November.

6. **Environment:** Coastal surf zone

7. **Advected Population or In Situ Growth:** Unknown

8. **Previous Occurrences:** October 1991 - June 1992

9. **Additional Comments:**

10. **Individual to Contact:**
Mary McCallum
Washington State Department of Health
Environmental Health Programs
P.O. Box 47824
Olympia, WA 98504-7824
Phone: (206) 753-5964

Harmful Algal Blooms in the United States – 1993

1. **Location:** PSP occurred at various localities around Puget Sound and in the surf zone of coastal beaches.

2. **Date of Occurrence:** June - October in Puget Sound
March through summer in the coastal surf zone

3. **Effects:** Shellfish toxicity exceeded closure level of 80 µg/100 g.

4. **Management Action:** In Puget Sound, there were short-term closures of some commercial growing areas and advisory closures for recreational shellfish harvest. In the coastal area, there was a partial closure of the recreational razor clam fishery.

5. **Causative Species:** Alexandrium catenella

6. **Environment:** Estuarine/inland waters/protected embayments in Puget Sound
Coastal surf zone

7. **Advected Population or In Situ Growth:** Puget Sound: in situ
Coastal area: ??

8. **Previous Occurrences:** Annually in Puget Sound
Occassionally in coastal zone

9. **Additional Comments:** Closures in 1993 were not unusal in terms of locations, duration, or maximum levels of toxicity in Puget Sound. In the coastal area, only razor clams were affected; toxin concentration above the closure level persisted in edible tissue through the summer.

10. **Individual to Contact:**
Mary McCallum
Washington State Department of Health
Environmental Health Programs
P.O. Box 47824
Olympia, WA 98504-7824
Phone: (206) 753-5964

DURATION OF TOXIC EPISODES

TYPE OF TOXICITY (PSP, DSP, ASP, NSP, ETC.): PSP

YEAR	area	code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum toxicity (ug/100g)
1993	Puget Sd	24						x	x	x	x	x			4,012 blue mussels
1993	coastal	23			x										180 edible tissue of razor clams

This table should be used to indicate the duration of the toxic episodes and the maximum level of measured toxicity.

DURATION OF TOXIC EPISODES

TYPE OF TOXICITY (PSP, DSP, ASP, NSP, ETC.): ASP

YEAR	area	code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum toxicity (ug/100g)
1993	coastal	23				x									17 ppm edible tissue of razor clams
1993	coastal	23											x		23 ppm edible tissue of razor clams

This table should be used to indicate the duration of the toxic episodes and the maximum level of measured toxicity.

HUMAN INTOXICATIONS

NONE IN WASHINGTON STATE

YEAR	MONTH	AREA (CODE)	COMMENTS

MORTALITY OF FISH AND OTHER MARINE ORGANISMS

NONE IN WASHINGTON STATE

YEAR	MONTH	AREA (CODE)	COMMENTS

Harmful Algal Blooms in the United States – 1993

1. Location: Oregon coast from Yachats to the California border, but not in the bays.

2. Date of Occurrence: PSP in mussels (only species affected) began in August.

3. Effects: One large mussel shipper was closed for 1 week until testing assured product safety.

4. Management Action: Commercial and recreational shellfish harvesting was closed on the beaches only, between between late August and early November. Bay clamming was not closed.

5. Causative Species: Not confirmed, thought to be Alexandrium catenella.

6. Environment: Typical late summer and fall weather conditions with water temperatures 10-13 C, salinity between 25-30 ppt or greater. Fall rains began in early November which is later than usual.

7. Advected Population or In Situ Growth: Not known

8. Previous Occurrences: The last Oregon PSP alert began on the northern beaches in August 1992 in mussels and continued to be present in razor clams through 1993.

9. Additional Comments:

10. Individual to Contact:

Deb Cannon
Shellfish Program Specialist
Oregon Department of Agriculture
635 Capitol St. NE
Salem, OR 97310
USA

Harmful Algal Blooms in the United States – 1993

1. Location: Oregon coast from Cape Lookout near Netarts to the Columbia River. This area is called the Clatsop Beaches.

2. Date of Occurrence: Domoic acid levels in razor clams increased to 10 ppm in November 1993. Levels were 16 ppm in late December 1993. Mussels tested at 1 ppm in November.

3. Effects: The razor clam fishery was already closed because of PSP.

4. Management Action: Razor clam harvest on Clatsop Beaches continued to be closed due to PSP.

5. Causative Species: Not known

6. Environment: Typical late summer and fall weather conditions with water temperatures 10–13 C, salinity between 25–30 ppt or greater. Fall rains began in early November which is later than usual.

7. Advected Population or In Situ Growth: Not known

8. Previous Occurrences: The last Oregon domoic acid alert started on the northern beaches in November 1991 in razor clams and continued to exceed 5 ppm until July 1992.

9. Additional Comments: Mussel sampling on Clatsop Beaches was difficult this fall making it impossible to see trends. Climate conditions in 1993 were different from 1991 when the rains came earlier and were more frequent than in 1993. Also, domoic acid levels were higher in 1991 being up to 122 ppm.

10. Individual to Contact:

Deb Cannon
Shellfish Program Specialist
Oregon Department of Agriculture
635 Capitol St. NE
Salem, OR 97310
USA

Harmful Algal Blooms in the United States – 1993

1. Location: Oregon coast from Cape Lookout near Netarts to the Columbia River (area known as Clatsop Beaches).

2. Date of Occurrence: Continuation of PSP even that began in August 1992. Toxin in mussels until April 1993. Razor clams contained PSP through all of 1993.

3. Effects: Toxin levels in razor clams ranged from 195–298 µg/100 g in late October 1993 to 50–93 µg/100 g in late December. Two razor clam processors have almost discontinued this part of their businesses. Motels and restaurants are affected because of fewer tourists. Intensified testing of razor clams has increased collection and laboratory costs of the Oregon Shellfish Program.

4. Management Action: Commercial and recreational harvest of razor clams on Clatsop Beaches remains closed. Harvest of mussels reopened in April 1993.

5. Causative Species: Not confirmed, but thought to be Alexandrium catenella.

6. Environment: Typical local conditions with late summer and fall water temperatures 10–13 C, salinity 25–30 ppt or greater. Fall rains began in early November which is later than usual.

7. Advected Population or In Situ Growth: Not known

8. Previous Occurrences: The last Oregon PSP alert began 9/25/91 in mussels, peaking at 150 µg/100 g and declining to < 50 µg/100 g by 10/30/91.

9. Additional Comments:

10. Individual to Contact:

Deb Cannon
Shellfish Program Specialist
Oregon Department of Agriculture
635 Capitol St. NE
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USA

DURATION OF TOXIC EPISODES

TYPE OF TOXICITY (PSP, DSP, ASP, NSP, ETC.): PSP

YEAR	area	code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum toxicity (ug/100g)
1993	coastal	22	x	x	x	x									mussels 50 ug/100 g
1993	coastal	22	x	x	x	x	x	x	x	x	x	x	x	x	razor clams: 298 ug/
															100 g

This table should be used to indicate the duration of the toxic episodes and the maximum level of measured toxicity.

DURATION OF TOXIC EPISODES

TYPE OF TOXICITY (PSP, DSP, ASP, NSP, ETC.): ASP

YEAR	area	code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum toxicity (ug/100g)
1993	coastal	22											x	x	razor clams: 16 ppm
1993	coastal	22											x	x	mussels: 1 ppm

This table should be used to indicate the duration of the toxic episodes and the maximum level of measured toxicity.

HUMAN INTOXICATIONS

NONE IN OREGON STATE IN 1993

YEAR	MONTH	AREA (CODE)	COMMENTS

MORTALITY OF FISH AND OTHER MARINE ORGANISMS

NONE IN OREGON STATE IN 1993

YEAR	MONTH	AREA (CODE)	COMMENTS

HARMFUL ALGAL BLOOMS IN THE UNITED STATES — 1993

1. **Location:** Point Louise: point of land on the mainland, S. point of entrance to Rudyerd Bay, Behm Canal (55°32'42"N, 130°52'05"W).

2. **Date of Occurrence:** 20 June 1993.

3. **Effects:** One person hospitalized for a day and has now recovered.

4. **Management Action:** Press release warning.

5. **Causative Species:** Mussels. Suspect *Alexandrium.*

6. **Environment:** Inside waters of southeast Alaska.

7. **Advected Population or In Situ Growth:** N/A.

8. **Previous Occurrences:** Unknown.

9. **Additional Comments:** Ate mussel on 19 June 1993 from area with no ill effect. Harvested product on 20 June 1993 and became ill within 5 minutes. Laboratory tests on mussels revealed over 400 µg/100 gms.

