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REPORT OF THE WORKING GROUP ON PHYTOPLANKTON AND THE MANAGEMENT OF THEIR EFFECTS

Centre de Recherche en Ecologie Marine et Aquaculture
de L'Houmeau (CNRS-IFREMER), France.

27 - 29 April 1992

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[1]*General Secretary
ICES
Palaegade 2-4
DK-1261 Copenhagen K
DENMARK

CONTENTS

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1 OPENING OF THE MEETING

1.1 The meeting was opened at 09.30 hrs on 27 April by Dr K. Jones, who was Acting Chairman in the absence of Dr R. Gowen. Dr S. Maestrini welcomed the Working Group to the Centre de Recherche en Ecologie Marine et Aquaculture de L'Houmeau.

1.2 The agenda was discussed and adopted by the meeting. This is attached as Annex 1. A list of participants is given in Annex II.

1.3 Dr S. Bates was appointed as rapporteur.

2 GENERAL DISCUSSION OF TERMS OF REFERENCE

The Chairman informed the Working Group of Council Resolution C.Res.1991/2:1:8, which requested that:

> The Working Group on Phytoplankton and the Management and their Effects will meet in La Rochelle from 27-29 April 1992 in conjunction with the ICES Symposium on the Measurement of Phytoplankton Primary Production from the Molecular to the Global Scale, 21-24 April 1992, La Rochelle, France, to review methods of determining primary production in eutrophic waters, in respect of the needs of ACMP.

The Working Group was reminded of the necessity to continue to address terms of reference established for the Working Group in 1990 and 1991, which called for (a) the group to evaluate available different methods with a view to the development of a standard method for measuring ^{14}C uptake that could be adopted for monitoring purposes in relation to studies of the relationship between changes in nutrient inputs and concentrations and phytoplankton activity, and (b) to make recommendations concerning the desirability and structure of an ICES primary productivity database and the nature of data which might be stored in it.

The Chairman also pointed out that it was one responsibility of the Working Group to advise ACMP of any pertinent issues which this Group had the expertise to present, and of which ICES should be aware. Members of the Working Group were encouraged to identify and recommend to ACMP such issues for discussion at future meetings of the Working Group.

Following the practice agreed upon at previous meetings, the Working Group would continue to record the occurrence of unusual or harmful algal blooms which had occurred in member countries since the last Working Group meeting.

3 SUMMARY

3.1 The ICES International Symposium on the Measurement of Primary Production from the Molecular to the Global Scale highlighted a wide range of different approaches, all of which had some relevance to the requirements of ACMP and ICES. The use of active and natural fluorescence measurements perhaps offers the greatest potential for future routine monitoring because of the possibility of automated determination of vertical profiles of phytoplankton photosynthetic parameters *in situ*, and the incorporation of such instrumentation into moored buoys to collect time series of primary production data at remote sites. Flow cytometry techniques, although not suitable for routine field use, could provide information on the physiology of individual cells within natural populations enabling an understanding of species dynamics which would be relevant to the development of harmful algal blooms. No definitive conclusions were drawn regarding the ^{14}C method for measuring primary productivity.

3.2 The Working Group discussed details of a proposed ICES standard protocol for ^{14}C uptake. There was agreement that the incubator proposed by F. Colijn could be modified to meet the requirements of the Working Group and Colijn had been asked to suggest appropriate modifications. The Group also discussed and made suggestions on an experimental protocol. There was a strong feeling within the Working Group that further progress towards the development, and ultimately the acceptance, of an ICES standard method now depended upon having a number of the modified incubators built and their performance and the recommended proto-

col tested by different laboratories. These tests should include studies of internal consistency and inter-laboratory comparisons. A description of the protocol and the results of such performance tests should be published in a recognised scientific journal before the protocol and incubator are adopted by ICES.

3.3 The Working Group acknowledged the desirability of a primary production database for use in the identification of environmental change associated with (a) climate change, and (b) anthropogenic nutrient inputs to the marine environment, and also in identifying relationships among primary production, recruitment, and fisheries. A suitable database must be capable of incorporating historical data as well as new data generated both by ICES standard methodology and other methods. It was felt desirable that, where possible, raw data should be archived to allow re-working of data by database users, if required. The Working Group highlighted the need for immediate action to collate sets of historical, raw data which might soon become unavailable.

3.4 Harmful algal blooms which had occurred in Canada and United Kingdom (Scotland) were reported to the Working Group.

4 DETAILED DISCUSSION OF THE TERMS OF REFERENCE.

4.1 Review of Methods for Measuring Primary Productivity

The Working Group meeting was held immediately after the ICES International Symposium on the Measurement of Primary Production from the Molecular to the Global Scale in order to benefit from the expertise of researchers who presented the latest information on methods for measuring primary productivity. The following is a brief summary of some of the highlights of the Symposium as relate to the terms of reference of the Working Group. It was not the intention of this group to review individual papers or provide a detailed review of the field of primary production measurements. The former is likely to be covered by the editors of the Symposium volume and the latter by Geider and Osborne (1992) and Falkowski and Woodhead (in press) amongst many others.

One strong theme which emerged from the Symposium was that there is a need to measure phytoplankton primary productivity over a range of temporal and spatial scales in order to fully describe and understand ecosystem function. This is because ecological processes act over a multitude of time and space scales associated with both the physiology of individual organisms and the dynamics of entire populations. We must first understand how ecosystems function before we can comprehend the effects of anthropogenic inputs and the impacts of climate change. This requirement therefore emphasises the need for a variety of measurement techniques for primary production which are appropriate to those spatial and temporal scales. It is consequently not realistic to expect a single method to be identified as the ideal tool. Indeed, for the study of complex ecological situations it is frequently desirable, if not essential, for several complementary approaches to be made. However, it is interesting to note, in this respect, that conventional primary production techniques involving ^{14}C uptake will continue to provide complementary, "ground truth" data required to calibrate many of the new methods.

Many of the new approaches presented at the Symposium are still in the developmental stage and will not be ready for routine use for several years to come. This makes them unsuitable at present for use as monitoring tools by ICES member countries. They are, nevertheless, presented here in order that managers can become more informed, as some of the methods will undoubtedly become more widely used and accepted in the future. Of particular importance is that some of the methods discussed will ultimately provide the ability to include in monitoring programmes direct, and even unattended, measurements of primary productivity in the water column, in much the same way as it is now possible to profile *in situ* chlorophyll fluorescence as an estimate of phytoplankton biomass. Some other methods discussed, whilst not being directly applicable to field monitoring programmes, have the potential to investigate phytoplankton community structure and physiology at the cellular level. This will enable a clearer understanding of phytoplankton dynamics and ecosystem function to be achieved.

The papers presented at the Symposium reflect five general approaches to productivity measurements. In what follows, we (a) briefly describe the rationale behind each approach; (b) indicate pertinent references, presented to the Symposium either as invited papers (which will be published at a later date in an ICES Marine Science Symposia series volume) or as posters (the abstracts of which appear in the Symposium programme, included in this report as Annex

III); (c) outline the general advantages and disadvantages of each approach; and (d) make recommendations as to the applicability of each approach to the problems relating to the determination of primary production and associated issues which are the concern of ACMP and ICES. The first four approaches (i.e., remote sensing, mesoscale, fluorescence, and flow cytometry/molecular biology) all have the common advantage, over ^{14}C incubation methods, of avoiding the artefacts caused by containing and incubating samples in bottles.

4.1.1 Remote sensing

With this approach, the reflectance of selected wavelengths of light from the sea surface is measured using satellite or aircraft mounted instrumentation (Sathyendranath, 1992; Hoepffner *et al.*, 1992). This is used to determine the amount of light absorbed by phytoplankton, which, in turn, is proportional to their biomass. Algorithms convert the amount of absorbed light into the concentration of phytoplankton pigments. The estimation of primary production from such ocean colour measurements requires additional empirical algorithms that incorporate parameters of vertical water column structure and photosynthesis (e.g., α and P_{max}). The latter are obtained by ground truth measurements of phytoplankton photosynthesis using traditional techniques.

Advantages:

- gives a synoptic view of a large area of the ocean, rather than having to extrapolate from a point-source measurement to values representative of larger spatial scales;
- gives a synoptic view over time, permitting repeated measurements to be made over the same wide area, from which changes in phytoplankton biomass and therefore productivity can be computed;
- can monitor the development of certain atypical phytoplankton blooms;
- can be employed during poor weather conditions that would otherwise prohibit measurements from being made at sea from a ship.

Disadvantages:

- measurements are confined to the upper 20% of the euphotic zone;
- the platform for deployment (e.g., aircraft or satellites) is expensive and requires high technology;
- a satellite for measuring ocean colour is not available until August 1992;
- measurements are affected by or not possible during cloud cover, haze, or at night;
- algorithms for converting ocean colour to phytoplankton biomass are still under development;
- the method requires "ground truth" calibration using methods which themselves have inadequacies.

Working Group Recommendation:

ICES member countries should continue and expand their collaboration with the EEC and North American agencies that are already developing remote sensing programmes (e.g., Commission of the European Communities Institute for Remote Sensing Applications, NASA).

4.1.2 Mesoscale ("free-water") approaches

These techniques measure changes in oxygen, carbon dioxide, or nutrient concentrations in identifiable water masses over specified time periods using moored or shipboard instrumentation (Emerson and Quay, 1992; Minas, 1992; Robertson and Watson, 1992; Weichart, 1992). Time series data characterising the distribution of these substances can be used to infer primary productivity in the water column because phytoplankton significantly influence their surface and vertical distribution. The approach has been effectively applied to open ocean water masses (e.g., central gyres where the water mass is most stable) and coastal waters over diurnal and seasonal scales.

Advantages:

- provides a measure of changes in biomass over large temporal and spatial scales;

- measures net community production, thus avoiding the problem of not being able to measure easily loss factors in other methods, and providing information about the activity of the whole ecosystem;

- gives a measure directly related to water quality (e.g., anoxia, nutrient concentration);

- can take advantage of automated methods (e.g., oxygen and nutrient measurements carried out on moored buoys), thus enabling measurements during unfavourable weather conditions when ships cannot be used;

- provides high temporal resolution allowing process-oriented studies.

Disadvantages:

- measurements are complex to carry out, requiring sophisticated, expensive instrumentation;

- a multidisciplinary approach is required to be able to interpret effectively the data (e.g., knowledge of physical oceanographic processes, such as advection of water masses, transfer of material across the pycnocline, gas exchange properties across the air/sea interface, is required).

Working Group Recommendations:

ICES should play an active role in encouraging the development of *in situ* instrumentation for chemical and biological measurements and encourage its deployment for the collection of long-term, continuous time series which will allow changes in eutrophic status to be evaluated.

4.1.3 Fluorescence techniques

Fluorescence arising from chlorophyll-*a* in photosystem II can be employed to assess the rate of photosynthesis (Doerffer, 1992; Falkowski and Kolber, 1992; Boyd *et al.*, 1992; Chekalyuk and Gorbunov, 1992a,b; Chekalyuk *et al.*, 1992; Schmuck *et al.*, 1992). Active fluorescence techniques (pulse amplitude modulated (PAM) and pump-and-probe) measure the response to an experimentally imposed light source and can be employed to generate a complete photosynthesis-irradiance (P-I) response curve. In theory, the pump-and-probe technique provides a measure of gross photosynthesis which does not need to be empirically calibrated, although in practice calibration may be necessary. Passive (natural) fluorescence techniques measure the response to solar stimulation. Instruments to measure passive fluorescence and PAM fluorescence are currently commercially available, and an instrument for measuring pump-and-probe fluorescence is expected to be commercially available in the near future. The theory required to interpret active and passive chlorophyll fluorescence has been developed, and the techniques are currently being compared with more conventional gas exchange (^{14}C or O_2) approaches.

Advantages:

- does not require sample collection and incubation (i.e., allows *in situ* determination of the rate of photosynthesis without potential bottle artefacts);

- high spatial and temporal resolution allow instruments to be employed as survey tools;

- passive fluorescence techniques have low power requirements and can be deployed unattended for extended periods to complement "free-water" approaches;

- passive fluorescence can be measured from aircraft and satellites for remote sensing applications;

- active fluorescence can be measured from low flying aircraft for remote sensing applications;

- active fluorescence techniques provide information on the "physiological state" of phytoplankton which cannot be readily obtained by other approaches;

- active fluorescence can be employed in conjunction with flow cytometry to examine the photosynthetic characteristics of individual species within a natural phytoplankton assemblage.

Disadvantages:

- provides a measure of gross photosynthesis uncorrected for losses such as phytoplankton respiration and dissolved organic carbon excretion;
- passive fluorescence techniques require empirical calibration against gas exchange (^{14}C or O_2) methods;
- in the pump-and-probe technique, the rate of photosynthesis is normalized to the number of photosynthetic reaction centres rather than to chlorophyll-*a* concentration; either a ratio of *reaction centre:chlorophyll* must be assumed or a means of counting reaction centres needs to be developed.

Working Group Recommendations:

Because active and natural fluorescence methods have great potential for future use as monitoring tools for assessing primary production, ICES should be aware of developments in this area of methodology. Since instruments for measuring natural fluorescence are now commercially available, and instruments for active fluorescence measurement may soon become so, ICES should encourage the use and evaluation of these methods as standard monitoring tools for primary production.

4.1.4 Flow cytometry and molecular biology

Flow cytometry allows the rapid determination of optical properties (scattering and fluorescence) of individual particles to describe complex natural phytoplankton communities (Li, 1992; Furuya and Li, 1992; Vaulot *et al.*, 1992). When employed in conjunction with molecular biological techniques (e.g., fluorescent probes conjugated to specifically designed antibodies or oligonucleotides), the technique can be used to determine community structure and physiological condition (La Roche *et al.*, 1992; Raven, 1992; Vaulot *et al.*, 1992). With regard to primary production research, antibodies against key photosynthetic proteins and the fluorescence of chlorophyll-*a* can be used to estimate cell-specific photosynthesis rates. Flow cytometry on its own, or when coupled to fluorescent probes, greatly facilitates investigations which could otherwise only be undertaken by using prohibitively time consuming techniques (such as micro-autoradiographic investigations of single cell photosynthesis rates and micro-spectrophotometric determinations of cell pigment content). The combination of flow cytometry with molecular biology should allow the mechanistic investigation of physiological and ecological processes in complex natural phytoplankton assemblages. Investigations of physiological responses, that are currently undertaken only under restrictive, artificial laboratory conditions using cultures, may become a common feature of experimental phytoplankton ecophysiology using natural assemblages under natural conditions. Although only indirectly applicable to determining the rate of photosynthesis, this approach should prove powerful in addressing questions of fundamental importance to species composition and succession.

Advantages:

- allows rapid assessment of cell-to-cell variability within a species;
- allows quantitative characterization of community structure;
- allows quantitative interspecific comparisons of photosynthesis rate and photosynthetic physiology.

Disadvantages:

- molecular probes are still under development;
- is not a survey tool.

Working Group Recommendation:

ICES member countries should encourage the application of flow cytometry and molecular biology in mechanistic studies of phytoplankton ecophysiology.