10. **Individual to Contact:** Michael J. Ostasz, Shellfish Coordinator, Seafood Program
Department of Environmental Conservation
Division of Environmental Health
State of Alaska
Dimond Center
800 East Dimond Boulevard, Suite 3-455
Anchorage, Alaska 99515
Tel: (907) 349-7343; Fax: (907) 349-4715

HARMFUL ALGAL BLOOMS IN THE UNITED STATES — 1993

1. **Location:** Near Island, Kodiak, Alaska. 1.5 mile long in St. Paul Harbor, 0.5 mile S. of Kodiak Island (57°47'N, 152°, 24'W)

2. **Date of Occurrence:** 15 June 1993

3. **Effects:** One person hospitalized and released. Ate butter clams (*Saxidomus giganteus)* and experienced symptoms of tingling to the feet, difficulty with walking, euphoria, sore stomach, mouth feeling funny and throat feeling like closing. Ate six (6) large butter clams raw. Onset from consumption to symptoms was one hour.

4. **Management Action:** Press release warning

5. **Causative Species:** Suspect *Alexandrium*

6. **Environment:** Small island near Kodiak, Alaska.

7. **Advected Population or In Situ Growth:** North end of Kodiak Island — small island within shipping/boat channel.

8. **Previous Occurrences:** Area has had PSP cases in the past. Mussels have been implicated in past episodes.

9. **Additional Comments:** PSP levels: 1824 µg/100 gms. 30 composited whole animals.

10. **Individual to Contact:** Michael J. Ostasz, Shellfish Coordinator, Seafood Program
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HARMFUL ALGAL BLOOMS IN THE UNITED STATES — 1993

1. **Location:** North Island — .4 mile long, off east shore of Favorite Channel, 1.2 miles SW of Yankee Cove and 37 miles NW of Juneau, Alaska (58°34'35"N, 134°55'40"W).

2. **Date of Occurrence:** 12 June 1993.

3. **Effects:** One person hospitalized and released. Symptoms developed within 10 minutes of consumption of mussels.

4. **Management Action:** Press release warning.

5. **Causative Species:** Suspect *Alexandrium.*

6. **Environment:** Inside waters in southeast Alaska.

7. **Advected Population or In Situ Growth:** Small island area.

8. **Previous Occurrences:** Unknown.

9. **Additional Comments:** PSP levels: Whole raw mussels — 3500 µg/100 gms.
   Cooked mussels — 1982 µg/100 gms.

10. **Individual to Contact:** Michael J. Ostasz, Shellfish Coordinator, Seafood Program
    Department of Environmental Conservation
    Division of Environmental Health
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HARMFUL BLOOMS IN ARGENTINE

Hugo Benavides

The shellfish Monitoring Program was established in 1981, after the first observation of a PSP outbreak caused by *Alexandrium tamarense*. Since that time, the species became endemic and the toxicity area expanded throughout the Argentine coast as far as Magallanes Strait. South of this place, the PSP monitoring on the coast of the Tierra del Fuego province started from 1985, but no detectable levels were measured.

In January 1992, a sharp toxicity increase in the mussel population of the Beagle Channel (55°S) was recorded, reaching a maximum of 127.000 μg STXeq.100gr^{-1} in about 10 days. The toxic species *Alexandrium catenella* was found in a high concentration (821 cells.ml^{-1}) decreasing towards the east side of the channel, same as toxicity distribution. An exceptionally high toxin content per cell (325 pg STX.cell^{-1}) was measured in the natural population. The mussel toxicity decreased at a low rate. The half time of detoxification was 17.5 days, however the toxicity level has never gone below 80 μg STXeq.100gr^{-1} since that time up to the present.

A research project will be starting from this year in order to test the hypothesis that, in addition to windstress and radiation, toxicity oubreaks could be related to the increase in the atmospheric UVB level; since this southern region is markedly affected by the seasonal decrease in the ozone layer, and this species, as well as *A. tamarense*, is known to produce UV-absorbing compounds, which could represent a significant competitive advantage with respect to other members of the phytoplankton community.

HARMFUL ALGAL BLOOMS IN CHILE

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HABs up to now are restricted to the archipelago and fjords systems.

Alexandrium catenella blooms and hence PSP outbreaks are located in the southermost part of South America and in recent years have been more severe than the last two decades.

DSP has been found in the north and midle parts of the fjords systems and the causative agent is Dinophysis acuta.
Salmonids kills have occurred due to the presence of large concentrations (> 10 000 cells/mL) of Leptocylindrus minimus.

A recent local and subsurface bloom of D. cf. acuminata in a strong stratified fjord seems to be an useful event which could be modelled due to the well defined boundaries conditions (2-D, X and Z). An important approach should focus on small scale of physical and biological vertical processes.

HARMFUL ALGAL IN 1991-1992 - MEXICO

1. **Location**: NW Pacific coast and bays (Baja California, Todos Santos bay, Cedros Island, Tortugas bay).

2. **Dates of occurrence**: Spring-summer 1991, summer 1992.

3. **Effects**: PSP was analysed in mussels cultivated on rafts at Todos Santos bay and it was not detected.

4. **Management decisions**: Emmergency planning started.

5. **Causative species**: Sampling was carried out with van Dorn bottles at surface and at Secchi disk lecture depth, during red tide blooms. Cells counts were performed using a in Setwick-Rafter and hematocymeter camera with an error of 0.09 and 7.54% among 6 replicates. During the 1991 espisode, two species were the most important in the area: at Tortugas bay at Baja California Sur, *Gymnodinium splendens* (5469 x 10^3 cel l^{-1}). In the mussel cultured area *G. splendens* (928 x 10^3 cel l^{-1}) and *Gonyaulax polyedra* (907 x 10^3 cel l^{-1}) were settled in one patch. In 1992 *Gonyaulax polyedra* was the predominant species (5469 x 10^3 cel l^{-1}). *Dynophysis* species were present during both events show low concentrations.

6. **Environment**: NW winds (breeze regime) with velocities up to 4 m s^{-1} predominate at Pacific cost. However, exceptional Eastern gust (10 m s^{-1}) took place on March, 25, 1991 and 14 April, 1991 were related with upwelling event and higher cell counts.

7. **Advected population or in situ growth**: Both mecanisms could occur. In 1991 event the displacement of red tide patchness were observed from the Southern area to Northern area and at the Island the same coastal species were observed. Also all dinoflagellates species seem to be growing authochtonous, while the tintinid species seem to be carried by "El Niño" waters.

8. **Previous occurrences**: During the summer, 1985 a *Prorocentum micans* and other species blooms were observed from along the coast recorded on satellite images (Pelaez, 1987). Every year during the summer the dinoflagellates are dominant in the coastal area but 1991 conditions were exceptional in extention and time. A very intensebut shorter and located phenomen was recorded in 1992. In the harbor a continuous discouloured water is observed during all the year due a mixed settled species.

9. **Additional comments**: Aditional information in Orellana Cepeda *et al.*, (*in literis*) Variabilty of *Gonyaulax polyedra* y *Gymnodinium splendens* during the red tide event at Mexican North Oriental Pacific.

10. **Individual to contact:** Elizabeth Orellana-Cepeda, Facultad de Ciencias Marinas, Universidad Autónoma de Baja California, Ensenada, Baja California, México.

International Council for the
Exploration of the Sea

C.M. 1994/L:13

REPORT OF THE ICES/IOC WORKSHOP ON INTERCOMPARISON ON *IN SITU* GROWTH RATE MEASUREMENTS (DINOFLAGELLATES)

Aveiro, Portugal, 25 - 29 July 1994

*General Secretary
ICES
Palægade 2-4
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DENMARK

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ICES/IOC Workshop on INTERCOMPARISON ON *IN SITU* GROWTH RATE MEASUREMENTS (DINOFLAGELLATES)

Aveiro, Portugal, 25 - 29 July 1994.

1. Opening the Workshop.

The workshop was opened by the chairman Dr. Maria Antonia Sampayo. The participants were welcomed by the director Dr. Manuel Sobral from the Aveiro Laboratory of the Portuguese Institute for Marine Research (IPIMAR), who hosted the workshop. Dr. Sobral also gave some information about IPIMAR and the work that is carried out at its regional center in Aveiro. It was pointed out by the chairman that the workshop was organized in co-operation with the Oceanographic Institute (IEO) from Vigo, Spain, the Aveiro University and the Hydrographic Institute (IH) from Lisbon.

1.1 Approval of the agenda and rapporteur.

The agenda was approved by the workshop. Dr. Odd Lindahl was appointed as rapporteur.

1.2 The purpose of the workshop.

The workshop was held according to Council Resolution 1993/2:48 in order to undertake an intercomparison study of *in situ* growth rates of dinoflagellates in support of the study of harmful algal blooms.

Good estimates of population dynamics parameters, such as growth rates, are essential to providing the means to quantify the detailed structure and processes which lead to a capability to model algal populations and bloom development. Ria de Aveiro has a model available, is physically uncomplicated which will facilitate intercomparison of techniques, and there is a certainty of finding relevant target species.

2. The Ria de Aveiro system.

Aveiro is situated 240 km north of Lisbon (N 40º 38.5', W 8º 44'). The Ria de Aveiro is a shallow lagoon with a wet area of 43-47 km^2. The Lagoon has a complex topography with three main channels radiating from the mouth, several branches, islands and mudflats (map 1). Organic pollution levels are high mainly from spring to autumn. Along its main channels and at some of the mudflats there is an important bivalve molluscs exploitation, mainly *Mytilus edulis*, *Cerastoderma edule* and *Venerupis pullastra*, which present almost yearly problems of PSP and DSP related with the presence respectiviely of *Gymnodinium catenatum* and *Dinophysis* spp.

The Ria de Aveiro system was presented by J. Dias, P. Silva, M.A. Esteves and M.A. Sampayo. The presentation began with the physical oceanography of the Ria and a numerical model on water currents, levels and tidal excursion was demonstrated. It was obvious from this presentation and the following discussion that the water in the Ria is usually well mixed.

The next presentation dealt with the nutrient status of the Ria, including the inputs from land run-off. Nutrient concentrations from 1992 and 1993 were presented, clearly demonstrating that the Ria is eutrophic. This was also obvious by the rich flora of diatoms which often is present.

The species composition of phytoplankton and the occurrence of toxic dinoflagellates were presented with particular emphasis on *Dinophysis* spp, and DSP in mussels in the Ria. From the phytoplankton monitoring programme it was shown that a rich variety of diatoms and dinoflagellates are generally found in the area and this was the case during the workshop. During this time *Dinophysis* cell numbers were low (<1000 cells·l^{-1}) in the Ria.

Finally, results from a cruise sampling outside the Ria de Aveiro four days prior to the Workshop were presented (T Moita, H. Cavaco and G. Vilarinho). Two sections were sampled on 21 July until Midshelf (Map 1). From temperature and salinity data it was obvious that the water column was stratified close to the coast, with higher salinities and lower temperatures observed innershelf (Fig. 1).

Cell numbers of *Dinophysis* were comparatively low also at sea reaching 800 cells·l^{-1} at the inner station (Fig. 2). Dinophysis was observed above 14 °C. High numbers of diatoms and dinoflagellates caracterized the phytoplankton community nearshore.

3. Logistics.

The aveiro laboratory was well equipped with the basic analytical equipment which was needed for the workshop. Two small research vessels was moored at fixed stations (map 2) for the sampling and the incubation studies: R/V MESTRE COSTEIRO (27 m) from Lisbon at the mouth of the Ria and R/V JOSE MARIA NAVAS (14 m) from Vigo, Spain in the commercial harbour. Two small boats were used for transfer between the laboratory and the vessels.

4. Presentation of techniques and measurements applied.

The participants presented the different methods and measurements which were applied for the intercomparison exercise.

4.1 Current meter measurements (P. Silva and J. Dias).

Instituto Hidrográfico collected current meter data in two stations at Ria de Aveiro (near the mouth - station 1 and inside the commercial Harbour - station 2) at three different levels in the water column (1 m above the bottom, middle water column depth and at 1 m below the surface).

4.2 Enclosed water column measurements (E. Dahl).

A main advantage of enclosed water column/mesocosm measurements is that the same waterbody with its organisms can be studied over time. In this experiment plastic bags mounted on aluminium frames with 1m diameter were used (Brockmann et al. 1977).

Five experiments were performed (Table 1). All the bags were filled and placed in the commercial harbour (map 2). The depth of all bags was approximately 2 m. When filled by pumping, water from 2 m depth in the bay was pumped into the bags using a Pumpex GA 200. On 25 July a natural water column was enclosed in

Bag 1-II by lowering the flattened plastic bag mounted on the frame to 2 m depth and then enclosing the upper 2 m water column by raising the bag to the surface. Zooplankton was removed by sieving the water through a 140 µm mesh. On 27 July nutrients were added to three bags. Parameters measured during the experiment were nutrients, chlorophyll and phaeopigments, particulate carbon and nitrogen and the phytoplankton composition with emphasis on selected species. Sampling was carried out with a tube to obtain integrated samples. When nutrients were added, the bag content was artificially mixed before sampling.

Table 1: An overview of the enclosed water column measurements

Bag number	Started	Filling technic	Zoopl. remov.	Nutr. added	Number of samplings	Ended
Bag 1	22th	Pump	Yes	No	4	25th
Bag 2	22th	Pump	Yes	27th	12	29th
Bag 3	24th	Pump	No	No	10	29th
Bag 4	24th	Pump	Yes	27th	10	29th
Bag 1-II	25th	Enclosure	No	27th	9	29th

Reference:

Brockmann, U.H., Eberlein, K., Hentzschel, G., Schöne, H.K., Siebers, K., Wandschneider, K. and Weber, A., 1977. Parallell plastic tank experiments with cultures of marine diatoms. - Helgol.Wiss.Meeresunters. 30:201-216.

4.3 Diffusion chamber method (M. Varela).

Primary production by phytoplankton is translated into population growth through increases in cell numbers by binary fission. General approaches have been taken to measure or, usually, estimate in situ growth rates of phytoplankton species or communities. One of these approaches consists in enclosing natural phytoplankton assemblages in containers that are incubated *in situ* or in simulated *in situ* conditions.

The method used here is based on that described by Furnas (1982) where the incubation chamber is made of clear acrylic plastic with polycarbonate filters or nitex mesh (10 µm) as the diffusion membranes.

Samples were taken at a fixed depth. A subsample was taken immediately and preserved with Lugol's solution for microscope counting to estimate the initial number of *Dinophysis* cells. Another subsample was poured into the chamber and incubated in situ for 48 h, after which the contents of chambers were poured into a plastic bottle and the content preserved with Lugol's solution. Microscope counting is made from this bottle to estimate the concentration of *Dinophysis* at 48 h. Daily growth rates (Furnas 1982) of *Dinophysis* will then be calculated from differences in concentration between T_{48} and T_0.

Reference:

Furnas, M.J., 1982. An evaluation of two diffusion culture techniques for estimating phytoplankton growth rates *in situ*. - Mar.Biol. 70: 63-72.

4.4 ^{14}C method *in situ* (O. Lindahl and L. Davidsson).

One of the purposes with the workshop was to compare the "old" ^{14}C-method with newly developed methods. The ^{14}C-method is known to give relatively good estimates of the gross production of the whole phytoplankton community in the

experimental bottle (Williams, 1993). Thus, in this workshop the community growth rates were going to be compared with growth rates of single species measured by both ^{14}C-uptake and by other methods, obviously a difficult task. However, according to the local experience the summer phytoplankton flora in the Ria de Aveiro is often dominated by a few species and a comparison between community and single species growth rates could be possible.

The ^{14}C measurements were performed in the traditional way by taking water from different depths with a water-bottle and incubated in a single glass bottle (125 ml) at each depth for 2 to 4 hours (BMB, 1976). 10 µCi of ^{14}C was added to each bottle. Immediately after the incubation three parallell subsamples of 10 ml were taken out of each bottle into a scintillation bottle and acidified and bubbled with air for 15 minutes. The carbon uptake of the whole phytoplankton community was thus measured.

14C-measurements *in situ* are time consuming and may introduce errors due to that water from different depth are brought to the deck of the ship and then back again. Especially cells which are dark adapted may become distributed by this handling. To reduce this problem Dandonneau (1993) developed an automated sampling and incubation device which closes while being lowered. This closing principle is suitable for homogenous and clear waters. However, in coastal stratified waters with low visibility and a high abundance of thin subsurface chlorophyll and production maxima an *in situ* incubator should contain a water representative for a certain depth or a thin layer. An *in situ* incubator which hopefully will meet these needs has been constructed (Lindahl and Haamer, unpubl.) and is still under development. This incubator is like a small water-bottle made of acrylic plastic and kept horizontal. The closing is triggered by a small hydraulic plunger after approximately 5 minutes. ^{14}C is added from a syringe after the incubator has closed. After incubation the *in situ* incubator and its sample is treated like an ordinary ^{14}C-bottle. Some parallel measurements were made with this *in situ* incubator.