4.1.5 Bottle incubation techniques

Measuring the gas exchange (CO_2, O_2) of samples enclosed in bottles has been the most widely employed technique for assessing primary production. When samples are attached to a line and incubated at the depth from which they were collected, the measurements are referred to as "*in situ* incubations" (Dandonneau, 1992). When samples are incubated in a deck-top incubator under natural light and at a temperature and irradiance chosen to mimic that at the depth from which they were sampled, the

measurements are referred to as "simulated *in situ* incubations" (Lohrenz, 1992). Finally, when incubated under artificial light at a range of irradiance levels, the measurements are referred to as "photosynthesis-irradiance (P-I) incubations", and a P-I curve is generated from the results (Tilzer, 1992). Although all three techniques are subject to potential biases referred to as "bottle effects", the *in situ* measurement is often taken as the "standard" against which other techniques are compared.

A number of different approaches have been employed to determine the gas exchange of phytoplankton in bottle experiments. These include measurements of net gas exchange using O_2 and total CO_2 (TCO_2), and tracer gas exchange employing the radioactive isotope ^{14}C, or the stable isotopes ^{18}O and ^{13}C. TCO_2 and O_2 exchange can be employed to determine net photosynthesis and dark respiration. $^{18}O_2$ exchange can be employed to determine gross photosynthesis, net photosynthesis, dark respiration and light respiration. ^{14}C assimilation into particulate and dissolved organic matter can be expected to yield a value between net and gross photosynthesis depending on the duration of the incubation. The uncertainty in what the ^{14}C technique measures is often of secondary significance, and the high precision of the technique allows the investigation of many important phenomena, such as the photosynthesis rate of single cells, the photosynthesis rate of particular taxa (through pigment labelling) (Gieskes, 1992) the rate of production of macromolecular classes (lipid, protein, carbohydrate), and the rapid determination of the P-I response characteristics.

Various potential sources of error associated with incubation techniques were discussed in several papers presented at the Symposium. These include the subtraction of the dark bottle value (Banse, 1992); nutrient recycling within bottles (Harrison, 1992); release of organic carbon (Jackson, 1992; Sakshaug, 1992); significance of respiration (Langdon, 1992; Williams, 1992); inter-user and inter-method comparison problems (Richardson, 1992); duration of the incubation (Gostan *et al.*, 1992; Legendre *et al.*, 1992); and fluctuating light (Hartig and Pahl-Wostle, 1992).

In applying any technique there is a trade-off between operational constraints and the quantity and quality of the desired information. This trade-off has been explored in some depth for gas-exchange techniques. In general, the price paid for higher quality information is an increase in the time required to complete an experiment.

In discussing the advantages and disadvantages of various gas-exchange techniques it is necessary to keep this trade-off in mind. In particular, the ^{14}C technique has become the most widely employed technique, in part because of the apparent ease of experimental manipulation.

Advantages:

- gas-exchange techniques are capable of very high precision and accuracy;
- potential artefacts have been subject to considerable investigation and, in theory, can be adequately controlled;
- experimental manipulation is possible (although it is often desirable to keep such manipulations to a minimum);
- gas-exchange techniques provide the basic measurements used to verify the efficacy of other approaches;
- observations can be made rapidly and techniques tailored to particular scientific requirements.

Disadvantages:

- biases (referred to as "bottle effects") may arise as a result of sampling (although when appropriate precautions are taken such effects should be negligible);
- the ^{14}C technique is subject to considerable methodological uncertainty and potential (and, to some extent, still unresolved) calibration errors;
- O_2 and TCO_2 exchange techniques typically require long (12-24 hours), often inconvenient, incubations;
- O_2 and TCO_2 techniques are more time consuming than the ^{14}C technique;
- the simulated *in situ* and P-I techniques may be subject to systematic errors associated with the inability to match adequately the irradiance and spectral quality, a problem not encountered with the *in situ* technique.

Working Group Recommendations:

ICES should encourage researchers employing incubation techniques to identify, evaluate and document sources of error within their methods.

4.2 Establishment of a Standard Protocol for the Measurement of Primary Production Using the ^{14}C Method

The Working Group chose not to reiterate many of the same arguments that had already been presented at the five previous Working Group meetings that considered this term of reference (C.M.1991/Poll:3; C.M.1990/Poll:7; C.M. 1989/L:20; C.M.1988/L:14; C.M.1987/L:29). The rationale for wanting to standardize a protocol and an incubator have already been stated. Members of the Working Group are now agreed that any standard protocol should deliver data from which it is possible to construct a P-I curve. This decision is based upon the theoretical grounds discussed and presented at the last Working Group meeting (C.M.1991/Poll:3) and also on the desirability of having photosynthetic parameters in a primary production database which might be used in conjunction with remote sensing measurements of ocean colour to generate primary production estimates for large areas (see Section 3.1.1 above).

The Working Group acknowledged that many modern methods for determining ^{14}C uptake already exist (e.g., "photosynthetron" (Lewis and Smith, 1983) and "linear-light gradient" incubators) and are in current use for research purposes. Several of these have been rigorously evaluated and are published in the scientific literature. The Working Group felt that some of these methods might even be adaptable for routine monitoring use. Although the incubator design used is frequently very different among the methods used by different research groups, there is no evidence in the scientific literature to suggest that the performance of any one type of incubation method, in terms of internal precision of estimates of ^{14}C uptake, is better than any other when carried out by proficient personnel who are aware of the potential sources of error in making these measurements.

In light of the above, and considering the proposal for standardizing methodology for use within the ICES area, it should be recognised that individual researchers are likely to select a method that is compatible with their own specific research requirements, dependent on the availability within their laboratories of the required equipment and based upon their own personal preferences concerning the ease of use of each of the techniques. Any method suggested as an ICES standard would probably have to demonstrate considerable advantages in terms of internal precision, accuracy or ease of use to gain general acceptance.

Nevertheless, there is compelling evidence (Anon., 1990; Richardson, 1991) which identifies a lack consistency among different laboratories measuring primary productivity. This is an unacceptable situation if ICES wishes to establish a primary production database that would include data from a wide range of sources.

In considering the goal of placing data into a common ICES database, this Working Group identified two possible routes by which the variability identified by the ICES intercalibration workshop might be reduced. The first would require further detailed investigation of the possible sources of error of all methods in current use and identification of all procedural steps required to reduce them. The second would recommend a standard protocol that would be rigidly defined to try to minimize the introduction of operator error and interlaboratory variability. The internal consistency of such a protocol would then have to be quantified by appropriate experiments.

The Working Group suggested that the first approach can only be carried out satisfactorily by individual researchers on their own methods. In the light of the results of the intercalibration experiment, workers should be advised to review critically all steps in their ^{14}C procedures. ICES should encourage the publication of method evaluations and the reporting of confidence limits on measurements for methods in current use. These might then be used to establish acceptable quality levels on data which might be submitted for inclusion in any future data base.

4.2.1 Discussion of an incubator for the standard protocol

The Working Group acknowledged the work of F. Colijn *et al.* (1992) in designing an inexpensive and practical incubator for the measurement of ^{14}C uptake in order to monitor primary production in coastal areas in ICES member countries. Following discussions at five previous Working Group meetings, the present Working Group recommended that the incubator be accepted for trial use and evaluation in coastal

waters. However, the Working Group suggested a number of modifications to improve the effectiveness of the incubator, taking into account the above requirements. They are:

i) In order to generate a P-I curve, measurements may be needed at more than the 11 possible light levels that the current design allows. The incubator's capacity for sample flasks could be doubled by fixing flasks on both sides of the revolving wheel.

ii) The Working Group is not entirely satisfied with the light environment in the incubator. The maximum light intensity measurable in the incubator (360 μE m^{-2} s^{-1}) has been questioned as to its suitability to saturate photosynthesis under all conditions. This might be increased most easily by placing another light bank on the other side of the incubator, or by placing reflective material behind the lamps. Alternatively, a different light source might be required (e.g., tungsten-halogen).

iii) It was recognised that the irradiance field across the light bank might not be uniform. Whilst rotation of the incubation flasks would serve to equalize the light incident on each flask, a well-defined protocol for irradiance measurement within the incubator, and within each incubation flask, is required to ensure that the mean irradiance level received by each flask is accurately and consistently determined by all users.

These are problems that will be most easily tackled by the designers of the incubator. Dr F. Colijn has indicated that modification of the incubator to meet these requirements should be possible and has agreed to report back to the Working Group on modifications which will lead to their solution.

4.2.2 Outline of the experimental protocol

The Working Group discussed details of the experimental protocol and made the following suggestions for inclusion in a standard method:

(i) Sampling should take place during the day, preferably around noon. However, it is recognised that constraints on ship-time may affect this. Water should be sampled from mid-way within the mixed layer or at the discretion of the user when faced with complicated physical oceanographic circumstances, as determined by CTD profiling.

(ii) Sample collection bottles should have any parts made of toxic, rubber materials removed and replaced with non-toxic, silicone parts. All containers used to hold water samples prior to filling the incubation flasks should conform to this standard and should be thoroughly cleaned to the same standard as the incubation bottles.

(iii) All transfers of water samples should take place in subdued light to avoid light-shock to the contained phytoplankton. Special care should be taken to avoid mechanical damage to phytoplankton cells. Incubation flasks should not be filled directly from water sampling bottles. The water sample should be gently mixed in another clean container before gently dispensing (by siphon) to incubation flasks.

(iv) An appropriate choice of incubator irradiance levels will have to be made by the operator for individual areas and circumstances, in order to ensure that a sufficient number of points falls within the regions of limited and saturated photosynthesis to allow reliable estimation of P-I parameters.

(v) The ^{14}C incubation should start as soon as possible, preferably within 0.5 h after sample collection.

(vi) The amount of ^{14}C activity added will depend on the biomass level present, but 1 μCi per 50 ml aliquot should be sufficient in eutrophic coastal waters. At least one dark bottle and one time-zero control sample should be run and reported, but not subtracted from light bottle values. The isotope should be added to each incubation bottle using a precise, calibrated micro-pipette. It is crucial that the stock isotope should be free of contaminants. It is recommended that the isotope, with acceptable quality with regard to contaminants, be purchased already at the desired dilution for dispensing, to avoid the possibility of contamination during any dilution step in the laboratory. The ^{14}C activity

added to each incubation flask should be determined by first adding an aliquot of the isotope to phenylethylamine in the scintillation vial, in order to trap the $^{14}CO_2$, prior to counting.

(vii) Samples should be incubated for 2 h. The incubation temperature should be within 0.5°C of the temperature at which the sample was collected. After 2 h, the contents of the bottles should be filtered immediately through 25 mm GF/F filters on a vacuum manifold fitted with enough filter units to filter all incubated samples simultaneously. The vacuum used should not exceed 0.3 Kp cm^{-2}.

(viii) After filtration, unassimilated inorganic ^{14}C should be removed from the filters by adding 0.1 ml of 0.1 M HCl to the filter in the scintillation vial and leaving for 24 h in a well-ventilated environment.

(ix) The radioactivity of the filters should be measured using liquid scintillation counting. The particular scintillation cocktail chosen will depend on the user, but the appropriateness of cocktail type to the samples counted should be investigated by each researcher, as factors such as the pH of the sample might affect the efficiency of the cocktail system. Following addition of the scintillation cocktail, vials should be left in the dark for at least 3 h to reduce any chemiluminescence.

Sufficient counts should be accumulated such that the counting error is not more than 5% for each sample. Counting efficiency should be determined either by the external-standards channels-ratio method or internal standardisation and corrections applied to obtain the DPM (disintegrations per minute) value for each sample. The possibility of colour quenching by algal pigments should also be taken into account and corrections applied, particularly in eutrophic waters where the phytoplankton biomass might be high.

(x) The chlorophyll-*a* and TCO_2 (weight of total carbonate present in the sea water) concentrations in the sea water should be determined at the time of the ^{14}C incubations.

Chlorophyll-*a* concentration should be determined by the fluorometric method of Strickland and Parsons (1972). The sample (10-100 ml) is filtered through a 25 mm GF/F filter at a vacuum not exceeding 0.3 Kp cm^{-2}.

TCO_2 is determined by measuring the total carbonate alkalinity, as described by Strickland and Parsons (1972). Alternatively, TCO_2 can be measured using modern instrumentation (e.g., infra-red gas analysis).

(xi) The following formula is used to calculate the rate of carbon uptake, P (mg C m^{-3} h^{-1}):

$$P = \frac{DPM_{LB} \times 1.05 \times TCO_2}{DPM_{added} \times t} \qquad (1)$$

where DPM_{LB} is the DPM in the light bottle; the isotope (^{12}C:^{14}C) discrimination factor is 1.05; TCO_2 is the weight of total carbonate carbon present in the sea water (mg m^{-3}); and t is the incubation time in hours.

The value of P can be normalized to the concentration of chlorophyll-*a* (mg m^{-3}) present in the same sample of water, in which case the units of photosynthesis for P^B become mg C mg $Chla^{-1}$ m^{-3} h^{-1}.

The relevant parameters of the P-I curve (P^B_{max} and α) are computed using an appropriate curve-fitting programme with equations (2) and (3) (Platt *et al.*, 1980):

$$P^B = P^B_s(1-e^{-a})e^{-b} \qquad (2)$$

where $a = \alpha I/P^B_s$, $b = \beta I/P^B_s$, I is the irradiance level, and P^B_s is the maximum rate of photosynthesis, normalized to chlorophyll-*a*, if there were no photoinhibition; the parameter α is the initial slope of the P-I curve and β is a photoinhibition parameter.

The value of P^B_{max} (the maximum rate of photosynthesis, normalized to chlorophyll-*a*, at light saturation) is given by

equation (3) which corrects for any photoinhibition:

$$P^{B}_{max}=P^{B}_{s}\left(\frac{\alpha}{\alpha+\beta}\right)\times\left(\frac{\beta}{\alpha+\beta}\right)^{\frac{\beta}{\alpha}} \qquad (3)$$

(xii) In addition to chlorophyll-*a* and TCO_2 determinations, which are essential for the calculation of biomass-normalized ^{14}C uptake, the following accompanying measurements and observations should be made and recorded for storage in a primary production data base:

- Station position, date, time and depth of water collection, start and end times of incubation;
- Sea water temperature at depth of sample collection, incubation temperature;
- Daily irradiance (hourly means) at the station;
- Secchi disk reading or vertical downwelling attenuation coefficient;
- Irradiance level in each incubation flask;
- *DPM* and *P* (calculated as above) for light incubations at each irradiance level and in dark and time-zero bottles. It is important to record raw data for DPM estimates so that recalculations can be made if necessary;
- Estimates of α and P_{max} with corresponding standard error estimates for each parameter.

4.2.3. Recommendations

The Working Group recommends that the next step towards acceptance of a standard protocol is to have incubators (with appropriate modifications) built for use and testing, and that the protocol be evaluated by individual laboratories so that internal consistency and interlaboratory comparisons can be made. We recommend that, before being adopted as a standard protocol, the method and the evaluation of its sources of error should be subjected to peer review and published in a recognised journal.