References:

Baltic Marine Biologists, 1976. Recommendations on methods for marine biological studies in the Baltic Sea. - BMB Publ. no. 1, 98 pp.

Dandonneau, Y., 1993. Measurements of *in situ* profiles of primary production using an automated sampling and incubation device. - ICES Marine Science Symposia, Vol. 197:172-180.

Williams, P.J.leB., 1993. Chemical and tracer methods of measuring plankton production. - ICES Marine Science Symposia, Vol. 197: 20-36.

4.5 Single cell ^{14}C uptake method (M. Varela, B. Reguera and I. Bravo).

The basic method is that of Rivkin and Seliger (1981). The purpose of the experiment is simply to conduct a typical ^{14}C productivity incubation, but in chambers of sufficient size that *Dinophysis* is not disturbed. Polycarbonate bottles of about 1 l volume are used. Water samples are gently poured into these bottles and alkalinity measured. Initial cell counts are taken and the ^{14}C is added at a rate of 1 µ Ci per ml. These are incubated *in situ* or simulated *in situ*.

Immediately after ^{14}C was added and mixed, an aliqout was taken to measure activity added to sample. After 24h incubation the samples were poured through a large sieve (130 µm) into a beaker. The material collected was then poured through a second 20 µm sieve, followed by at least 2 liters of filtered seawater. The sieve content was washed into a small tube, which was placed in a beaker on ice in a cooler and kept dark.

1 ml sub-samples were taken from this suspension and placed on slides in order to isolate the cells. Cells were washed thoroughly in drops of filtered sea water before placing them into scintillation vials, keeping track of the exact number of cells isolated. Around 50 cells should be isolated into each vial to give good statistics. It is also necessary to have control vials, in which you draw 50 samples of the background water (i.e. no cells) approximately equal in volume to the amount drawn with each cell that is isolated. This is also placed in a scintillation vial for counting.

In order to estimate a growth rate , it is necessary to estimate the amount of carbon in *Dinophysis* cells. Therefore, we need to measure a number of them so that calculations of cell volume and cell carbon can be made.

References:

Rivkin R.B.and Seliger H.H. 1981: Liquid scintillation counting for ^{14}C uptake of single algal cells isolated from natural populations. - Limnol.Oceanogr., 26: 780-784.

Granéli E., Anderson D.M., Maestrini S.Y. and Paasche E. 1992: Light and dark carbon fixation by the marine dinoflagellate genera *Dinophysis* and *Ceratium*. - ICES Marine Science Symposia, vol. 197: 274.

4.6 Species-specific division rates via morphological differences in cells undergoing mitosis (I. Bravo, E. Garcés and B. Reguera).

Our objective was to estimate *in situ* division rates of *Dinophysis* spp by applying the model of McDuff and Chisholm (1982). The application of this model is based in the observation and quantification of morphological differences observed in cells undergoing mitosis. The observations to be quantified were:

i) Frequency of double nucleated cells.

ii) Frequency of paired cells.

iii) Frequency of just divided cells.

Double nucleated cells will be recorded by epifluorescence of cells stained with a DNA-specific dye, DAPI (4'6-diamindino-2 phenylindole, Sigma Chemical) at a final concentration of 1-2 $\mu g \cdot ml^{-1}$.

Paired cells of *Dinophysis* spp can be easily observed before the end of cytokinesis when sampling at the appropriate hours of the day. In the case of *Dinophysis acuminata* division in natural populations seems to be very synchronized, and is observed during a narrow window of time, between 5 am and 7am (GMT) , both in Atlantic and Mediterranean waters of the Iberian peninsula (unpubl. data).

Just divided cells of *Dinophysis* spp show complementary sulcal lists, each daughter cell missing either the left or the right sulcal list. These marked morphological differences will allow a good application or even a refinement of McDuff and Chisholm's model.

Samples are taken every hour or every other hour, except between 2.^{00} am and 8.^{00} am (GMT) when the frequency is increased (every half an hour). Some parameters and processes that will be under study and need further refinement in the course of the present (this Workshop) and future monitorings of *Dinophysis* cell cycle are:

i) Determination of the division time (T_D) .

ii) Constancy of T_D under varying environmental conditions and different seasons.

iii) Time lag for the full development of the sulcal lists in the daughter cells.

iv) Possible existence of bimodal cycles when hypothetical gamet production

takes place at different hours of the day (MacKenzie, 1992) or different stages of the population growth (Reguera et al, 1990).

References:

McDuff, R.E. and Chisholm, S.W., 1982. The calculation of *in situ* growth rates of phytoplankton populations of cells undergoing mitosis: a clarification. - Limnol.Oceanogr. 27: 783-788.

MacKenzie, L., 1992. Does *Dinophysis* (Dinophyceae) have a sexual life? - J.Phycol. 28: 399-406.

Reguera, B., Bravo, I. and Fraga, S., 1990. Distribution of *Dinophysis acuta* at the time of a DSP outbreak in the Rias of Vigo and Pontevedra. ICES C.M. 1990/L:14.

4.7 RNA and DNA Measurements as Indicators of Growth Rate (D.M. Anderson and D. Kulis).

RNA and DNA measurements can be used in several different ways to obtain estimates of growth rates in phytoplankton. For example, the ratio of RNA:DNA is used extensively in studies of fish, fish larvae, and other larger marine organisms as an indicator of physiological condition. The concept has been explored for marine bacteria (Delong et al., 1989) and phytoplankton (Dortch et al., 1983). For some of these organisms, it is clear that the ratio varies systematically with growth rate (e.g. Dortch et al., 1983; Delong et al., 1989). Nevertheless, considerable work remains, especially with microorganisms, to determine whether the environmental variables that limit growth affect the ratio in different ways (Dortch et al., 1985; Berdalet et al., 1992, 1994).

With respect to toxic or harmful dinoflagellates, relatively little is known about the utility of the RNA:DNA ratio as an indicator of physiological condition or growth rate. One of the objectives of this subproject within the workshop was to investigate how this ratio might vary in a *Dinophysis* population.

Another potentially useful measurement would be of DNA alone, as shown by Chang and Carpenter in a series of papers (Chang and Carpenter 1988, 1991, 1994; Carpenter and Chang 1988). DNA-specific stains are used to quantify the amount of DNA in individual cells through time which can then be used to estimate growth rate using the mitotic index approach (McDuff and Chisholm 1982; Weiler and Chisholm 1976).

Given the potential utility of RNA:DNA ratios and DNA measurements by themselves, an approach was pursued during this workshop to obtain both types of data. In order to obtain simultaneous measurements of RNA and DNA in the same cell, double-labeling with DNA-specific stains (propidium iodide, DAPI, or Hoechst) will be used in conjunction with fluorescently-labeled ribosomal RNA probes. The latter are short segments of synthetic DNA designed to bind to the rRNA of target organisms. Since rRNA represents the vast majority of total RNA (Kemp et al., 1993), this provides a useful estimate of the RNA content in a cell and avoids the problem of attempting to find a RNA-specific general stain that does not bind to DNA and does not vary stoichometerically due to conformation of the rRNA (Danzynkiewicz et al., 1987). In an ideal case, the rRNA probe could also be species-specific, and thus serves two purposes; identifying the target species and quantifying its rRNA at the same time. With respect to *Dinophysis*, no rRNA probes yet exist, so a "universal" probe (Giovannoni et al., 1988) that binds to rRNA of all organisms will be used instead. The bright orange phycoerytherin fluorescence of *Dinophysis* in combination with size information from 90^{o} or forward light scatter measurements will be used to distinguish this organism from the rest of the mixed population.

Since it is not clear whether simultaneous RNA and DNA measurements will be possible on most standard flow cytometers, a fall-back position was pursued to measure DNA content alone and to use the distributions of cells going through mitosis through time to calculate growth rate.

Procedures

Every two hours for 36 hours a 20 M plankton net was lowered to within 2 meters of the bottom of the water column and raised vertically twice in sucession to provide a nonquantative, integrated plankton sample. The sample was then screened through a 130 µm nitex sieve and the effluent was rinsed through a 20 M sieve to concentrate dinoflagellate species. Cells were preserved in 2.5% formaldehyde, and stored at 4 °C in the dark until analysis.

To quantify the RNA/DNA ratio by flow cytometry a subsample was removed and rinsed again through a 35 µm sieve to further purify the dinoflagellate cell component. The washed cell slurry was resuspended in a 15 ml centrifuge tube and was centrifuged at 7500 x g for 5 minutes. The supernatant was aspirated and 0.5 ml hybridization buffer containing 5X SET (750 mM NaCl, 100 mM tris-HCl, 5 mM EDTA, pH 7.8), 0.1mg/l polyadenylic acid, 0.1% Tergitol NP-40, 10% formamide was added to the cell pellet. The sample was prehybridized at 37 °C for 30 minutes. 50 l of a FITC conjugated universal or negative shipworm bacterium control (Distel et al., 1991) rRNA probe (final conc. 5 ng/l) were added and the sample was incubated for an additional 2 hours at 37 °C. The sample was then centrifuged as described above and the cell pellet was washed in 0.2X SET buffer for 10 minutes at 37 °C. Following the wash the sample was again centrifuged, the supernatant aspirated, and the hybridized pellet was resuspended in 5X SET containing a DNA specific stain such as PI, DAPI, or Hoechst. These samples will be analyzed on a flow cytometer or microscope photometer to quantify the rRNA and DNA fluorescence of *Dinophysis* sp.

References:

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Chang J., and E. J. Carpenter. 1988. Species-specific phytoplankton growth rates via diel DNA synthesis cycles. II. DNA quantification and model verification in the dinoflagellate *Hetreocapsa triquetra*. *Mar. Ecol. Prog. Ser.* 44:287-296.

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Weiler, C. S., and S. W. Chisholm. 1976. Phased cell division in natural populations of marine dinoflagellates from shipboard cultures. *J. Exp. Mar. Bio. Ecol.* 25:239-247.

4.8 DNA/PCNA cell cycle method (E. Carpenter and S. Lin).

We measured growth rates of phytoplankton using a cell cycle technique. Basically, we obtained the growth rate by sampling the phytoplankton at 2 hr intervals over a 24 h period, then determining the percentage of cells which are dividing. From this information and a determination of the length (duration) of the division phase (or some other "terminal event"), growth rate was calculated. A terminal event is defined as being a marker occurring at the end of cell division cycle. It can be a microscopic observation of the number of paired cells, a measure of cells with 2x DNA or the presence of a chemical which might only be present at one stage of the cell cycle or some other type of observation. We used two methods for determining the percent which will divide, DNA and PCNA.

For the DNA technique, we collected phytoplankton and preserved them in methanol. The methanol serves to remove photosynthetic pigments which might fluoresce and also preserves the cells. Next we add the DNA- specific fluorochrome DAPI. DAPI fluorescence is proportional to DNA content, and we measure DNA in single cells using a TV-computer-based microscope system. After the DNA content of about 300 cells of a selected species is saved on the computer, we can plot a histogram of the DNA profile of the population. By examining profiles at 2 hr intervals through the day we can see how the population progresses through the cell division cycle. Equations are then used to deconvolute the histograms and extract each of the cell cycle phases: G, S, G_2+M. The G, S, G_2+M phases are used as the "terminal event" and we calculate growth rate by comparing those which are dividing (with a "terminal event") with those that are not.

Since the above method is time consuming and involves a lot of expensive equipment, we have developed an antibody method to substitute as the "terminal event". The presence of the cell cycle protein PCNA (proliferating cell nuclear antigen), a cyclin compund is used as the event. All that is required is to add fluorescent labeled antibodies to PCNA to a sample and then to visually examine the sample using a standard epifluorescence microscope. This way, the investigator can visually examine the species composition of the whole phytoplankton population and obtain growth rates for all species. Sample collection and formulas for determining growth rates are identical to that used for the DNA method.

4.9 Monoclonal antibodies, species specific diel DNA measurements and bioassay (L. Peperzak).

1. Collection of Dinophysis spp, to be used for the production of monoclonal antibodies (Vrieling et al, 1994).

2. 48 hours of sampling for flowcytometric species and DNA measurements. Samples will be labelled with a species specific label and a DNA dye. The species label will trigger the f.c.m. that will then measure the amount of DNA present. Growth rates can then be calculated with the Carpenter-cell cycle method (Chang and Carpenter, 1988). (Species labels: *Prorocentrum micans, Alexandrium tamarense, Pseudonitzschia pungens f. multiseries*).

3. Samples for bioassay experiment were incubated in bottles that were moored *in situ*. The following additions were made: 1.) none, 2.) growth factors, 3.) pH lowering, 4.) chelator, 5.) PEP-Si growth medium with extra vitamins, 6.) All (6 bottles in duplicate). Effects were measured as *in vivo* chlorophyll fluorescense and cell (*P. micans, Dinophysis spp*) concentration.

References:

Chang, J. and Carpenter, E.J., 1988. Species-Specific phytoplankton growth rates via diel DNA synthesis cycles. II. DNA quantification and model verification in the dinoflagellate *Heterocapsa triquetra*. - Mar.Ecol.Prog.Ser. 44:287-296.

Vrieling, E.G., Peperzak, L., Gieskes, W.W.C. and Veenhuis, M., 1994. Monoclonal antisera: an immunochemical tool for the specific detection of the ichtyotoxic dinoflagellate *Gyrodinium aureolum* and morphologically related *Gymnodimium* species. - Mar.Ecol.Prog.Ser. 103: 165-174.

5. Preliminary results and some comments.

5.1 Current meter data.

Station 1 (near mouth of Ria de Aveiro):

1. The values of the currents observed were highly related to ocean tidal wave, as expected.
2. The velocity of the current near the mouth was approximately constant in he vertical, although the values were bigger near the surface. The maximum values occurred in ebb situations. The ebb mean time was longer than the flood mean time, 5h 40 and 6h 30 respectively.
3. The maximum velocities were observed at intermediate tide (±2 h after the high and low tide), which showed the tidal wave in the Ria, at least near this location, was a mixture between a progressive and stationary wave.

Station 2 (Commercial Harbour):

1. In flood situations the velocity currents had a significant value while in the ebb situations the velocity was almost zero. This showed that the harbour could be considered as a reservoir that filled fast end emptied slowly during the tidal cycle.
2. The currents were not constant in the vertical; they were more intense near the surface and decreased with depth.

5.2 Enclosed water column measurements.

The results from counting *Dinophysis* spp. on filters in microscope with epifluorescence attachment are shown in tables 2-6. From each sampling two or three subsamples of 50 ml were concentrated by filtration and counted. This method should theoretically detect concentrations of *Dinophysis* spp. down to 10 cells/l. Only *D. acuminata* was present in numbers high enough to get reliable data of their concentration. In all bags this species increased in numbers during the first 24 h.

From data in Tables 2-6 during the first 24 h of the experimental period, the following growth rates for *D. acuminata* was calculated

Bag no.	Div./day
1	0.09
2	0.11
3.	0.23
4	0.40
1-II	0.5-1.1

according to the formula (Eppley and Strickland, 1968):

$$k = 3.32 \cdot (\log n_t - \log n_{t0}) \cdot (t-t_0)^{-1}$$

where k = growth rate as divisions per day (24 h)
t_0 and t = point of time for two different measurements of cell concentration, unit days
n_{t0} and n_t = the corresponding concentration of cells
log = $\log_{10}$

After about 24 h, however, the concentration of *D. acuminata* decreased in all bags. Even if the concentration of the other species of *Dinophysis* were too low to get reliable data on growth one may, from Table 2-6, get the general impression that the heterotrophic species, *D. rotundata*, showed somewhat better survival in the bags than during the experiment. The addition of nutrients, 11 a.m. on 27 July, to bag 2, 4 and 1-II did not stimulate growth of *Dinophysis* spp. during the next 48 h, while phytoplankton biomass measured as chlorophyll increased significantly during the same period.

Accompanying species in all the bags were dominated by diatoms, mainly *Leptocylindrus danicus*, *Thalassionema nitzschioides* and *Pseudonitzschia* sp. Their content of chlorophyll per cell became less and less untill 27 July when nutrients were added to the bags. After the addition of the nutrients the chloroplasts recovered and the diatom population very soon showed a much more healthy condition. This, together with the immediate increase of chlorophyll biomass after addition of nutrients indicate nutrient limitation during the first days of the experiment.

As harmful dinoflagellates occurred in rather low numbers during the experiment, more abundant dinoflagellates as *Ceratium fusus*, *Helgolandinium subglosum* and *Prorocentrum micans* were also counted. Such data together with data on *Dinophysis* counted by other technics and data on nutrients and particulate carbon and nitrogen will be presented in a later report.

By the end of the experiment the sediment in each bag was qualitatively checked for algae, and the preliminary results revealed a rather strong sedimentation in the bags during the experiment, especially of diatoms.

Reference:

Eppley, R.W. and Strickland, J.D.H., 1968. Kinetics of marine phytoplankton growth. In: Droop, M. and Ferguson Wood, E.J. (eds.) Advances of Microbiology of the Sea 1:23-62.