4.3 Primary Production Database

The Working Group identified three potential uses for a primary production database:

(i) Identification of long-term trends associated with global climate change;

(ii) Identification of the effects of anthropogenic nutrient inputs on eutrophication in coastal waters; and

(iii) Establishment of relationships among primary production, recruitment and fisheries.

The evidence presented by Richardson and others (Anon., 1990; Richardson, 1991) highlights the difficulties associated with making meaningful interpretations of long-term changes, for the above purposes, from data collected by different workers using different methods. Consequently, the Working Group recognised the desirability of establishing a standard protocol for collecting primary productivity data to be incorporated into an ICES database. However, it was also recognised that there is likely to be much useful information contained in historical primary production data sets and from new investigations which do not use the ICES standard method, even if there was uncertainty about the quality or compatibility of those data. The views of this Working Group were therefore in accordance with those expressed at the Working Group meeting held in Oban in 1990 (C.M.1990/Poll:7), which expressed the desirability of inclusion in an ICES primary production data base of historical primary productivity data, and new data sets collected by non-ICES-standard protocols, in addition to any which might be collected using a new ICES standard method. In order to aid intercomparison of such data, the Working Group recommended that any database should contain raw data (e.g., DPM) and all associated measurements (see Section 3.2.2, above) related to productivity estimates, in addition to calculated parameters (e.g., P^{B}_{max}, α). This would then allow some recalculation of stored data, by users of the database, if it was thought desirable. On a cautionary note, since it is now 40 years since the first ^{14}C productivity measurements were made, it is essential that effort be focused immediately on the collation of suitable raw data sets before they become unavailable.

The requirement to collate data in a variety of different forms, and from different sources,

would demand a flexible data base structure for data entry and retrieval. The Working Group was aware that primary production databases exist in Europe and the USA (e.g., HELCOM, NODC), although no information about their detailed structure was available at the meeting. The Working Group recommended that existing primary production databases be investigated by the Working Group on Phytoplankton and the Management of Their Effects, with regard to the nature and complexity of data contained within them and their general accessibility to users. If a suitable existing database is identified, then this should be considered for adoption as the ICES format after adequate discussion with potential users of the data base, providers of data, and data managers.

When this has been accomplished, a framework should be developed by ICES data managers to ensure compatibility of the ICES primary production database with databases maintained outside the ICES area.

5 PRESENTATION OF NATIONAL REPORTS ON HARMFUL EVENTS

Because the attendance at the Working Group meeting mainly reflected interests in primary production measurement rather than those of toxic bloom monitoring, only Canada and the United Kingdom (Scotland) submitted national reports to the meeting. Reports from France, Poland, Sweden and the USA were received after the meeting. These reports are presented in Annex III. The main highlights of the reports are summarised below:

5.1 Summaries of New Events Since 1991

Canada

The pattern of occurrence and causative species of phytoplankton blooms occurring in Canada during 1991, and species involved, showed no unusual features. Shellfish harvesting was closed due to PSP at various locations in the Bay of Fundy as usual. No harvesting areas were closed due to domoic acid contamination in the Bay of Fundy. Low, but detectable, levels of DSP toxins were recorded in cultured mussels from Mahone Bay, Nova Scotia, during May and June, but no toxins were found in the plankton. A late-September to November bloom of *Dinophysis norvegica* was later documented at Mahone Bay, but toxins were undetectable in the mussels or the plankton. In contrast to previous years, there was no bloom of *Nitzschia pungens f. multiseries* in Cardigan Bay, Prince Edward Island. However, low levels of domoic acid caused temporary closure of shellfish harvesting in Malpeque, Cascumpec and New London Bays in northern Prince Edward Island. No toxins were reported in the Quebec region. The west coast of Canada (British Columbia) experienced minor blooms of *Heterosigma akashiwo* and *Chaetoceros convolutus*, but no fish kills were reported. No domoic acid was detected in British Columbian waters, despite its presence in the coastal waters of Washington, Oregon and California to the south.

France

Elevation of DSP toxicity above the safety level in shellfish resulted in a ban in shellfish marketing in northern Brittany (Douarnenez Bay) between June and October and in southern Brittany (Vilaine Bay) and the Loire estuary between mid-June and mid-July. The high toxicity levels were associated with the occurrence of *Dinophysis* spp. High DSP levels associated with *Dinophysis* spp were also detected in the western Mediterranean Sea from July to August on the Camargue coast and on the Rousillon coast between mid-August and early-October.

The occurrence of 'green water' associated with blooms of *Gymnodinium* spp was accompanied by fish and shellfish mortalities in southern Brittany and on the Orlonne coast in August and September. Anoxia is suspected as the cause of death.

Poland

Gonyaulax catenata caused brown water in the Gulf of Gdansk at the end of April. Blooms of *Nodularia spumigena* and *Aphaniomenon flos-aquae* were observed in the southern Baltic Sea in early August.

Sweden

Blooms of *Nodularia spumigena* and *Aphaniomenon flos-aquae* were observed in the Baltic Sea (between 57-59°N, 16-22°E). Some samples were found to contain hepatotoxins but no serious effects were reported.

United Kingdom (Scotland)

PSP outbreaks were detected around the coast from Berwick, on the east coast, to Ardnamur-

chan on the west. PSP was also detected in the Orkney Islands and the Isle of Skye. Both bivalve molluscs and crustacea were affected by the outbreaks. Regular monitoring for PSP was carried out for the first time in the Orkney Islands in 1991. Toxicity was found to persist through into the winter months in crustacea.

There was one reported fish kill of Atlantic salmon caused by *Heterosigma akashiwo*.

United States

The neurotoxin, domoic acid, appeared for the first time along the Pacific coast of the United States. It was first manifested in the mortality of brown pelicans and Brandt's cormorants in Monterey Bay, California in September 1991. The source of the toxicity was anchovies, which had been feeding on the marine diatom *Pseudonitzschia australis*; few, if any, cells of *Nitzschia pungens f. multiseries*, the domoic acid producer known from eastern Canada, were found. Subsequent analysis of anchovies demonstrated that domoic acid was present not only in the gut (typically to 200 ppm; maximum 2300 ppm), but had also been incorporated into the flesh of the fish. Domoic acid was found in net tow samples (up to 26 pg/cell) containing *P. australis* collected off the coast of California. Culture experiments confirmed that *P. australis* produces domoic acid (up to 36 pg/cell). This was the first documented case of marine food web effects by this toxin.

In October, during routine screening tests, domoic acid was found in Pacific razor clams (*Siliqua patula*) along the coasts of Washington and Oregon, resulting in closures of shellfish harvesting. Subsequently traces of domoic acid were found in Dungeness crabs (*Cancer magister*) from Washington and Oregon, leading to the closure of the crab season in those areas. The domoic acid was distributed throughout the body of razor clams, with the highest values occurring in the foot and mantle. In contrast, the toxin was restricted to the viscera of crab, except on cooking in boiling water, when it may be transferred to the meat. Oysters, bay clams and mussels were not contaminated with domoic acid. Analyses of canned samples indicate that domoic acid could have been present earlier in the year and as early as 1985. The source of the domoic acid in Oregon, Washington and Alaska has not yet been established. An unknown number of people suffered from Amnesic Shellfish Poisoning (ASP) as a result of this event, but at least two presented significant neurological symptoms.

6 ANY OTHER BUSINESS

6.1 Cooperative Research Report

The Chairman advised the Working Group that ICES Cooperative Research Report No. 181 entitled "Effects of Harmful Algal Blooms on Mariculture and Marine Fisheries", produced by the former Working Group on Harmful Effects of Algal Blooms on Mariculture and Marine Fisheries, has now been published. However, it was noted that some members of that Working Group had not received a copy of the report. This Working Group urges ICES to ensure that all members of the former and present Working Groups receive a copy of this report in the near future.

6.2 The Use of Algal Bioassays as an Environmental Monitoring Tool

In response to the Chairman's request for the Working Group members to suggest topics relevant to ICES interests and expertise within the Working Group, Dr Maestrini suggested that, in considering approaches to identifying trends in the increase in coastal eutrophication and identification of its causes, insufficient attention had been given to the use of bioassay techniques as an environmental monitoring tool in the marine environment, even though such techniques had been widely applied in freshwater environments.

The attention of the Working Group was drawn to two comprehensive articles on the subject (Maestrini *et al.*, 1984a; Maestrini *et al.*, 1984b). Dr Maestrini submitted a short outline of some possible bioassay approaches (included as Annex V). Because of a shortage of time, it was not possible for the Working Group to consider this topic in detail. However, the Working Group felt that this subject merited further discussion and therefore recommended that the Working Group on Phytoplankton and the Management of Their Effects meet to discuss the range of algal bioassay techniques available and their applicability to environmental monitoring in coastal waters.

7 RECOMMENDATIONS

7.1 ICES member countries should continue and expand their collaboration with the EEC and North American agencies that are already developing remote sensing programmes (e.g., the Commission of the European Communities Institute for Remote Sensing Applications; NASA).

7.2 ICES should play an active role in encouraging the development of *in situ* instrumentation for chemical and biological measurements and encourage its deployment for the collection oflong-term, continuous time-series which will allow changes in eutrophic status to be evaluated.

7.3 ICES should be aware of developments in instrumentation to measure active and natural fluorescence and should strongly encourage the use and evaluation of these methods as standard monitoring tools for primary production.

7.4 ICES should encourage the application of flow cytometry and molecular biology in mechanistic studies of phytoplankton ecophysiology.

7.5 ICES should encourage researchers employing ^{14}C incubation techniques to identify, evaluate and document sources of error within their methods.

7.6 The next step towards acceptance of a standard protocol should be to have incubators (with appropriate modifications) built for use and testing; the ^{14}C-uptake protocol should then be evaluated by individual laboratories, in different geographical areas, so that internal consistency and interlaboratory comparisons can be made.

7.7 Before being adopted as a standard ICES protocol for the measurement of ^{14}C uptake, the method and the evaluation of its sources of error should be subjected to peer review and published in a recognised scientific journal.

7.8 Existing primary production databases should be investigated by the Working Group on Phytoplankton and the Management of Their Effects with regard to the nature and complexity of data contained within them and their general accessibility to users.

7.9 Following the recommendations of the 1991 Working Group meeting (C.M.1991/Poll:3), and in accordance with the wishes of the 1991 meeting of ACMP, the Working Group on Phytoplankton and the Management of Their Effects recommends that it should meet at ICES Headquarters, Copenhagen, in early 1993 to undertake the following tasks:

a) Examine and analyze the value of temporal or geographical trends in primary productivity identified by Working Group members during the intersessional period;

b) Review the programmes and plans of ICES member countries in order to assess their adequacy with respect to understanding the dynamics of algal blooms;

c) Report on the state of development and routine applicability of methods for the detection and quantification of phycotoxins that affect man or marine organisms and, if appropriate, recommend particular methods on the basis of their accuracy, sensitivity, ease of use and, as appropriate, make specific recommendations for demonstration workshops;

d) Discuss the range of algal bioassay techniques available and their applicability to environmental monitoring in coastal waters;

e) Discuss, evaluate and report on case histories of new management techniques to carry stocks through phytoplankton-related harmful events;

f) Evaluate existing national and intergovernmental databases used to archive primary production data and report on their suitability for ICES use.

8 ACTION LIST

8.1 All national representatives to continue to submit National Reports on Harmful Algal Bloom Events, including null reports, as these may in the long term provide a data series suitable for trend analysis.

8.2 All national representatives to seek information about the composition and structure of national databases maintained within their own countries to archive primary production data and to bring details of these to the next Working Group meeting for assessment of their suitability for

ICES requirements based on suggested criteria given in Section 4.3, above.

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The meeting was closed at 12.30 h on Wednesday, 29 April.

ANNEX I

WORKING GROUP ON PHYTOPLANKTON AND THE MANAGEMENT OF THEIR EFFECTS

27 - 29 April 1992.

Centre de Recherche en Ecologie Marine et Aquaculture
de L'Houmeau (CNRS-IFREMER), France

AGENDA

1. Opening of Meeting (09.30 h Monday April 27th).
2. Adoption of the Agenda.
3. Election of Rapporteur.
4. General discussion of Working Group tasks.
5. Detailed discussion of Working Group tasks.
6. Presentation and discussion of national reports on incidence and effects of harmful algal blooms in 1991.
7. Any other business.
8. Action list for Working Group members.
9. Recommendations to ICES.
10. Adoption of Working Group Report.
11. Close of Meeting.

ANNEX II

List of Participants

BATES Stephen S. **(Rapporteur)**
Dept. of Fisheries and Oceans ; Gulf Fisheries Centre Moncton, New Brunswick, Canada E1C 9B6
Tel : (1) 506-851-3982
Fax : (1) 506-851-2079

DEMERS Serge
Institut Maurice Lamontagne
CP 1000, Mont Joli Québec G5H 3Z4, Canada
Tel : (1) 418-775-05-21
Fax : (1) 418-775-65-42

EDLER Lars
Swedish Meteorological and Hydrological Institute (SMHI)
Doktorsgatan 9D
S-262 52 Ängelholm, Sweden
Tel : (46) 431-80854
Fax : (46) 431-83167

FINENKO Zosim
Institute of Biology of the Southern Seas
Sevastopol St.
Nachimova 2, Ukraina
Tel : 52-45-27
Telex : 187124 IBSS SU
Fax : (7) 871-140-23-43

GEIDER Richard J.
University of Delaware
College of Marine Studies
Lewes, DE 19958-1298, U.S.A.
Tel : (1) 302-645-4015
Fax : (1) 302-645-4007

GUDMUNDSSON Kristinn
Marine Research Institute
P.O. Box 1390
121 Reykjavik, Iceland
Tel : (354) 1-20240
Fax : (354) 1-623790

JONES Kenneth J. **(Chairman)**
Dunstaffnage Marine Laboratory
P.O. Box 3, Oban, Argyll,
Scotland, PA34 4AD, UK
Tel : (44) 0631-62244
Fax : (44) 0631-65518

LEGRAND Catherine
Centre de Recherche en Ecologie Marine et Aquaculture de L'Houmeau (CNRS-IFREMER)
B.P. 5 ; 17137 L'Houmeau, France
Tel : (33) 46-50-94-40
Fax : (33) 46-50-93-79

MacDONALD Elspeth
SOAFD Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB9 8DB, Scotland, UK
Tel : (44) 224-295425
Fax : (44) 224-295511

MAESTRINI Serge Y.
Centre de Recherche en Ecologie Marine et Aquaculture de L'Houmeau (CNRS-IFREMER)
B.P. 5 ; 17137 L'Houmeau, France
Tel : (33) 46-50-81-03 ; 46-50-94-40
Fax : (33) 46-50-93-79

REY Francisco
Institute of Marine Research
P.O. Box 1870 Nordnes
N-5024 Bergen, Norway
Tel : (47) 5-238500
Fax : (47) 5-238531/238584

SCHULZ Sigurd
Baltic Sea Research Institute (BSRJ)
D-O-2530 Warnemünde, Germany
Tel : (37) 81-58263
Fax : (37) 81-58336

VARELA Manuel
Instituto Español de Oceanografia
Aptdo n° 130
15080 La Coruña, Spain
Tel : (34) 81-205362
Fax : (34) 81-229077

ANNEX III

Programme of the ICES International Symposium on the Measurement of Primary Production from the Molecular to the Global Scale

Paper No. 1

Banse, Karl
School of Oceanography, University of Washington, Seattle, WA 98195, USA

On the dark bottle in the ^{14}C-method for measuring marine phytoplankton production.