5.3 Diffusion chamber method.

Cell counts of the inverted bottle sample used for in situ incubations for the single cell ^{14}C uptake, and to fill the diffusion chambers showed a very low concentration of *Dinophysis* spp (100-300 cells/l), but much more abundant

populations of *Prorocentrum micans* and *Helgolandinium* sp. Therefore, attention will be focused in these two species besides the attention on *Dinophysis* spp.

The low concentration of *Dinophysis* spp will not affect the method based on mitotic indices, because this is based on frequencies (not on concentrations) and because the net haul (20 μm) sampling will assure the supply of enough cells.

Preliminary counts of the dinoflagellate populations at time zero (t_0) and after 48h of incubations (t_{48}) incubated at 0 and 5 m depth, showed that all phytoplankton populations had a drastic decrease in numbers. The content of the diffusion chamber had a very high proportion of detritus that prevented any growth and caused damage to the surviving cells that did not look very healthy. This was due to the high content of detritus in Ria de Aveiro combined with the use of 20 μm mesh size in the extremes of the chamber.

5.4 ^{14}C method in situ.

Three measurements on 26 July and one on 27 July were carried out at the station situated in the mouth channel of the Ria. The very strong tidal currents involved that only the samples incubated close to the surface (0.5 m) were accurate.

Day	Time	Chlorophyll *a*	Prim. prod. 0.5 m	Chl./Pp.
		$\mu g \cdot l^{-1}$	$mgC \cdot l^{-1} \cdot h^{-1}$	
26	08.15 am	11.6	128	10.8
	11.10 am	9.6	55	5.5
	14.30 pm	15.1	131	8.5
27	08.15 am	no data	107	no data

Both the chlorophyll *a* concentration and the primary production were high, i.e. in a range typical for an eutrophied area. However, the chlorophyll to primary production ratios (assimilation number) were comparatively low, indicating that the phytoplankton community at this station was not growing at a high rate. At present there is no other explanation than patchiness to the large variation in chlorophyll and productivity between the different measurements.

In order to avoid the strong currents an incubation was carried at the raft with the bags in the afternoon on the 27th. One bottle was incubated at each 0.5 m down to 4 m depth (figure 2). Light inhibition at the surface involved that a maximum productivity of 340 $\mu gC \cdot l^{-1} \cdot h^{-1}$ was found at 0.5 m depth. This was a very high value. Still at 2 m depth the productivity was around 200 $\mu gC \cdot l^{-1} \cdot h^{-1}$ and at 4 m (just above bottom) a productivity of 22 $\mu gC \cdot l^{-1} \cdot h^{-1}$ was measured. (As a comparison it could be mentioned that a high spring bloom value may reach 75 $\mu gC \cdot l^{-1} \cdot h^{-1}$ and high summer values are around 25 $\mu gC \cdot l^{-1} \cdot h^{-1}$ in Scandinavian coastal waters). When integrated over depth the productivity was 699 $mgC \cdot m^{-2} \cdot h^{-1}$ and the daily production was estimated by the light factor method (BMB, 1976) to 7700 $mgC \cdot m^{-2} \cdot d^{-1}$, which indicated that the primary production was very high on this occasion. Unfortunately, no chlorophyll samples were taken during this day. The Secchi-depth was 1.5 m at all primary productivity measurements.

5.5 Monochlonal antibodies, species specific diel DNA measurements and bioassay.

Because *Dinophysis* spp abundance was low, there was no opportunity to collect enough cells for monochlonal antibody production. Therefore, *Dinophysis* specific growth rates can probably not be measured with the NICMM flowcytometer in the near future.

The 48 h sampling programme was reduced to 36 h. Two vertical net hauls were taken with a 20 µm plankton net at two stations. Sample processing will begin in 1995. Division rate measurements will be focussed on *Prorocentrum micans*.

Bioassay samples were incubated for 49 h at 1 m depth. *In vivo* fluoresence measurements suggested that GF, Chel and pH were not significantly different from NONE ($p \geq 0.05$) and that PEP-Si and ALL were not significantly different from NONE ($p > 0.05$). However, they were all different from NONE, GF, Chel and pH as a group ($p < 0.05$). PEP-Si and ALL were not significantly different from each other.

The preliminary cell counts showed as a general trend that *Helgolandium subglosum* and *Leptocylindrus danicus* increased during the incubation, while *Ceratium fusus* declined. The effect of the different treatments seems negligible or even negative. A complete report, including references, will become available later this year at the National Institute for Coastal and Marine Management (Holland).

6. Action list.

The participants of the workshop agreed on the following action list:

6.1 To prepare results so that a comparison and evaluation of methods and techniques used during the workshop can be made. This work should be done within a year and finally be presented as an ICES Co-operative Research Report.

6.2 To prepare a poster regarding the workshop for the7th International Conference on Toxic Marine Phytoplankton in Sendai, Japan, 1995. Dr M.A. Sampayo and Dr O. Lindahl agreed to co-ordinate this work.

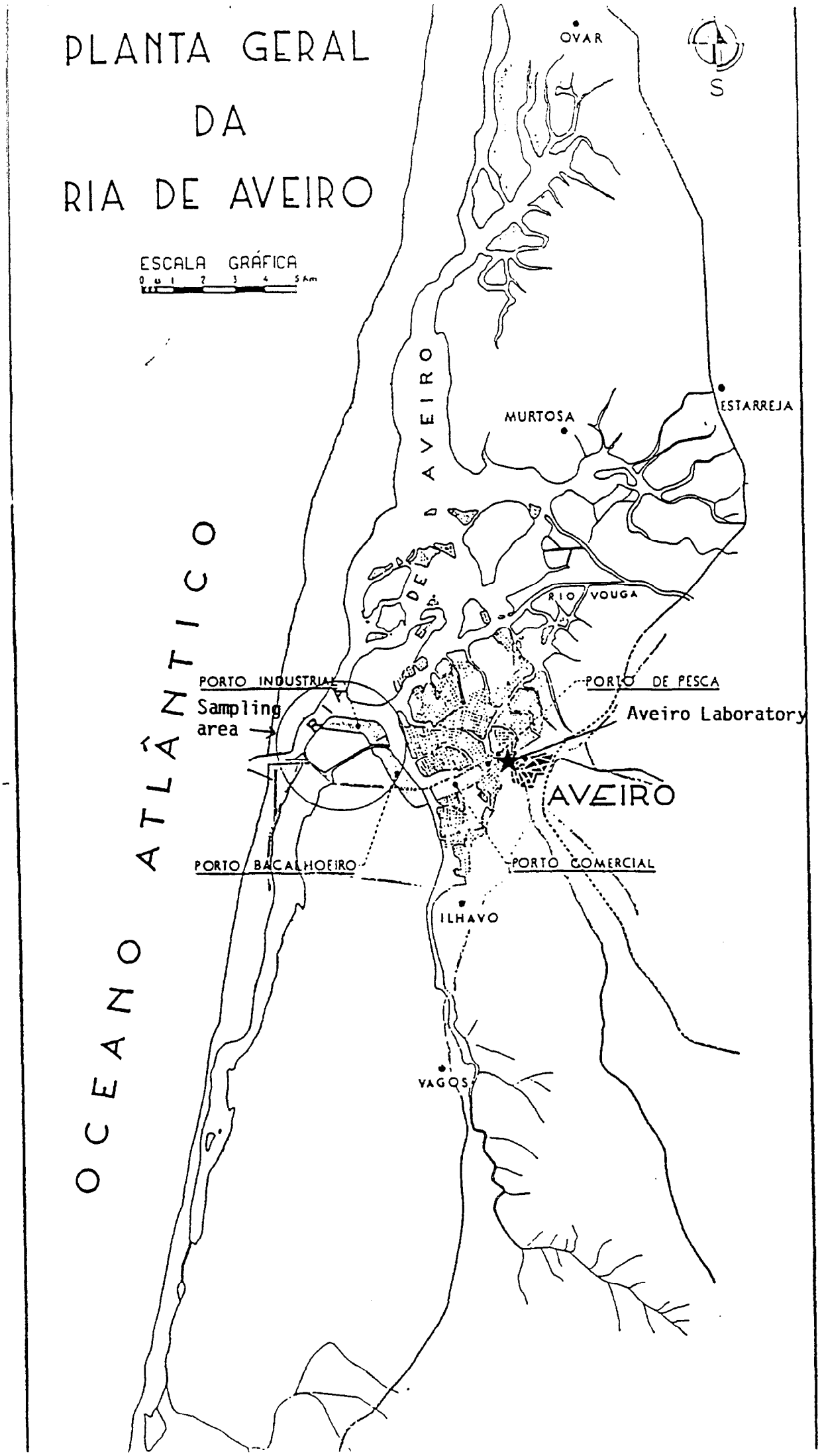
7. Recommendations.

7.1 The Workshop strongly recommends that a final report of the obtained results and a comparison and evaluation of the different methods which were used, are made. It is suggested that this report shall be in the ICES Co-operative Research Report series.

7.2 In order to effectively fulfil recommendation 7.1 the Workshop suggests that the participants of the workshop reconvene for two full days, just before the meeting of the WG on "The dynamics of algal blooms" in Helsinki, Finland in May 1995.

7.3 The Workshop finally recommends that more workshops on phytoplankton growth rates are carried out, where intercalibration of existing methods are tested and evaluated against new ones.

Annex 1.
Map 1


PLANTA GERAL
DA
RIA DE AVEIRO
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0 1 2 3 4 5 km
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RIO VOUGA
PORTO INDUSTRIAL
Sampling area
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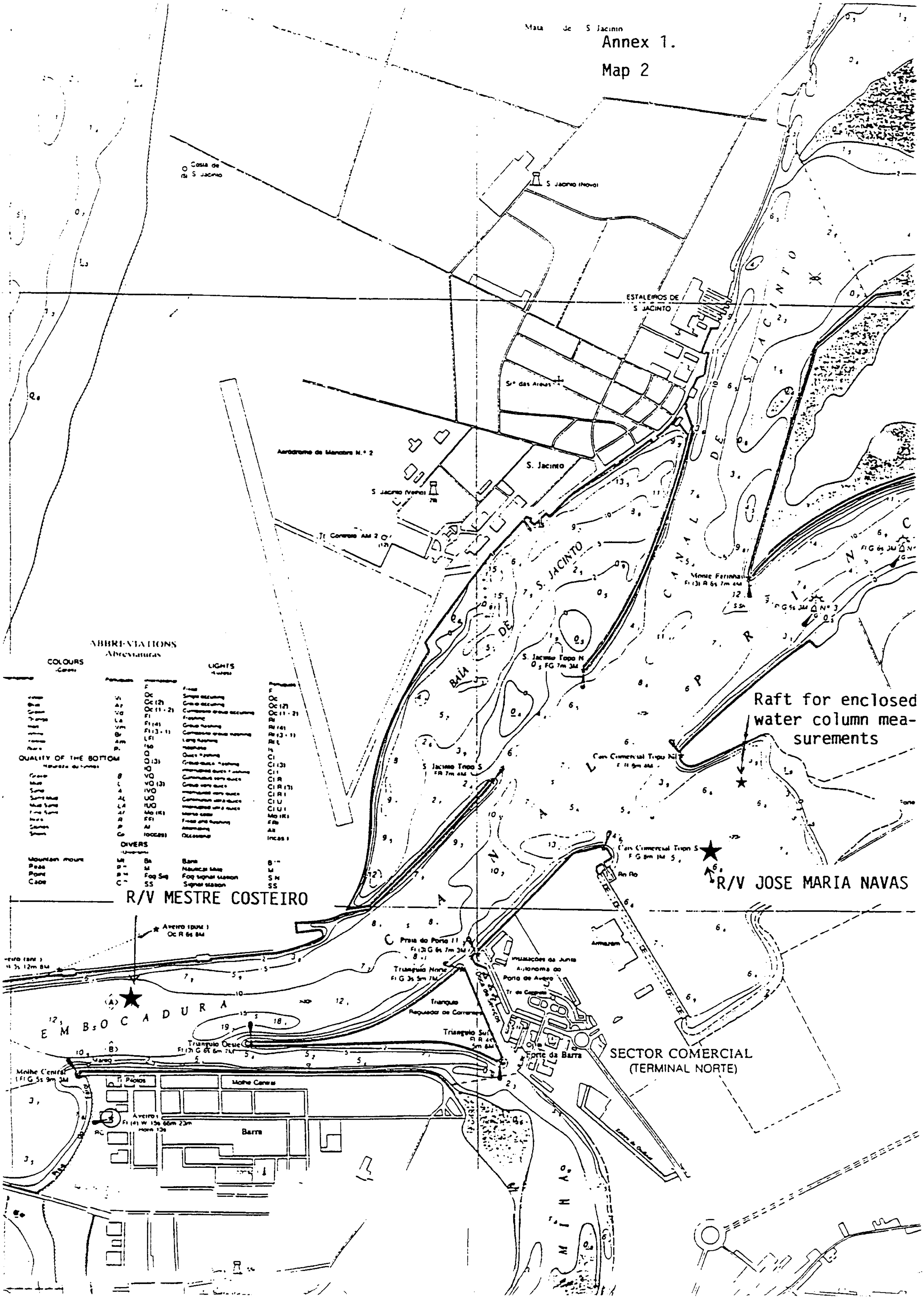
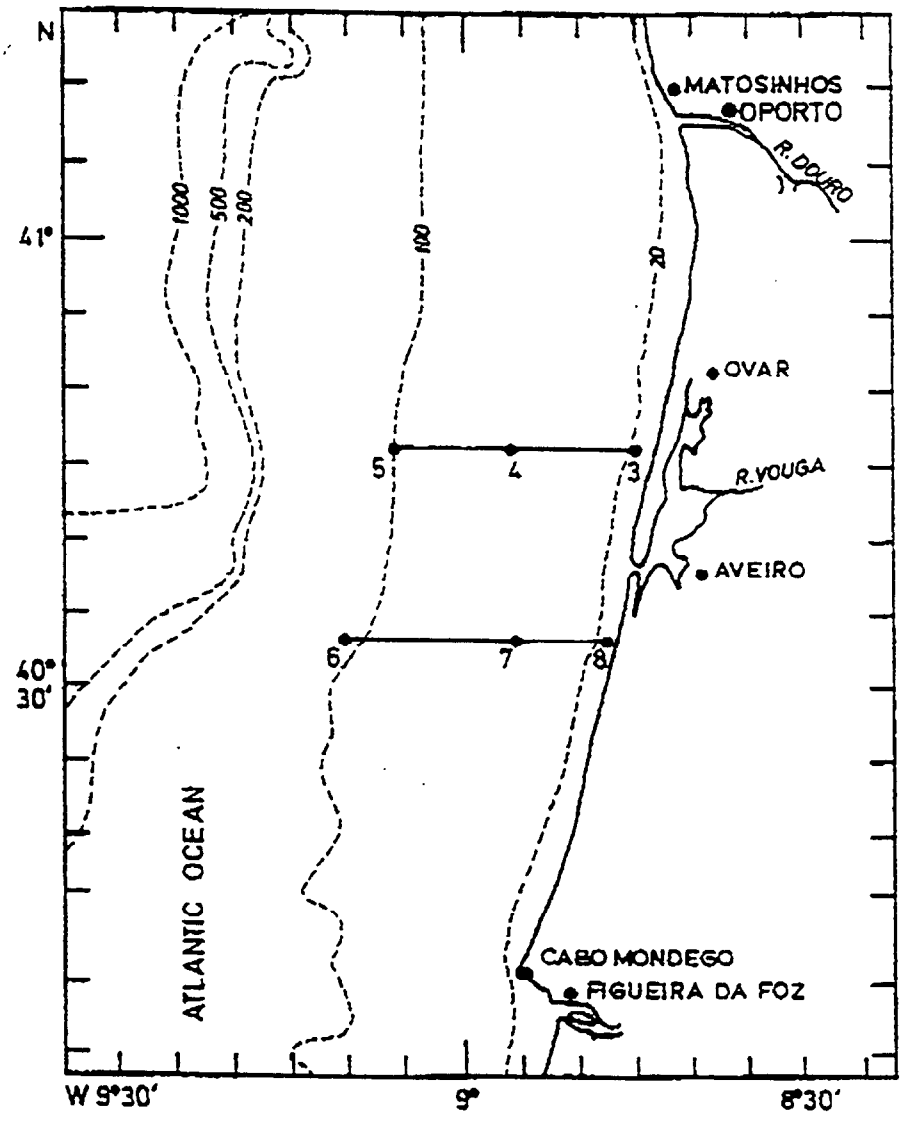
Aveiro Laboratory
AVEIRO
PORTO BACALHOEIRO
PORTO COMERCIAL
ILHAVO
VAGOS

Annex 1.