In the radiocarbon method for determining planktonic photosynthesis, the original purpose of the dark bottle (DB) is to correct the light bottle (LB) values for abiotic and biotic uptake of radiocarbon unrelated to photsynthesis. A perusal of the literature suggests that the processes that regularly lead to significant uptake in the DB occur also in the LB. During the past one or two decades, however, a variety of protocols have been introduced for the DB, some even omitting the DB and foregoing any corrections to the LB values. It should be cautioned that zero-time uptake corrections may not account fully for abiotic uptake, and published data will be used to illustrate that the DB should continue to serve as a blank or quality control. Reasons for artifactually high DB rates will be mentioned. Carbon uptake in the DB may or may not be proportional to initial chlorophyll or photosynthesis in the LB, and renewed recommendation of routine subtraction of DB values from LB rates will depend on understanding the cause(s).

Paper No. 2

Dandonneau, Yves
LODYC, Université Pierre et Marie Curie, Tour 14, 2ème étage, 4 Place Jussieu, 75252 Paris Cedex 05, FRANCE

The measurement of in situ profiles of primary production.

In situ measurements of marine primary production using the ^{14}C raised much interest in the fifties, and efforts were undertaken by many nations in order to map the primary production in the world ocean. Early enthusiasm was quickly tempered when severe errors were found in the results, which corresponded to theoretical or handling problems. many of these problems have now been identified, and practical solutions are currently used which minimize these errors. The counterpart is increasing complexity and cost of the measurements, for which sophisticated equipment (i.e. "clean technique") is now recommended.
Mapping the primary production in the ocean is a task for satellite-borne sea color sensors. There remains however a need for many *in situ* measurements of primary production to locally validate the algorithms which permit to derive the primary production from sea color data, and this need will hardly be met using the difficult-to-operate clean technique.
A simple device is presented here, which uses the energy of the weight at the bottom of the *in situ* incubation drifting line to enclose a sea water sample inside a transparent incubation chamber at a pre-determined depth, and to inject the ^{14}C. The ^{14}C labelled samples then remain at depth for incubation. Operating this device requires very few ship time, and no winch, so that it might be used during any oceanographic cruise. In addition, high quality results are expected, since the stresses which occur in the traditional *in situ* technique between sampling and return to the incubation depths are suppressed.

Paper No. 3

Doerffer, Roland
GKSS Forschungszentrum, D-2054 Geesthacht, GERMANY

Estimation of primary production by observation of solar-stimulated fluorescence.

Sunlight induced fluorescence of chlorophyll-a augments the backscattered radiance of water around 685 nm. This signal has been used to derive the concentration of chlorophyll within the upper layer of sea or fresh water from airborne spectrometer data. In most cases, a linear relationship between the concentration and the fluorescence line height could be found. However, the conversion of solar energy into fluorescence is variable, it depends mainly on the physiological state of the phytoplankton population. It is assumed theat the fluorescence efficiency is inversely related to quantum efficiency. This opens the possibility to estimate remotely not only the chlorophyll concentration but also the primary productivity. The approach is to combine the quantum efficiency (derived from the sunlight induced fluorescence), the chlorophyll concentration (derived from its light absorption in the blue and red part of the spectrum) and the PAR (derived from the spectral light attenuation at all wavelengths of the measured radiance spectrum). The technique to estimate these parameters from radiance spectra is inverse modelling of the radiative transfer. Present airborne radiometers and future spaceborne imaging spectrometers enable us to use this technique. The paper will demonstrate the procedure to derive the various parameters and present first results of radiative transfer calculations and of measured spectra. The assumptions which have to be made and thus the limitations of the method will be discussed.

Paper No. 4

Emerson, Steven and Quay, Paul
School of Oceanography, WB-10, Seattle, WA 98195, USA

Estimation of primary production by observed changes in the mesoscale oxygen field.

Net oxygen production resulting from photosynthesis and respiration in the euphotic zone provides an attractive tracer for estimating the export of biologically mediated nutrients from the surface ocean. Because nonsteady state physical mechanisms, like radiative heating and air injection by breaking waves, also produce oxygen supersaturation, it is rarely possible to accurately quantify the biologically induced oxygen signal without a time course and corresponding measurements of "inert" atmospheric gases. Case studies in the subtropical Atlantic and subarctic Pacific Oceans indicate that net oxygen production can be determined to an accuracy of ±40-50% by modeling these data. The main uncertainties are the rate of transfer between the mixed layer and upper pycnocline and the rate of gas exchange between the surface occean and atmosphere. The net oxygen flux in the subtropical Atlantic Ocean is greater than that predicted from sediment trap studies or ^{14}C primary production incubations, while different approaches agree within a factor of two in the subarctic Pacific. The disparity in the comparisons is likely attributable to greater episodisity of photosynthesis in the subtropical ocean. While the oxygen mass balance is a tracer for net biological production, the stable isotope ratio of O_2 in surface waters is influenced by the relative rates of photosynthesis and respiration because of differences in the $\partial^{18}O$ of atmospheric oxygen and water and isotope fractionation during respiration. Incomplete knowledge of the fractionation factor is presently the

main uncertainty in applying this tracer. Preliminary results of recent measurements of N_2, Ar, O_2 and $\partial^{18}O$-O_2 at the U.S. JGOFS Pacific time series station illustrate the potential of these tracers for constraining the rate of photosynthesis and respiration in the euphotic zone.

Paper No. 5

Falkowski, Paul and Kolber, Zbigniew
Oceanic and Atmospheric Sciences Division, Brookhaven National Laboratory, Upton, NY 11973, USA

Estimating phytoplankton photosynthesis by active fluorometry.

Photosynthesis can be described by target theory. The photosynthetic apparatus has a photon capture cross section, which varies with wavelength. At low photon flux densities, photosynthesis is a linear function of irradiance (I), the number of reaction centers (n), their photon capture (i.e. absorption) cross section (σ), and a quantum yield (ϕ). As photosynthesis becomes light saturated, the maximum photosynthetic rate is given as the product of the number of reaction centers (n) and their maximum electron tranport rate (τ). Using active fluorometry it is possible to measure σ and ϕ directly. τ can be readily calculated from knowledge of I_k and σ. We built a pump and probe fluorometer, which measures the fluorescence yield of a weak probe flash preceding and succeeding a pump flash from a CTD. Vertical profiles of variable fluorescence reveal I_k and ϕ non-destructively and in real time. A benchtop pump and probe fluorometer is used to measure σ, Using biophysically robust equations derived by comparing variable fluorescence with oxygen evolution measured on a bare platinum rate elctrode, we calculate instantaneous photosynthesis as it occurs *in situ*. Correlations with short-term simulated *in situ* radiocarbon measurements are extremely high. The slope between photosynthesis derived from fluorescence and that measured by radiocarbon is the photosynthetic quotient. The intercept is respiration. Profiles of photosynthesis and sections showing the variability in its composite parameters provide insight into the coupling of physical mixing to primary production. (This research was supported by the National Aeronautic and Space Administration and the US Dept. of Energy).

Paper No. 6

Geider, Richard, J.
College of Marine Studies, University of Delaware, Lewes, Delaware 19958-1298, USA

Quantitative phytoplankton physiology: implications for primary production and phytoplankton growth.

Oceanographers commonly normalize photosynthesis rates to chlorophyll *a* concentration because chlorophyll *a* is the only readily measured index of phytoplankton abundance. In addition, recent approaches to estimating primary production from remote sensing of chlorophyll require that typical chlorophyll-specific photosynthesis rates be established for the regions under investigation. Normalization of photosynthesis rates to chlorophyll concentration begs the question "How good an indicator of phytoplankton biomass and/or photosynthesis rate is chlorophyll *a* concentration?" To address this question, a review of quantitative information on phytoplankton growth and photosynthesis obtained from studies employing clonal phytoplankton cultures has been undertaken. Where data permit, both chlorophyll-specific and carbon-specific photosynthesis rates have been obtained. The starting point for

this analysis is the photosynthesis-light response curve obtained within the context of an energy budget for phytoplankton growth. The components of an energy budget are defined and an attempt is made to assess the interspecific and phenotypic variability in the parameters. Variability in the chlorophyll-specific light absorption coefficient (a^{chl}), the maximum photon efficiency of photosynthesis (φ_m), and the chlorophyll-specific light-saturated photosynthesis rate (P_m^{chl}) contribute to variations in photosynthesis rate. In addition, variability in the chlorophyll *a*:carbon ratio, and the respiration and excretion rates contribute to uncoupling growth from gross photosynthesis. Finally, the relationship between the traditional approach to the photosynthesis-irradiance (PI) curve based on the light-saturated photosynthesis rate (P_m^{chl}) and the light-limited initial slope (α^{chl}), and the biophysical approach based on the photosynthetic electron transfer (τ) and the photosynthetic unit size (chlorophyll:PSU), is examined.

Paper No. 7

Gieskes, Winfried, W.C.
University of Groningen, Department of Marine Biology, Box 14, 9750 AA Haren, The NETHERLANDS

^{14}C labelling of algal pigments to estimate the contribution of different taxa to primary production in natural seawater samples.

Each taxonomic group in the phytoplankton has its own set of optimal environmental conditions, so growth of one species may differ widely from that of another in mixed populations. Several attempts have been made in the past to measure taxon-specific growth rates in field samples in order to evaluate the conditions leading to success of individual taxa, estimate their role in the food web, and explain succession. We have adopted the method of Redalje and Laws, who studied the pattern of ^{14}C labelling of chlorophyll *a* (the pigment common to all microalgae), by following ^{14}C incorporation into carotenoids that are typical for taxonomic species groups. The results obtained so far indicate that both in eutrophic and in oligotrophic regions different species co-occurring in one sample may grow at a very different rate. However, the method that we employ is still open to challenges from several directions. More research must be done in order to either tramsform our approach into a technique that is undeniably accurate and reliable for the assessment of growth rates of algal taxa - or to show when and under what circumstances it cannot be used. In any case, the method we present can be applied directly for studies of the turnover and eventual fate of the various pigments synthesized by algae, be they photosynthetically active or photoprotective. Moreover, ^{14}C labelling of both chlorophylls and carotenoids could become an important tool in studies of carbon cycling. Indeed, a considerable part of phytoplankton carbon biomass is associated with pigments.

Paper No. 8

Harrison, W. Glen
Biological Oceanography Division, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, CANADA

Nutrient recycling in production experiments.

Longstanding debate has continued on how representative *in vitro* methods for measuring primary productivity are of natural productivity rates in the field. Among the principal concerns have been "containment effects" from bottle incubations which may disrupt natural loss (i.e. sinking and grazing) as well as supply (i.e. nutrient regeneration) processes. This paper will deal specifically with the latter; to what extent do bottle incubations disturb natural nutrient resupply processes and what effect does this have on primary productivity?
Early speculation was that *in vitro* incubation techniques either excluded or accelerated the mortality of the principal nutrient recyclers, leading to nutrient exhaustion in productivity experiments. Subsequent studies employing isotope tracer techniques have shown, on the contrary, that nutrient recycling is substantial in incubation bottles and may be enhanced over *in situ* rates. Highlights of this work will be discussed with emphasis on both the methodologies and experimental findings.
An understanding of the dynamics of nutrient recycling in production experiments would be incomplete without some knowledge of the responsible organisms. Discussion will also centre on the latest experimental evidence for the contribution of bacteria, micro- and meso-zooplankton to nutrient recycling *in vitro*. The paper will conclude with a more general discussion of the impacts of the above on primary productivity measurements.

Paper No. 9

Jackson, G.A.
Department of Oceanography, Texas A&M University, College Station, TX 77843, USA

The importance of the DOC pool for primary production estimates.

Release of dissolved organic matter by phytoplankton has important consequences for the planktonic ecosystem which can be compared with rates of dissolved organic carbon (DOC) release measured in field incubations. Furthermore, DOC release rates must be consistent with other incubation measurements, such as those for bacterial growth and nitrate and ammonium uptake. In this paper, comparisons are made between these different sets of measurements to test for their consistency.

Paper No. 10

LaRoche, Julie[1], Geider, Richard[2] and Falkowski, Paul[1]
[1] Oceanic and Atmospheric Sciences Division, Brookhaven National Laboratory, Upton, NY 11973, USA
[2] College of Marine Studies, University of Delaware, Lewes, DE 19958-1298, USA

Molecular biology in studies of oceanic primary production.

Remote sensing and the use of moored *in situ* instrumentation has greatly improved our ability to measure phytoplankton chlorophyll and photosynthesis on global scales with high temporal resolution. However, the interpretation of these measurements and their significance with respect to the biogeochemical cycling of carbon relies on their relationship with physiological and biochemical processes in phytoplankton. For example, the use of satellite images of surface chlorophyll to estimate primary production is often based on the functional relationship between photosynthesis and irradiance. A variety of environmental factors such as light, temperature, nutrient availability affect the photosynthesis/irradiance (P *vs* I) relationship in

phytoplankton. While biophysical techniques allow for a description of the variability in the P *vs* I relationship, molecular biology provides the means to determine how specific environmental factors limit and control primary production in the ocean. We present three examples showing how molecular biology can be used to provide basic insight on the factors controlling primary productivity at three different levels of complexity: 1. Studies of light intensity regulation in unicellular alga show how molecular biology can help understand the processing of environmental cues leading to the regulation of photosynthetic gene expression. 2. Probing of the photosynthetic apparatus using molecular techniques can be used to test existing mechanistic models derived from the interpretation of physiological and biophysical measurements. 3. Exploratory work on the expression of specific proteins during nutrient-limited growth of phytoplankton may lead to the identification and production of molecular probes for field studies. (This research is supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH00016).

Paper No. 11

Langdon, Christopher
Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964, USA.

The significance of respiration in production measurements based on both carbon and oxygen.

Thirty-four years ago Steemann Nielsen and Hansen stated that phytoplankton respiration averaged 10% (5-24%) of the light-saturated photosynthetic rate (P_m) on an hourly basis. Today everyone would agree that the method they employed, extrapolation of the short-term ^{14}C productivity-irradiance curve to ordinate, underestimates the true respiration rate. Chemical and isotopic oxygen techniques now offer more precise respiration measurements. The taxonomic breakdown of relative respiration rate on an hourly basis ($R:P_m$) is 0.08 ± 0.04 (0.02-0.17) for diatoms, chlorophytes, chrysophytes and cyanobacteria, 0.13 ± 0.04 (0.08-0.16) for prymnesiophytes, and 0.21 ± 0.09 (0.04-0.32) for dinoflagellates. The proportion of production that is respiration is actually 2- to 4-fold greater than suggested by the $R:P_m$ because P_m is only achieved in the upper of the water column for a fraction of the day. The ratio of respiration to production at a particular depth on a daily basis ($R_d:P_d$) is given by the expression:

$$\frac{24R}{P_m \int_0^L \tanh[I_m \sin^3(\pi t/L)/I_k]dt}$$

To illustrate assume L = 12 h, I_k = 100 μmols photons m^{-2} s^{-1}, and $R:P_m$=0.11, then $R_d:P_d$ can be shown to vary from 0.27 on a clear day (I_m = 2000 μmols photons m^{-2} s^{-1}) to 0.34 on an overcast day I_m=400). Respiratory losses are even larger when the entire euphotic zone is considered. These calculations assume that respiration is constant over a 24 hr period, a fact we recognize as a simplification. ^{18}O techniques have been used to show that there is a general trend among the phytoplankton for the ratio of light respiration to dark to be greater than 1. Detailed time courses made with O_2 sensors have established that respiration rates decline during the night, often exponentially. The emerging theoretical framework is that respiration rate is limited by substrate supply. Respiration rates are high during the day because substrate levels are high. Respiration rate declines at night in direct proportion to the decline of available substrate. If production estimates are based on 24 h O_2 exchange, these effects are taken into acount. However, if ^{14}C is used to measure production, especially short-term experiments, net production may be significantly overestimated.

Paper No. 12

Le Bouteiller, Aubert
ORSTOM, B.P. A5, Nouméa, New Caledonia

Comparison of in-bottle measurements using ^{15}N and ^{14}C.

Since their introduction in oceanography, the ^{14}C and ^{15}N methods used to estimate the primary production of phytoplankton in terms of carbon and nitrogen, have received a number of improvements reducing many of their original imperfections. When great precautions are taken for sampling, tracer addition and simulation of natural conditions in incubations, especially in oligotrophic waters, these methods make it possible to share total production between new and regenerated production. However, a double ambiguity remains, in direct consequence of the necessary duration of experiments. First, because of respiration and excretion of phytoplankton during incubation, it is very delicate to determine to what extent these methods, and especially the ^{14}C one, measure gross primary production, net primary production or a rate intermediate between these two. Secondly, the micro-community enclosed in the incubation bottle often contains at least as many heterotrophs as autotrophs, all interacting during the experiment. Grazing by zooplankton, dissolved organic carbon and nitrogen uptake by bacteria, remineralization and isotope dilution, all these processes occur more or less simultaneously. Hence, inflence of experimental bias has to be taken into account in order to provide as satisfactory a value of the actual carbon and nitrogen flux as possible. Finally, it appears essential, for a better understanding of the different mechanisms concerned, to multiply the measurements suitable to follow the evolution of phytoplankton and heterotrophs within bottles during incubation. The flow cytometer is probably one of the best means to do this.

Paper No. 13

Li, William
Biological Oceanography Division, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, CANADA

Estimation of primary production by flow cytometry.

Flow cytometry (FCM) is a method for the rapid quantitative analysis of the fluorescence and size-related characteristics of single cells. It is well-suited for examining the phytoplankton component in marine microbial assemblages because of the distinctive red fluorescence emitted by chlorophyll. The use of FCM in phytoplankton ecology is relatively recent and studies to date have focused on the spatial and temporal distributions of various cell groups. The unique advantage of FCM lies in its ability to analyse large numbers of individual cells. Given this, FCM offers the potential to recover the bulk production of phytoplankton from an analysis of the constituent flora. To date, rates of primary production have been estimated for oceanic cyanobacteria, prochlorophytes and other groups easily detected by FCM (i.e. numerically abundant groups). However, the broader goal of estimating overall primary production by FCM has not been achieved. To this end, efforts are being made to use FCM to study phytoplankton population growth, cell division, viability and photosynthetic activity. These studies are discussed here under the general headings of cell counting methods, cell staining methods, chlorophyll fluorescence methods and cell sorting methods.

Paper No. 14

Lohrenz, Steven E.
Center for Marine Science, University of Southern Mississippi, Stennis Space Center, MS 39529, USA

Estimation of primary production by the simulated *in situ* method.

The simulation of *in situ* conditions for primary production incubations may seem a clear objective. However, the inherent assumptions of the method, that subsurface *in situ* conditions are fully understood and can be duplicated in a surface incubator, are inevitably invalid. It is not surprising then that there have been various reports of differences between *in situ* (IS) and simulated *in situ* (SIS) incubation measurements. My objective in this paper is to critically evaluate the SIS incubation method and discuss its utility. I consider evidence for potential factors contributing to differences between IS and SIS incubations. These factors may be grouped as 1) irradiance effects, 2) temperature effects, 3) sample handling effects including, for example, sample collection methods and incubation duration, and 4) methods of data analysis by which a final production number is calculated. I argue that proper control of these factors can minimize, although not necessarily eliminate, differences between IS and SIS incubation measurements. The question remains whether residual differences are significant compared to errors, of either IS or SIS methods, in estimating the true value of primary production. The answer to this question, that of the accuracy of the measurements, requires that the true value of primary production be known. I conclude that the SIS method, by facilitating characterization of relationships between environmental conditions and biological responses, provides an important tool to help in defining the true value of primary production.

Paper No. 15

Minas, Hans, J.
Centre d'Océanologie de Marseille, Campus de Luminy, case 901, 13288 Marseille cedex 9, FRANCE

Estimation de la production primaire a partir des changements observes dans la distribution des nitrates a moyenne echelle.

Détecter par l'observation les changements dans les concentrations en nutriments, et en déduire la productivité des masses d'eau, constitue une méthode ancienne qui devrait reconquérir toute son importance dans les programmes J-GOFS. En dehors de l'intérêt porté à la consommation des nitrates, expression même de la Production Nouvelle (PN), des évaluations des variations biologiques concomitantes d'oxygène et de CO_2 ont conduit à la notion de Production Communautaire Nette (PCN), elle-même quasiment équivalente à la PN. Aux moyennes et hautes latitudes, la méthode PCN, soutenue par un contrôle hydrologique rigoureux, s'applique avec succès aux intersaisons entre fin d'hiver et été suivant. Des exemples types sont présentés pour l'Arctique, l'Antarctique et la Méditerranée. Dans les upwellings tropicaux, la détermination des fractions nutritives consommées ($-\Delta NO_3$) et des laps de temps correspondant (ΔT) s'effectue par l'analyse de diagrammes de paramètres chimiques et hydrologiques. Une étude théorique des interactions auto-hétérotrophes dans la communauté pélagique permet d'établir des relations entre la consommation nutritive et le stock de chlorophylle observé en cours d'accroissement. Trois types de diagrammes température-nitrates sont indicateurs de cinétiques d'assimilation lentes ou rapides. La discussion, reconnaissant l'utilité de ces résultats pour la télédétection, conclut à la nécessité de développer l'approche PCN dans le but d'une meilleure compréhension de la signification des méthodes par incubation *in vitro*.

Paper No. 16

Platt, Trevor
Department of Fisheries & Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, CANADA

Conceptual bases of primary production measurements.

Given the goal to measure daily, water-column primary production, the various impediments to an unambiguous result are reviewed. These include the problem of definition of primary production, in both the fundamental and operational senses; the extrapolation of the results of short-term incubations to daily rates; the problem of respiration; and the problem of heterotrophic activity. The intrinsic time-scales associated with different methods of measuring primary production are discussed, leading to an examination of the issue of comparing the results of bulk property methods with those of *in vitro* methods. The question of extrapolation of results from local measurements to values representative of larger spatial scales is introduced. Finally, the utility of mathematical results as complementary tools to field measurements is addressed. Whenever possible the points discussed are related to talks to be presented by other speakers later in the symposium.

Paper No. 17

Raven, John A.
Department of Biological Sciences, University of Dundee, Dundee DD1 4HN, NITED KINGDOM

The potential of molecular biological and stable isotopic ideas and techniques for field measurements of marine primary production.

This contribution offers no instant solution to problems of measuring marine primary productivity in nature, but points out some techniques which can yield important supporting information.

1. Diversity of marine primary producers. Gene sequences for 16S rRNA from O_2-evolving photolithotrophs in natural, marine plankton samples show that the 'culturable' organisms from assemblages are minor components on a genotype or cell number basis.
2. Qualification of the contribution of major taxa to assemblages. A combination of *in vivo* determination of the major photosynthetic pigments present in cells, and of immunological properties of the cell surfaces permit assignment of individual cells to major taxa (Divisions, Classes). The technique used for both measurements is fluorescence, and measurements can be automated.
3. Restriction or achieved growth rate due to resource limitation. Molecular techniques are of use here in the immunological detection of cell surface components occurring in resource-deficient cells. This technique has the potential to detect components related to N,P, and Fe deficiency, as well as components related to extracellular inorganic C manipulation.
4. Determination of inorganic sources of C and N for phytoplankton and of the fate of their C,N, and S. The natural abundance of stable isotopes of C,N and S is useful in determining the inorganic C and N sources used by phytoplankton (there is no contest for S!), and of the biotic fates of C and N and (potentially) the contribution of biotic DMS to atmospheric CCN sulphuric acid.

These methods have limitations as well as potnetial, but together could help contribute to our knowledge of the organisms involved in marine primary productivity, the resources which they use and the extent to which their growth is limited by them, and the fates of the organisms.

Paper No. 18

Richardson, Katherine
Danish Institute for Fisheries and Marine Research, Charlottenlund Castle, DK-2920 Charlottenlund, DENMARK

The ICES ^{14}C primary production measurement intercomparison exercise.

In 1987, an intercomparison exercise organised by the ICES Working Group on Primary Production and concerning measurement of aquatic primary production using the ^{14}C method was carried out. It was the results from this exercise that ultimatley provided the impetus for the current meeting. Thus, although a summary of the results of this exercise has been reported elsewhere (Richardson, 1991), it is also relevant that the results from the exercise be presented and discussed within the context of this meeting. The exercise, itself, was divided into two parts. In the first, different types of filters onto which ^{14}C containing algae had been filtered were distributed to 24 different laboratories from 15 countries. These laboratories counted the associated radioactivity using their own methods and equipment. Significant differences were recorded in the results obtained by different laboratories. From a given data set, the participating laboratories were also asked to calculate total water column production using their commonly employed method. Results from the different laboratories varied by about 15%. The second part of the study consisted of field studies in which 12 laboratories representing 9 different countries participated. Primary production measurements using "own" and "standard" methods on pooled and non-pooled samples were carried out. Significant differences were recorded between laboratories even when a "standard" method was employed on pooled samples. The results suggest that incubator and filtering procedures are potentially significant sources of error in ^{14}C primary production determinations.

Paper No. 19

Robertson, Jane E.[1,2] and Watson, Andrew J.[2]
[1] Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UNITED KINGDOM
[2] University of Wales: Bangor, School of Ocean Science, Menai Bridge, Gwynedd, LL59 5EY, UNITED KINGDOM

Estimation of primary production by observations of changes in the mesoscale carbon dioxide field.

The rate of primary production significantly influences the surface and vertical distribution of inorganic carbon in the ocean. Biological activity shifts the inorganic carbon system by the fixation of inorganic carbon into organic carbon and by changing the alkalinity of the water through the uptake of nutrients and precipitation/dissolution of calcium carbonate. Time series data characterising the inorganic carbon system can be used to infer productivity in the water column. These estimates have the advantage over traditional bottle incubations that they are naturally averaged over large space and time scales, and are free from artificial containment effects.

A brief review of work published in this field is presented along with a discussion of the problems often encountered in interpretation, methodology, sampling design, and necessary corrections associated with this type of approach. In particular we highlight the patterns of variability in the inorganic carbon system, the role of physical and meteorological exchange and how to estimate the production of organic carbon from changes in the inorganic carbon system. Measurements made during UK BOFS cruises in the North-east Atlantic, 1989 and 1990 are presented as case studies.
Generally the dominant effect of biological activity on the inorganic carbon system is through the formation of organic carbon, however we present preliminary results of the perturbation observed from measurements taken during an intense coccolithophore bloom with high calcification rates in the North-east Atlantic, June 1991, as aprt pf the UK BOFS programme.

Paper No. 20

Sakshaug, Egil
Trondhjem Biological Station, the Museum, University of Trondheim, Bynesveien 46, N-7018, Trondheim, NORWAY

The relationship between phytoplankton growth and production with emphasis on excretion and respiration.

Commonly used models for primary production, i.e. P-I curves, are usually calibrated on the basis of short term (<1 h) carbon uptake and thus estimate gross production. Similarly, models for the growth rate on the basis of light absorption estimate the gross growth rate. The net growth rate is smaller, because part of the energy which is fixed by photosynthesis is spent on nutrient uptake, production of extracellular matter, and respiration. The growth rate thus is related to the net particulate photosynthetic rate instead of the gross rate. Because the rate of mitochondrial respiration and the rate of production of extracellular matter depend on the environmentally determined physiological status of the cells as well as on the species, there is no simple relationship between photosynthetic and net growth rates: moreover, the photosynthetic rate depends on the method of measurement. The resulting variations are reflected as variations in the factor Φ_{max} i.e. the maximum quantum yield of photosynthesis. Because Φ_{max} is implicit in the photosynthetic efficiency α^B and the maximum photosynthetic rate P^B_m, these factors vary similarly.

Paper No. 21

Sathyendranath, Shubha[1,2]
[1] Dalhousie University, Halifax, Nova Scotia, B3H 4J1, CANADA
[2] Biological Oceanography Division, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, CANADA

Estimation of primary production by remote sensing.

Satellite observations of ocean colour at selected wavelengths have made it possible to map of near-surface distribution of phytoplankton pigments at the global scale. While the advantage of remote sensing in providing synoptic coverage of large-scale surface features is incontestable, the estimation of primary production from these data requires additional information inaccessible to present-day satellite remote sensing, such as the parameters for conversion of *biomass* to *growth rates*, and the parameters of vertical structure. The value of remote sensing would therefore be enhanced considerably if the satellite data could be combined with *in situ* data to provide the missing information. Since satellite and *in situ* data are collected at very different time and space scales, conceptual schemes are necessary to render the two data sets compatible. The concept of bio-geochemical provinces has proved to be very useful in this context. Both

empirical and analytic approaches have been used to address the problem of estimating primary production from satellite-derived biomass estimates. The various analytic models that have been proposed can be classified according to their level of complexity. In any application, a suitable model has to be selected, based on: (1) validity of the model assumptions in the particular context, (2) computational requirements, (3) availability of auxiliary data, and (3) acceptable levels of error.

Paper No. 22

Tilzer, Max, M., Haese, Clivia and Conrad, Ines
Limnological Institute, University of Constance, D-W-7750 Konstanz, GERMANY

Estimation of *in situ*-primary production from parameters of the photosynthesis-light curve obtained in laboratory incubators.

Parameters of the photosynthesis-irradiance curve in laboratory incubators in general are determined under uniform temperature conditions and spectral composition of the light by using phytoplankton collected from one water depth. In the natural environment by contrast, both temperature and light quality vary with depth, and phytoplankton often exhibit vertical shifts in photosynthetic light responses owing to differential light-shade adaptation.
In Lake Constance green underwater light (550 nm) is best transmitted and the euphotic zone is thernally stratified in summer. We in parallel assessed photosynthesis *in situ*, and in incubators at 15°C in white and green light. Phytoplankton from 50-% and 1-% light depths were used.
Light-saturated photosynthesis rates were temperature-dependent with a Q_{10} of 2.3. Slopes of light-limited portions in photosynthesis-irradiance curves in general were greater in white than in green light incubators, but *in situ* exceeded incubations in white light.
Optimal prediction of *in situ* productivity can be achieved by temperature correction of light saturated photosynthetic rates and by using green-light incubations of deep phytoplankton for light-limited rates.