Map 2


Mata de S. Jacinto
S. Jacinto (Novo)
ESTALEIROS DE S. JACINTO
Srª das Areias
Aeródromo de Manobra N.º 2
S. Jacinto
S. Jacinto (Velho)
BAÍA DE S. JACINTO
CANAL DE S. JACINTO
CANAL PRINCIPAL
Monte Farinha
S. Jacinto Topo N
S. Jacinto Topo S
Cais Comercial Topo N
Cais Comercial Topo S
Raft for enclosed water column measurements
R/V JOSE MARIA NAVAS
R/V MESTRE COSTEIRO
ABBREVIATIONS
Abreviaturas
COLOURS
LIGHTS
QUALITY OF THE BOTTOM
DIVERS
EMBOCADURA
Praia do Porto
Triangulo Norte
Triangulo Oeste
Triangulo Sul
Molhe Central
Barra
Aveiro
Forte da Barra
Armazem
SECTOR COMERCIAL
(TERMINAL NORTE)

Annex 1.
Map 3

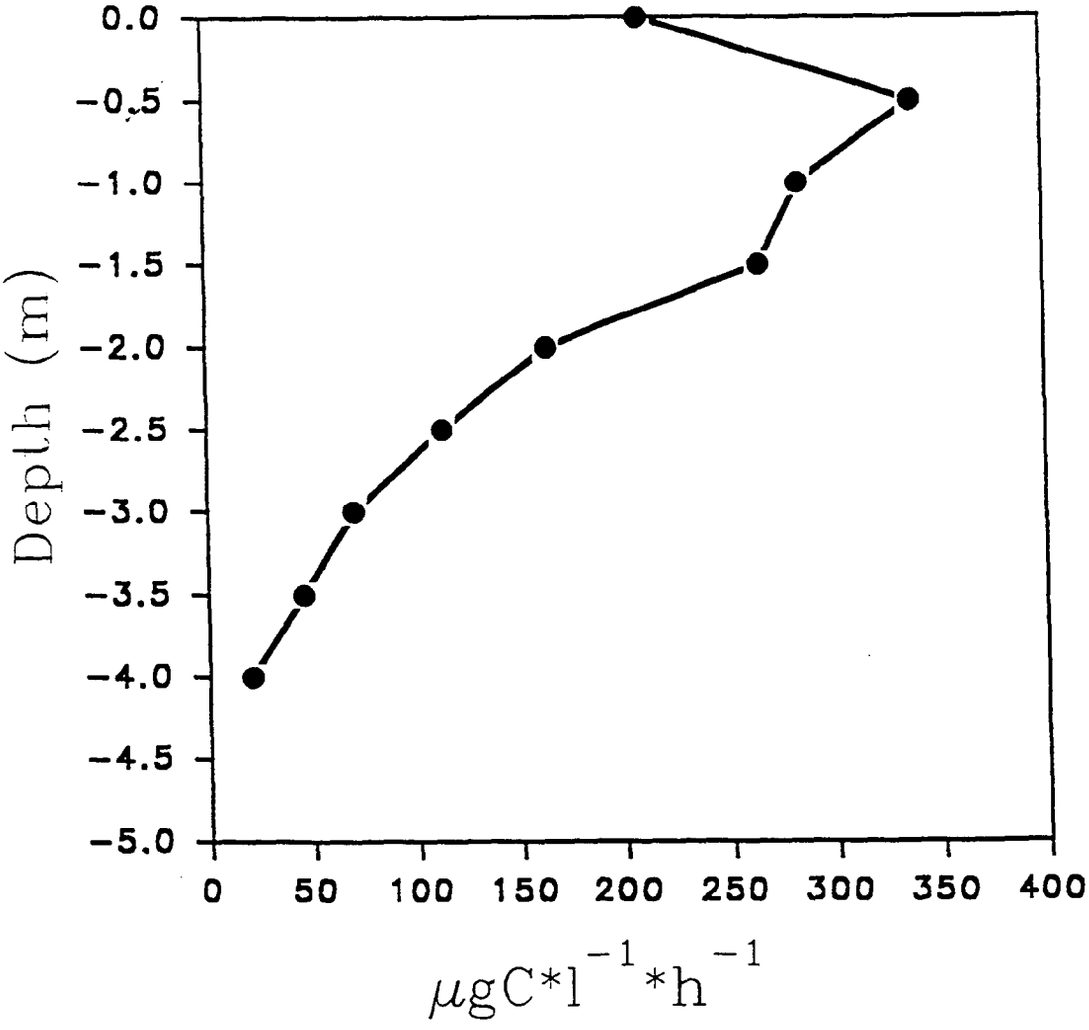


- Sampling stations on 21st July.

Primary productivity

"Einars raft"*, Ria de Aveiro

94.07.27



* the raft where the enclosed water column measurements were carried out.

Annex 1.

Tables 2-6

Table 2. Occurrence of Dinophysis spp. (cells/l) and chlorophyll (µg/l) in bag 1

Date	Time	Hours	D. acuminata	D. acuta	D. caudata	D. rotundata	D. tripos	Chloroph.	Phaeopig.
22 July	1800	0	1070	30	0	20	20	6.39	2.57
23 July	1200	18	1120	60	0	20	60	7.10	2.67
24 July	1000	40	1060	160	0	60	30	5.56	1.91
25 July	1300	63	800	30	10	30	0	3.98	1.34

Table 3. Occurrence of Dinophysis spp. (cells/l) and chlorophyll (µg/l) in bag 2

Date	Time	Hours	D. acuminata	D. acuta	D. caudata	D. rotundata	D. tripos	Chloroph.	Phaeopig.
22 July	1800	0	1020	40	0	30	20	6.70	2.32
23 July	1200	18	1080	50	20	30	0	7.26	2.60
24 July	1000	40	1060	100	10	50	0	5.34	1.74
25 July	1300	63	760	40	10	40	0	2.25	0.68
26 July	700	81	640	70	10	130	10	3.80	1.97
26 July	1300	87	400	40	0	70	0		
26 July	1900	93	280	10	0	50	0		
26 JUly	2400	98	210	0	0	40	0		
27 July	700	105	300	10	0	60	10	2.64	1.16
27 July	1400	112	280	10	0	90	0	2.62	0.69
28 July	1200	134	200	20	0	30	0	14.51	3.38
29 July	1400	160	90	10	0	90	0	14.16	3.06

Table 4. Occurrence of Dinophysis spp. (cells/l) and chlorophyll (µg/l) in bag 3

Date	Time	Hours	D. acuminata	D. acuta	D. caudata	D. rotundata	D. tripos	Chloroph.	Phaeopig.
24 July	1000	0	700	40	0	100	10	5.73	2.22
25 July	1300	27	840	20	0	60	0	7.31	2.08
26 July	700	45	610	60	0	160	20	4.58	1.93
26 July	1300	51	650	30	0	80	20		
26 July	1900	57	570	40	0	110	0		
26 July	2400	62	430	40	0	150	0		
27 July	700	69	520	100	0	140	0	4.09	3.48?
27 July	1400	76	540	40	0	150	20	5.64	1.58
28 July	1200	98	180	0	0	110	10	4.80	2.24
29 July	1400	124	40	0	0	150	0	2.60	0.83

Table 5. Occurrence of Dinophysis spp. (cells/l) and chlorophyll (µg/l) in bag 4

Date	Time	Hours	D. acuminata	D. acuta	D. caudata	D. rotundata	D. tripos	Chloroph.	Phaeopig.
24 July	1000	0	820	80	0	50	0	7.16	2.26
25 July	1300	27	1120	20	0	70	30	11.03	2.90
26 July	700	45	670	120	0	50	10	5.68	2.54
26 July	1300	51	860	30	20	50	10		
26 July	1900	57	400	0	0	50	10		
26 July	2400	62	320	40	0	70	0		
27 July	700	69	370	50	0	20	30	6.65	2.46
27 July	1400	76	180	10	0	110	0	6.08	0.34
28 July	1200	98	240	30	0	40	0	18.21	4.07
29 July	1400	124	130	30	0	70	0	18.60	3.36

Table 6. Occurrence of Dinophysis spp. (cells/l) and chlorophyll (µg/l) in bag 1-II

Date	Time	Hours	D. acuminata	D. acuta	D. caudata	D. rotundata	D. tripos	Chloroph.	Phaeopig.
25 July	1800	0	670	160	0	30	10		
26 July	700	13	690	90	0	20	40	15.32	3.64
26 July	1300	18	1180	90	10	10	0		
26 July	1900	24	950	20	0	30	0		
26 July	2400	29	-	-	-	-	-		
27 July	700	36	640	100	0	70	30	12.49	3.80
27 July	1400	43	870	80	0	0	0	5.29?	3.37
28 July	1200	65	870	70	0	40	0	22.33	6.00
29 July	1400	91	270	50	0	30	10	19.80	3.36

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