Paper No. 23

Williams, Peter J. leB.
School of Ocean Sciences, University of Wales, Bangor, UNITED KINGDOM

Chemical and tracer methods: what do they measure?

The review consists of two parts: (i) a consideration of the terminology used in the measurement of plankton production, (ii) an attempted interpretation of the rates obtained by chemical (O_2 and ΣCO_2) and tracer (^{14}C) techniques.
From the first part of the review, it is concluded that for overall studies of plankton production, we will probably continue to use techniques based on both the atoms oxygen and carbon. The former is of value in fundamental ecophysiological work, for oxygen flux is closely related to energy flux and so provides a measure of energy flux through the community. Of the precise chemical methods, oxygen is still by far the simplest. Carbon based methods (either the ^{14}C or ΣCO_2 techniques) provide the most convenient measure of biological material flux and so are of value in trophic studies.
From the second part of the review it is evident, paradoxically, that most if not all the current major problems with the interpretation of either chemical or tracer techniques for the measurement of planktonic photosynthesis lie with our lack of understanding of the details or rates of algal respiration. In the case of the ^{14}C technique, our interpretation of the method either as a measure of groos or net primary production seems to hinge on the scale of algal biomass-normalized respiration, the fate of respiratory CO_2 in the algal cell and the extent to which newly fixed material is respired. In the case of the chemical technique the single problem is the determination of respiration in the light bottle and the extent to which our dark bottle measurement either over- or under-estimates this rate. The classical RUBISCO-associated respiration does not appear to be a major source of error in the case of micro-algae. There are fewer uncertainties in the interpretation of light respiration in the case of ΣCO_2 as compared with oxygen.

Poster No. 1

Andrushaitis, A., Balode, M. & Lagzdins, G.
Institute of Biology, Latvian Academy of Sciences, 229021, Salaspils, 3 Miera Str., Latvia.

Eutrophication of the Gulf of Riga.

The Gulf of Riga is one of few regions of the Baltic Sea where average concentration of nitrogen and phosphorus continue to increase, while in most of other regions they are stabilizing since 1984. Average annual loads of eutrophying substances during last decade are estimated as 55.6×10^3 tons of BOD_o, 80.2×10^3 tons of N_{tot} (precipitation and N-fixation not included) and 2.3×10^3 tons of P_{tot}. Loads of both N and P are increasing for 4.5×10^3 tons and 180 tons $year^{-1}$, respectively. The rates of primary production and mineralization of organic carbon are 1.4-1.6 times higher while surface-specific load of organic carbon is 10 times greater in comparison with entire Baltic.
The maximal observed phytoplankton standing stock is 34 g m^{-3}. High nutrient concentrations remaining during summer stimulate development of such mesosaprobic diatom species as *Nitzschia acicularis* and *Skeletonema costatum*. Dominance period of blue-greens gradually becomes longer. Mass development of toxic cyanobacteria *Microcystis aeruginosa* has been observed in coastal waters during summer. Since the 70's a drastic increase of abundance of bottom molluscs, and decrease of bottom crustaceans is going on. This has caused a 4-15 fold increase of macrozoobenthos standing stock.

Poster No. 2

Aristegui, J.[1], Montero, M.F.[1], Ballesteros, S.[1], Basterretxea, G.[1] & Vanderschuur, R.[2]
[1]Facultad de Ciencias del Mar, Universidad de Las Palmas de Gran Canaria, Spain
[2]Rijksuniversiteit Groningen, Biologisch Centrum, Haren, The Netherlands

Response of size-fractionated plankton metabolism to upwelling events on the wake of a subtropical oceanic island (Gran Canaria).

The waters of the Canary Current, in the Eastern Boundary of the North Atlantic Ocean, are essentially oligotrophic. However, the flow disturbance by some oceanic islands, like Gran Canaria, induce the generation of contra-rotating pairs of eddies on their leeward side, which alter significantly the productivity and distribution of plankton in these areas. Due to the ageostrophical character of the eddies during their early stages, cold nutrient-rich water is upwelled into the photic layers of the cyclonic eddies, while warm water is concentrated in the core of the anticyclonic ones.
Here we present data from two hydrographical surveys around Gran Canaria Island carried out during two different seasons: (a) late winter, without a seasonal thermocline and coinciding with the phytoplankton bloom, and (b) late spring, when the seasonal thermocline was already developed. Samples were collected in the centre of the cyclonic and anticyclonic eddies in order to determine the contribution of the different size fractions of the microplanktonic community (<200μm) to the productivity and respiration. Although there were differences between both surveys, due to the seasonal changes, the local upwelling in the centre of the cyclonic eddies always enhanced net (community) production in relation to the nearby waters. Picoplankton (defined as organisms passing 2μm pore size filters) contributed between 11-56% and 67-75% of the total measured chlorophyll-*a*, and between 16-82% and 27-73% of the total measured activity of the electron transport system (ETS), during late winter and late spring, respectively. However, differences between the cyclonic eddies and the surrounding waters were considerable during both seasons. Cyclonic

eddies were characterized by presenting low numbers of microheterotrophs, low concentrations of chlorophyll-*a*, low values of community respiration, but a high net production. During the phytoplankton bloom season, R/ETS indexes in surface waters of the cyclonic eddy approach the values obtained for pure cultures of phytoplankton. All this indicates that cyclonic eddies act like upwelling centers during their development, enhancing productivity and producing sharp changes in the microbial composition and metabolism, in relation to the vecine oligotrophic waters.

Poster No. 3

Babin, M.[1], Levasseur, M.[2], Michaud, D.[1] & Legendre, L.[1]
[1]Dép. de Biologie, Univ. Laval, Québec, Canada, G1K 7P4
[2]Inst. Maurice-Lamontagne, C.P. 1000, Mt-Joli, Québec, Canada, G5H 3Z4

Effect of the angular distribution of light on photosynthesis at the scale of a phytoplankton cell.

An analytical and a numerical model has been developed to assess the effect of angular distribution of light (parallel, isotropic and two *in situ* distributions) on the quatum yield of photosynthesis at the level of a phytoplanktonic cell. The model was run with the following factors varying: cell diameter, intracellular pigment concentrations, distribution of cellular matter (homogeneous vs inhomogeneous) and light intensity (unsaturating to saturating). The first results of calculations show that, under realistic conditions, the angular distribution of light has a significant effect on the quantum yield at the cell scale as it affects substantially the shape of the P vs I relationship. These observations could have an impact on technical aspects of primary production measurements as well as on the interpretation of primary production at sea.

Poster No. 4

Banse, K. & Postel, J.R.
School of Oceanography, University of Washington, Seattle, WA, U.S.A.

Further observations on sources of variability in satellite-derived estimates of phytoplankton production.

Observed column production of phytoplankton (P_t) correlates only loosely with PigSat at the same stations, i.e., with the signal (simulated by us from in situ data of chlorophyll and phaeopigment)) that a satellite would have measured. Hence, the precision of P_t to be predicted frpm satellite pigment observations leaves much to be desired. Banse & Yong (1990. J. Geophys. Res. 95[C5]: 7201-7215) showed that a principal cause of this variability at 138 stations, distributed broadly and seasonally over the eastern tropical Pacific, is ignorance about the level of light-saturated carbon uptake per unit of chlorophyll (P_{max}), which cannot be estimated from satellite-derived information. As their ^{14}C-data were demonstrably too low, they reported their conclusion with reservation.
We repeated these calculations for modern data sets, one from approx. the same area (15 stas. between 15°N and 15°S along 150°W, by Barber and others during winter 1988) and two from upwelling regions off the west coast of the United States, one between Pt. Reyes and Cape Mendocino, California (14 stas. approx. between 37° and 40°N to about 200 km from the shore; Cruise SQ87, spring 1987, by Hayward and others) and the other off Washington (31 stas. near 47°N to about 120 km from the shore, summers of 1974 to 1983, by Anderson, Perry, and others of our school). All sets comprise marked gradients of surface

temperature and nitrate, as well as of surface and column chlorophyll concentrations. Incubations started between about 10:00 and 16:00 hr except some equatorial stations (08:30 hr).
The results (see table, from linear regression analysis) bear out Banse & Yong's conclusion for the equatorial Pacific, but knowing P_{max} does not lead to similarly improved correlations for the two coastal upwelling regions. At present, no explanation can be offered for the difference. A paper is in preparation.

P_t, mgC m^{-2} hr^{-1} Mean (Range)	PigSat, mg m^{-3} Mean (Range)	P_t on PigSat r^2 (S.E.%)*	P_t on PigSat, P_{max} r^2 (S.E.%)*
Equatorial Pacific (P_t per day)			
332 (49-739)	0.22 (0.08-0.33)	0.60 (37)	0.87 (22)
California			
97 (34-195)	2.5 (0.14-16.3)	0.49 (48)	0.51 (49)
Washington			
116 (16-422)	5.6 (0.09-26.1)	0.73 (66)	0.74 (65)

*S.E.%: Standard Error over mean P_t x 100

Poster No. 5

Barlow, R.G., Gough, M.A., Mantoura, R.F.C. & Fileman, T.W.
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK

Pigment signatures of the phytoplankton composition in the north eastern Atlantic during the 1990 spring bloom.

Pigment signatures were used to track the development of composition of the phytoplankton bloom in the north eastern Atlantic during May/June 1990 using reverse phase high performance liquid chromatography. Chlorophyll *a* concentrations at 5m increased from 1.2 to 3.7 $\mu g.l^{-1}$ during the first half of May, and decreased progressively thereafter in the post-bloom stage. Multiple regression analysis of chlorophyll *a* and selected accessory pigments indicated that diatoms (fucoxanthin) (23-75%) and prymnesiophytes (19'-hexanoyloxyfucoxanthin) (40-25%) dominated the chlorophyll *a* biomass in the development phase, with prymnesiophytes dominating the post-bloom stage (45-55%). Dinoflagellates (peridinin) (5-25%) and 'green" algae (chlorophyll *b*) (5-10%) were secondary components of the microalgal community. Depth distributions revealed that the pigment maxima occurred near the surface at 5 to 15m, with concentrations decreasing rapidly below 15m. At the peak of the bloom, diatoms (fucoxanthin) were dominant throughout the water column down to 300m, while in the post-bloom phase, prymnesiophytes (19'-hexanoyloxyfucoxanthin) dominated the community in the upper 20m with diatoms accumulating in deeper water. Concomitant measurements of nutrients and downwelling irradiance suggested that nitrate availability limited the growth of the phytoplankton in the upper 15m and below this depth limitation was due to low irradiance levels.

Poster No. 6

Berdalet, E. & Estrada, M.
Institut de Ciéncies del Mar, P. Nacional, s/n 08039 Barcelona, Spain

Relationships between nucleic acid concentration and primary production in the Catalan Sea (Northwestern Mediterranean).

Measurements of primary production (^{14}C method) and concentration of DNA and RNA (double staining fluorimetric technique) were carried out on a series of plankton samples taken across the Catalan front in May 1989 and February 1990, corresponding, respectively, to periods of stratification and moderate mixing. Significant correlations between RNA concentration and primary production were found during both surveys. DNA concentration was significantly coorelated with chlorophyll *a* in February 1990, but not in May 1989, when a marked deep chlorophyll maximum was present. The usefulness of nucleic acid determinations as indicators of biomass and physiological state of planktonic populations is discussed.

Poster No. 7

Blanchard, G.F.[1] & Montagna, P.A.[2]
[1] CREMA L'Houmeau, CNRS-IFREMER, B.P. 5, 17137 L'Houmeau, France.
[2] The University of Texas, Marine Science Institute, P.O. Box 1267, Port Aransas, Texas 78373, USA.

Short-term changes in $H^{14}CO_3^-$ uptake by benthic microalgae throughout the photic layer of the sediment.

^{14}C-bicarbonate uptake rates of microphytobenthos throughout the photic layer were calculated using photosynthetic parameters (α^B, P^B_s and β^B), Chl *a* concentration from the upper 5 mm of the sediment, recordings of in situ quantum irradiance, and the light attenuation coefficient in the sediment. Photosynthetic activity was restricted to a thin layer at the sediment-water interface and was strongly attenuated through the upper mm of the sediment. The large short-term variability in bicarbonate uptake during May 1990 (1.83-600.37 mg C m^{-2} d^{-1}) might be attributed to variability of wind-induced resuspension. On the other hand, a chrysophyte bloom in June-July prevented penetration of light through the water column, and decreased the rates and variability of microphytobenthos uptake. This study shows that benthic microalgal production varies greatly on short-time scales due to physical and biological control.

Poster No. 8

Boucher, N.P. & Prézelin, B.B.
University of California at Santa Barbara, CA 93106, USA (Omnet: B.Prezelin)

Bio-optical approaches to prediction of UV-inhibited rates of primary production in Antarctic waters.

In Oct-Nov 1990, *in situ* incubations carried out in the Bellingshausen Sea showed that the influence of UV radiation on primary production could be described by the relationship:
$P_{QTOT} = P_{QPAR} (1 - FI_{UVA} - FI_{UVB})$
where P_{QPAR} is the rate of primary production for organsims exposed to PAR (400-700 nm) radiation and P_{QTOT} is the rate of primary production for organisms exposed to unfiltered radiation (PAR+UVA+UVB). FL_{UVA} and FL_{UVB} represent the fractional inhibition (FI) of primary production attributable to Q_{UVA} and Q_{UVB} respectively. P_{QPAR} was estimated from *in situ* moorings, deckboard incubations (simulated *in situ* PAR), and instantaneous determinations of P-I parameters for phytoplankton samples. Sampling occured along a 100 km east-west transect and across a 150 km north-south transect of the marginal ice zone (MIZ). Here we present a comparison between measured and bio-optically derived estimates of primary productivity in Antarctic waters and an estimation of the UV inhibition of primary production over the study area for the duration of the ozone depletion.

Poster No. 9

Boyd, P.[1], Aiken, J.[2], Bellan, I.[2], Kolber, Z.[3], and Trees, C.[4]
[1] Queens University of Belfast, UK.
[2] Plymouth Marine Laboratory, UK.
[3] Brookhaven National Laboratory, USA.
[4] CHORS, San Diego State University, USA.

A comparison of rates of primary production as derived from radiochemical methods, active and solar-stimualted fluorescence.

Measurements of active and solar stimulated fluorescence offer the potential to extend the temporal and spatial domain of primary productivity estimates. However, prior to adoption, the reliability and robustness of these techniques must be rigorously tested by comparison with long established methods of estimating primary production. A recent research cruise in the North East Atlantic provided an opportunity to contrast and compare rates of primary production obtained using the ^{14}C technique, pump and probe fluorometry and an optical sensor measuring solar induced fluorescence. Rates of primary production obtained from 24h *in vitro* ^{14}C incubations and photosynthetic characteristics derived from short term ^{14}C P:I experiments were thus compared with fluoresence based estimates obtained from a series of vertical profiles using pump and probe and natural fluorometry.

Poster No. 10

Braun, J.G.
Ministerio de Agricultura, Pesca y Alimentacion, Instituto Español de Oceanografia, Centro Oceanografico de Canarias, Carretera San Andres S/N., 38120 Santa Cruz de Tenerife

Primary production cycles in Canary Island waters over the last 20 years.

As from 1971 the Centro Oceanografico de Canarias del Instituto Español de Oceanografia has undertaken the study of varied seasonal cycles so as to try to relate production in the waters to environmental physicochemical parameters and also the possibility of understanding the workings of the marine ecosystem in the zone.

As with the majority of marine ecosystems, seasonal variations are usually observed in basic oceanographic parameters such as temperature, salinity and dissolved oxygem.
With regard to functional nutrients, no definite cycles are observed in the photic zone and during the year, with slight variations, few nutrient values are obtained. Basing ourselves on these findings, the waters have been categorised as oligotrophic.
In the different cycles under study average primary production values are around 300 mgC m^{-2} day^{-1} with variations being observed depending on the season of the year. On occasions complex situations have been observed during the most productive period in spring or towards the end of the winter, producing parallel variations in the distribution of the zooplankton biomass.

Poster No. 11

Carreto, J.I.[1], Lutz, V.A.[2], Negri, R.M.[1], & De Marco, S.G.[1]
[1]Instituto Nacional de Investigacion y Desarrollo Pesquero, CC 175 Playa Grande, Mar del Plata, Argentina.
[2]Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1.

Variability of *in vivo* absorption spectra of particulate material along a transect from the coast to the continental shelf-break in the Argentine Sea.

The spectral characteristics of *in vivo* absorption of particulate material in the sea are important in studies of primary production, radiative transfer in seawater, and in passive remote sensing of phytoplankton. *In vivo* absorption spectra of particulate material along a transect in the Argentine Shelf show a noticeable structure both in the vertical and horizontal dimensions. In the coastal system, sediment in suspension was the main factor contributing to light attenuation, while, further offshore, the effect of sediment was significant only at depth. Close to the shelf-break front, where a bloom of *Nitzschia* sp. was detected, *in vivo* absorption spectra resembled those obtained with diatom cultures.
The ratio of the specific absorption coefficients in the blue (437 nm) and the red (674 nm) parts of the spectrum showed a general tendency to increase from the coast towards the shelf-break. This variation is interpreted in relation to the vertical stability of the water column, nutrient availability, and species composition of phytoplankton.

Poster No. 12

Charpy, L.
ORSTOM, Centre de Tahiti, BP 529, Papeete, Polynesia, France

The importance of the small cyanobacteria *Synechococcus* in the primary production of atoll lagoons.

High quantity of phycoerythrin-rich *Synechococcus* ($150x10^6$ cells L^{-1}) was found in Tikehau atoll lagoon in April 1986 (Tuamotu Archipelago). Sampling performed later in this same atoll at different months showed *Synechococcus* concentrations ranging from $100x10^6$ cells L^{-1} to $200x10^6$ cells L^{-1}. High density of *Synechococcus* was observed also in another atoll of the Tuamotu Archipelago (Takapoto). Their chlorophyll content was 1.8 fg $cell^{-1}$ and their cellular C/chl-*a* ratio was 82. The average phytoplankton production was 0.82 gC m^{-2} d^{-1} with 60.3% due to the *Synechococcus* with a size <1 µm. Their P/B was very high: 11 µgC h^{-1} 10^9 $cells^{-1}$ and 13 to 21 µgC h^{-1} µg chl-a^{-1}. It seems that cyanobacteria are the most important component of plankton primary production.

Poster No. 13

Chekalyuk, A.M. & Gorbunov, M. Yu
Moscow State University, Physics Department, Moscow 119899, Lenin Hills, Russia

Laser remote *in situ* measurements of phytoplankton photosynthesis efficiency.

The new remote technique and special double-pulse LIDAR system are described. By using this technique, it is possible to make express monitoring of sea surface from the board of a moving carrier (a ship, a helicopter, an aircarft). The results of laboratory experiments and the examples of applications in oceanography investigations are reported.

The method described is a remote modification of the lamp *pump-and-probe* technique [1]. The remote measurements are provided by using laser pulses for excitation of chlorophyll "a" fluorescence in subsurface water layers. This fluorescence is consecutively excited by the single probing pulses and by the probing pulses following the pumping pulses. In the first case, the original chlorophyll "a" fluorescence intensity level (Φ_o) is detected, in the second case - the maximum one (Φ_m). As a result, the value of relative yield of chlorophyll "a" variable fluorescence ($\eta=(\Phi_m-\Phi_o)/\Phi_m$) is determined which characterizes the efficiency of light energy conversion in primary photosynthetic reactions. An important feature of the described technique is the normalization of detected fluorescence intensity by the intensity of water Raman scattering, excited by the same laser pulse.

The special double-pulse LIDAR system has been constructed. It consists of two pulsed YAG:Nd^{3+} - lasers, the optical system including an optical multichannel analyser (OMA) and the computer for the instrument control and data processing. The laboratory investigations on the different algae species have shown that for correct measurements of η, the pumping pulse photon flux density in probing volume of the water must be more than 5×10^{22} $sm^{-2}s^{-1}$, the probing pulse one - less than 10^{22} $sm^{-2}s^{-1}$, and the delay between the pumping and probing pulses must be about 40-50 μs. By gating the OMA detector synchronously with the probing pulses, it is possible to select necessary fluorescent response and to make the correct measurements regardless of intensive day illumination.

The first tests of the laser method for phytoplankton photosynthesis efficiency (*PPE*) measurements have been carried out in the spring of 1990 in North-Western Atlantic during shipboard expedition. As a result, we have obtained the valuable information about the character and scales of the photosynthetic activity horizontal variability in that region of the Ocean. It has been shown that there may exist a strong correlation between the horizontal distributions of *PPE* and subsurface hydrological structures. Now we are working in order to understand the nature of this phenomenon and to develop on this base the method of remote hydrological structure search by *PPE* monitoring. Another possible application of this technique is an *estimation of primary production* using data obtained [1].

This technique was also successfully applied for *in situ* investigation of the diurnal rhythm of phytoplankton photosynthesis efficiency and its fluorescence intensity in the April of 1991 in the Mediterranean Sea. The typical features of time behaviour of Φ_o, Φ_m and $\eta=(\Phi_m-\Phi_o)/\Phi_m$ are discussed in the report. An analysis of the results has shown that the main causes of such variations were photosynthesis photoinhibition and energy-dependent quenching of chlorophyll "a" fluorescence under the influence of natural sunlight illumination variations.

1. Falkowski, P.G. Estimation of primary production by measurements of active fluorescence. This Symposium.

Poster No. 14

Chekalyuk, A.M., Demidov, A.A., Fadeev, V.V. & Gorbunov, M. Yu
Moscow State University, Physics Department, Moscow 119899, Lenin Hills, Russia

Shipboard LIDAR investigations of marine phytoplankton.

In this communication, we present the review of methods and equipment development as well as results obtained by our group during more than 16 years of activity in this field. Some of them may be useful for the future development of the new methods of primary production estimation by using of LIDAR remote sensing. The possible way to solve this problem is consolidation of approaches developed in [1] and [2]. The LIDAR methods are based on the exciation of subsurface water layer by powerful laser pulse and remote detection and spectral analysis of optical response from the media. The contribution of phytoplankton (*PP*) is the chlorophyll-a (*Chl-a*) fluorescence band (λ_m=683 nm) forming as a by-product of primary photosynthetic processes induced by laser pulse excitation. The contribution of the water to the detected response is Raman scattering band (ν_m=3440 cm^{-1}). Normalization of *Chl-a* fluorescence intensity by water Raman scattering enables one to reduce the influence of registrating conditions unstability (geometry, water surface variations, etc.) on the results of the measurements.
Now it is possible to make estimations of two important phytoplankton characteristics by remote LIDAR measurements of *Chl-a* fluorescence: averaged *Chl-a* concentration (C*a*) and, using laser remote modification [2] of "*pump-and-probe*" technique [1], the efficiency of light energy conversion in primary photosynthetic reactions (by measuring relative yield η of *Chl-a* variable fluorescence). In a special report [3], we discuss the problems of correct estimation of C*a* and η from LIDAR data.
The special shipboard double-pulse LIDAR system [1] has been constructed to provide simultaneous C*a* and η remote measurements. The results are averaged in subsurface layer of 3-5 m. The space resolution of the system is better than 100 m, so it is possible to investigate fine structures of C*a* and η horizontal distributions. The system is fully computer-controlled and enables one to obtain the results in *real-time* mode during the measurements.
The results of our measurements within the Atlantic, Pacific, Indian, and Antarctic Oceans as well as Baltic, Black and Mediterranean Seas are analysed and generalised. The problems of spatial variability of C*a* and η in local, mezo- and synoptic scales, *PP* patchiness, dynamics of *PP* bloom, *PP* fluorescence diurnal rhythms, correlation of *PP* distributions with hydrological structures are discussed.

1. Falkowski, P.G. Estimation of primary production by measurements of active fluorescence. This Symposium.
2. Chekalyuk, A.M. & Gorbunov, M. Yu. Laser remote *in situ* measurements of phytoplankton photosynthesis efficiency. This Symposium.
3. Chekalyuk, A.M. & Gorbunov, M. Yu. Some problems of phytoplankton characteristics estimation by LIDAR remote sensing of *in vivo* chlorophyll fluorescence. This Symposium.

Poster No. 15

Chekalyuk, A.M. & Gorbunov, M. Yu
Moscow State University, Physics Department, Moscow 119899, Lenin Hills, Russia

Some problems of phytoplankton characteristics estimation by LIDAR remote sensing of *in vivo* chlorophyll fluorescence.

The LIDAR methods are based on the excitation of subsurface water layer by powerful laser pulses and detection and spectral analysis of optical response from the water medium. The contribution of phytoplankton is the chlorophyll-a (*Chl-a*) fluoescence band (λ_m=683 nm) forming as a by-product of primary photosynthetic processes induced by laser pulse excitation. The intensity of *in vivo Chl-a* fluorescence is the sum of the two components: the so-called "constant" (Φ_c) and "variable" (Φ_v) fluorescence.
Now it is possible to make estimations of two important phytoplankton characteristics from remote LIDAR measurements of *Chl-a* fluorescence: averaged *Chl-a* concentration (C*a*) and, using laser remote modification [1] of "*pump-and-probe*" technique [2], the efficiency of light energy conversion in primary photosynthetic reactions (by measuring relative yield η of *Chl-a* variable fluorescence). The problems of correct estimation of C*a* and η from LIDAR monitoring data are discussed in the present report.
Although the intensity of *Chl-a* fluorescence is obviously proportional to the concentration of C*a*, there exist some factors, complicating the C*a* estimation. The first group of factors is connected with the *natural variations of in vivo Chl-a fluorescence quantum yield* due to the variations of algae species composition, nutrients limitation, sunshine illumination, etc. In accordance with our latest results, some of these factors can influence not only the "variable" component of *Chl-a* fluorescence, but also the "constant" one. Taking these factors into consideration seems to be important not only for LIDAR data interpretation, but for any *Chl-a* fluorometric technique.
The second group of factors is defined by the features of powerful pulse laser excitation, mostly - by the *saturation of Chl-a fluorescence*, caused by the singlet-singlet annihilation of excitons within light-harvesting antenna. Theoretical models and experimental data on laser-induced saturation of "constant" and "variable" components of *in vivo Chl-a* fluorescence are discussed.
The influence of both groups of factors on the results of C*a* and η estimations are discussed on the basis of laboratory experiments with algae species and *in situ* LIDAR measurements in various regions of the Ocean. The recommendations in order to improve the results of the measurements and the accuracy of estimations are formulated.

1. Chekalyuk, A.M. & Gorbunov, M. Yu. Laser remote *in situ* measurements of phytoplankton photosynthesis efficiency. This Symposium.
2. Falkowski, P.G. Estimation of primary production by measurements of active fluorescence. This Symposium.

Poster No. 16

Colin, F.[1], Peperzak, L.[1], Kraay, G.W.[2], & Veldhuis, M.J.W.[2]
[1] Tidal Waters Division/Rijkswaterstaat, PO Box 20907, 2500 EX The Hague, The Netherlands
[2] Netherlands Institute of Sea Research (NIOZ), PO Box 59, 1790 AB Den Burg, The Netherlands

Design and tests of a novel incubator to be used for measuring the phytoplankton primary production in ICES monitoring studies.

An inexpensive and simple incubator for primary production measurements is presented along with a protocol for achieving strictly and comparable ^{14}C-fixation rates of phytoplankton. The incubator, based on Stemann-Nielsen and Aabye Jensen (1975), is comprised of incubation bottles revolving in a water bath at a fixed irradiance. The recommended protocol and incubator have been tested in different waters, such as Dutch and Finnish coastal waters and in the North Sea, and give reliable estimates of photosynthetic rate at the fixed irradiance used. Coefficients of variation were between 0.6 and 7.6 in incubation experiments with three and five samples. No difference between P_{max} measured in the Baltic incubator and the ICES incubator were found.

Poster No. 17

Dauta, A. & Capblancq, J.
Laboratoire d'Hydrobiologie (UA 695 CNRS), Université Toulouse III, 118, route de Narbonne, 31062 Toulouse cedex, France

PHOTOSYNTHESIS-SIMULATOR: a tool to simulate the gross primary production of phytoplankton.

PHOTOSYNTHESIS-SIMULATOR is a WINDOWS* Application. This model allows quick and easy estimates of phytoplankton primary production in a water column. The aquatic environment and the parameters related to photosynthesis are defined by: depth, non-algal water turbidity, surface irradiance and daylength. A function may also estimate the daylength and maximal daily irradiance for a combination of latitude, month and day. The Photosystem is described by

- a model of gross primary production (possibility of a choice among commonly used models: Jassby & Platt, Peeters & Eilers, Steele, Talling ...) and its parameter values.
- the concentration of chlorophyll. PHOTOSYNTHESIS-SIMULATOR allows to consider the heterogeneity of vertical repartition of phytoplankton, with a maximum of ten water layers characterized by various algae concentrations and different photosynthesis performances.

From the set of parameters defined in the configuration Menu, PHOTOSYNTHESIS-SIMULATOR graphs the profile of gross primary production and the light penetration for each hour of a given day. Are also printed the values of primary production, integrated hourly and daily on the water column.
This global model appears to be a helpful tool to understand or explain the main features of primary production, to calculate easily a profile or a daily budget of gross primary production to test some hypothesis about stratification of phytoplankton and its atypic responses, and to plan field experiments.

**WINDOWS is a Microsoft Product.*

Poster No. 18

Demidov, A., Baulin, E. & Chernyavskaya
Moscow State University, Physics Department, Moscow 119899, Lenin Hills, Russia

Use of laser fluorometry *in vivo* and *in vitro* seawater phyto- and zooplankton analysis.

There are developed the fluorometric methods for plankton investigations based on impulse Nd:YAG laser (λ=532 nm) and steady state He-Cd laser (λ=440 nm). These methods use the fluorescence of phyto- and zooplankton pigments excited by laser light. There is detected simultaneoulsy the water Raman signal as calibration signal. Developed methods were tested in laboratory as well as in native sea-water conditions. They can be used in analyzing of intact algae *in vivo* and pigment extracts *in vitro*. Our methods enable one a) to detect chlorophyll *a* concentration in native intact algae up to 10 nanogram liter^{-1} without conccentration *a* probe; b) to estimate the photosynthetic activity of algae without using any chemicals like DCMU; c) to detect chlorophyll *a* and pheophytin *a* concentrations in acetone extrcats of phyto- and zooplankton up to 1 nanogram liter^{-1}; d) to control the feeding process of individual sample of zooplankton.

Poster No. 19

Descolas-Gros, C. & Oriol, L.
Observatoire Océanologie Laboratoire Arago, 66 650 Banyuls-sur-mer, France

Importance of β carboxylation (dark carbon assimilation) in carbon flux studies.

Carbon flux studies in aquatic ecosystems require a good knowledge of primary production and of carbon inputs and outputs. Primary production is usually measured by the Steemann-Nielsen method. This methodology involves the incubation of samples in the presence of ^{14}C-bicarbonate which provides a global estimate of production that does not permit the study of rapid variations in carbon assimilation. Activity measurements of the enzymes (carboxylases) which are involved in inorganic carbon fixation are well adapted to the study of this problem especially for short-term adaptative processes.
Inorganic carbon may be assimilated through the Calvin Benson cycle via the enzyme ribulose-1,5-bisphosphate carboxylase (Rubisco) or by β-carboxylation (phosphoenolpyruvate carboxylase (PEPC), phosphoenolpyruvate carboxykinase (PEPCK) or pyruvate carboxylase (PC)). Carboxylase activity measurements for marine phytoplankton are described. Two indices measuring carboxylase activity in marine phytoplankton were used. The first measures Rubisco activity per unit chlorophyll (R/Chl : nmol CO_2/h/μg Chl a+b+c) while the second is the ratio of β carboxylase activity to Rubisco activity, expressed as % (βC/R) which reflects the proportion of inorganic carbon fixed by these two groups of carboxylases. These ratios were studied in i) different algal species in culture, ii) during the different growth phases of a culture, and iii) after a light-dark transition to measure the time response of carboxylase activity after a change in external factors (physico-chemical) iv) in the field in different parts of the world ocean. These indices were very different from one species to another at the same stage of growth. Heterotrophic species fixed large amounts of inorganic carbon through β carboxylase activity. The importance of β carboxylation (dark carbon assimilation) in carbon flux studies is discussed. These measurements give us essential information which cannot be obtained by other means and is a powerful technique for the better understnading of the dynamics of carbon assimilation in the open ocean and, in more physiological orientated work, the carbon cycle in phytoplankton.

Poster No. 20

Edwards, A.
Natural Environment Research Council, Dunstaffnage Marine Laboratory, P.O. Box 3, Oban, Argyll, PA34 4AD, Scotland

A mechanistic model of the photoinhibited P-I curve.

A simply constructed model of the kinetics of the relationship between algal photosynthetic rate and light intensity has been made. Photoinhibition is explicit in the model at all light intensities. The mathematical expression of the model leads to an analytic solution coincident with that derived empirically by Platt, Gallegos and Harrison (1976)*.

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Poster No. 21

Erez, J.[1], Iluz, D.[2], Lazar, B.[3] & Dubinsky, Z.[2]
[1]Institute of Earth Sciences, Hebrew University, Jerusalem, Israel.
[2]Department of Life Sciences, Bar-Ilan University, Ramat-Gan, Israel.
[3]Interuniversity Institute of Elat, Israel.

Primary production in the northern Gulf of Elat, Red Sea: a case study for open-sea coral-reef interactions.

Temporal and spatial patters in the primary production of phytoplankton in the Gulf of Elat were determined during 1989-1991. Water were sampled monthly in a cross-section at 600m, 150m and 50m bottom depth. Duplicate 330 ml pyrex BOD bottles were spiked with 5 μCi ^{14}C and incubated *in situ*. The dark and the time-zero controls were in the range of instrumental background while the light incubations were at least an order of magnitude higher. Rates of primary production for the upper photic zone (0-50m) ranged between 0.5 to 1.5 $\mu gC\ l^{-1}\ hr^{-1}$ and are similar to those reported previously for the same region (Levanon-Spanier *et al.* 1979). Depth-integrated and time-averaged rates yield primary production of 80 to 120 $gC\ m^{-2}\ y^{-1}$. Oxygen consumption rates below the seasonal thermocline yielded minimum values for new production which are around 160 $gC\ m^{-2}\ y^{-1}$. In an effort to resolve for this discrepancy we tested for some of the commonly cited methodological pitfalls involved in primary productivity measurements: bottle size effect, plastic vs. glass bottles, trace-metal contamination in the radiotracer and the length of incubation. None of these factors seem to have a significant effect on our measurements. It is possible that the high oxygen consumption rates are caused by oxidation of sedimentary organic matter transported down slope from the adjacent coastal fringing coral reefs.
During the oligotrophic summer period we observed a sharp increase in phytoplankton primary production towards the coastal fringing coral reefs. This observation is in good agreement with a similar productivity gradient reported by Levanon-Spanier *et al.* (1979). These gradients are associated with distinct (although much sharper) gradients of nitrate and occasionally DON and phosphate, showing decreasing concentrations towards the open sea. Stable carbon isotopes, and plankton distribution studies suggest that the reef obtains the bulk of its nutrients from feeding and digestion of pelagic plankton. The excess nutrients are transported back to the open sea and support the elevated photosynthetic rates of phytoplankton. During the winter period (Jan-Mar) the thermocline is destroyed and complete vertical mixing brings nutrients to the photic

zone. Under these conditions the nutrient and productivity gradients reverse their direction because benthic primary producers in the reef take up dissolved inorganic nutrients from water and the phytoplankton responds with lower productivity.

Reference
Levanon-Spanier, I., Padan, E. & Reiss, Z. (1979). Primary production in a desert-enclosed sea - the Gulf of Elat (Aqaba), Red Sea. Deep-Sea Res. 26:673-685.

Poster No. 22

Figueiras, F.G., Pérez, F.F. & Pazos, Y.
Instituto de Investigacions Mariñas, CSIC. Eduardo Cabello, 6, 36208-Vigo, Spain.

Phytoplankton P-I curves and maximum quantum yield near the ice edge of the Weddell Sea (Summer 1988-1989).

P-I curves were used to study the photosynthetic response of Antarctic phytoplankton at the receding ice-edge between Elephant Island and South Orkney Island.
On only 18 out of 55 occasions was photo-inhibition observed (range of β = 0.1 x 10^{-3}, 2.9 x 10^{-3} mgC/mgChl*a*•h•µE•m^{-2}•s^{-1}). The light limited parts of the cutves (α = the same units as β) varied between 0.024 and 0.11. P_m (mgC/mgChl*a*•h) varied between 0.7 and 4.78. I_k (µE•m^{-2}•s^{-1}) was low, as has been observed previously in Antarctic waters, and varied between 20 and 84. The maximum quantum yield (Φ_m = molC assimilated per mol PAR absorbed) was calculated using α and the specific absorption coefficient of chlorophyll estimated from the regression between diffuse attenuation underwater light and chlorophyll plus phaeopigment concentrations. Φ_m varied between 0.019 and 0.089.
An analysis of variance showed that all these parameters were significantly different between stations, but not between depths. All values were distributed along a gradient, with the highest at stations near Elephant Island and the lowest near South Orkney Island.
This distribution is discussed in relation to the distribution of water masses and the phytoplankton composition. Warmer water characteristic of the Bransfield Strait was found in the western part (Elephant Island), in which *Nitzschia cylindrus* was the most abundant species. In the eastern part the water of Weddell Sea was modified by ice melting, and the most abundant species was *Corethron criophilum*.

Poster No. 23

Finenko, Z.Z.
Institute of Biology of South Sea, Ukranian Academy of Sciences, Sevastopol, Ukraine.

Mesoscale change of primary production estimated from knowledge of chlorophyll vertical profile and photosynthesis-light curve parameters.

Estimation of primary production has been carried on for the Black Sea, using the averaged monthly data on the space distribution of chlorophyll *a* and the photosynthetic intensity obtained during 1988-1990. For calculation of primary production, the data of 415 vertical profiles of chlorophyll and 108 sets of parameters derived from photosynthetic light experiments have been used. This information was used for the parameterization of the photosynthesis light curves and for the vertical pigments profiles for different

regions. The obtained parameters have been used for calculation of primary production for each of the four seasons. The results of systematic observation have made it possible to describe in detail the seasonal periodicity of production cycle.
Similar to other middle latitude seas, two maxima in the phytoplankton production were found: those are spring and autumn ones, the former being usually higher than the latter. Maximum production of phytoplankton in western part of the sea was observed in February-March, while that in inshore waters was in February.
Average annual production of the open sea is correspondingly, 125-150 g C m^{-2}. The horizontal distribution of primary production reveals a great inequality. Poorly productive central regions of the open sea taking about 50% of the area gave some 30% of total production; inshore waters and those of north-western part which take 15% of the total area gave more than half of the whole production.

Poster No. 24

Furuya, K.[1] & Li, W.K.W.[2]
[1]Faculty of Bioresources, Mie University, 1515 Kamihama, Tsu 514, Japan.
[2]Biological Oceanography Division, Bedford Institute of Oceanography, Box 1006, Dartmouth, Nova Scotia, Canada, B2Y 4A2

Evaluation of photosynthetic capacity of phytoplankton population by flow cytometry.

Applicability of flow cytometry was examined to evaluate photosynthetic capacity of phytoplankton population by detecting enhancement of chlorophyll-*a* fluorescence in DCMU (3-(3,4-dichlorophenyl)-1,1-dimethylurea)-poisoned cells. Distinct enhancement was observed in the cultures tested, and significant positive correlations were found between photosynthetic capacity and the magnitude of the enhancement (ERF) expressed as a ratio of enhanced fraction to the fluorescence with DCMU. The relationship was dependent on species and growth irradiance: the regression coefficient ranged more than five times according to species, and cells under light-saturated growth showed lower ERF than light-limited cells, although the former had higher photosynthetic capacity than the latter. Furthermore, there was a strong instrumental dependence in the ERF. A FACS analyzer fitted with mercury-cadmium arc lamp produced distinct ERF, whereas a laser-based flow cytometer yielded little ERF. The magnitude of the ERF was sensitive to excitation intensity. The variability in the ERF will be discussed in relation to its practical use in the field. The method was applied to natural assemblages during spring bloom in Bedford Basin, and temporal variations of the ERF of dominant diatom species and cryptophytes were well documented.

Poster No. 25

Goes, J.I., Gomes, H. do R. & Parulekar, A.H.
Biological Oceanography Division, National Institute of Oceanography, Dona Paula 403004, Goa, India

Evidence of high rates of dark $^{14}CO_2$ fixation in a tropical oceanic environment.

We provide evidence from three recent oceanographic cruises in the Bay of Begal (northeastern Indian Ocean) which suggesting that rates of uptake of ^{14}C in the dark constitute a significant fraction of total CO_2 assimilation in the euphotic layer. In some instance, the average uptake rates of ^{14}C in the dark far exceeded those in the light. When expressed as a percentage of light uptake, rates of dark uptake were much higher in less productive waters. Below the euphotic layer too, rates of dark uptake were significant. A substantial fraction of dark fixation of CO_2 was attributable to organisms in the picoplankton size range. The kinetics of dark uptake in samples from the euphotic and disphotic zones are examined and possible implications for carbon flux are discussed.

Poster No. 26

Goldman, J.C.
Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA

Potential role of large oceanic diatoms in new primary production.

Very large phytoplankton species >50 μm in size, particularly diatoms, generally are found in background numbers throughout the euphotic zone of oceanic waters. Yet, when responding to episodic injections of new nutrients across the nutricline at the base of the euphotic zone these phototrophs may make a disproportionately large contribution to new primary production. To test this concept, we isolated a group of large diatoms from the Sargasso Sea and found that the specific growth rate of several of these species in culture was great enough at the .2% light level in oligotrophic waters to meet the requirements of several hypothetical scenarios in which annual rates of new production from the sum of one or more episodic blooms were equal to contemporary estimates. Two of the fast-growing species, *Stephanopyxis palmeriana*, and *Pseudoquanardia recta* v. Stosch, formed giant flocculant masses while growing. Such masses could sink rapidly out of the euphotic zone or be a direct food source for invertebrates or fish higher up the food chain. Not only would a short, simple trophic system with low losses result, but the events would virtually be impossible to observe with conventional sampling.

Poster No. 27

Gostan, J.[1], Fiala, M.[2], and Nicolas, E.[3]
[1] Observatoire Océanologique de Villefranche, Station Zoologique, URA 716, BP 28, 06230 Villefranche-sur-mer, France.
[2] Observatoire Océanologique de Banyuls, URA 117, 66650 Banyuls-sur-mer, France.
[3] Observatoire Océanologique de Villefranche, Laboratoire de Physique et Chimie Marines, URA 353, BP 8, 06230 Villefranche-sur-mer, France.

Effect of incubation duration on the estimation of the P *vs* I curve parameters.

Using cultures (*Isochrysis galbana*), P *vs* I curves were determined (^{14}C incorporation) as a function of incubation duration (T) under the same light and temperature conditions. An increase in T led systematically to a decrease in P. Samples, also, were collected at 0.2% PAR in the Mediterranean Sea (MEDIPROD VI, 1990), and exposed to different irradiances (37, 315, 1050 and 2088 $\mu E \cdot m^{-2} \cdot s^{-1}$) up to 10 h. The carbon fixation rate ($P=DPM \cdot ml^{-1} \cdot h^{-1}$), the numerical density of chlorophyll-containing particles (N; size ≥ 2 μm) and their fluorescence (F) were monitored every 2 h (N and F by flow-cytometry). The results allowed to distinguish two different phases: T ≤ 4h and T ≥ 4h. During the first phase P was constant and negligible at strong irradiances; during the second phase P generally increased, except for the lowest irradiance, where there was no change.
The results show that there is a delay of about 4h before photoacclimation overbalance photoinhibition and photooxidation. The delay observed by Lewis *et al.* (1983) was shorter and there was no delay (up to 6h) in Vermij *et al.* (1985) works. More monitorings of N,F and P under different intensities and environmental conditions, are necessary in order to improve our knowledge on the time-scales of photoacclimation and photoinhibition.

Poster No. 28

Granèli, E.[1], Anderson, D.M.[2], Maestrini, S.Y.[3] & Paasche, E.[4]
[1]Department of Marine Ecology, University of Lund, Box 124, S-221 00, Lund, Sweden.
[2]Biology Department, Redfield 3-32, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
[3]CREMA-L'Houmeau (CNRS-IFREMER), BP 5, F-17137, L'Houmeau, France
[4]Department of Marine Botany, Biology Inst., University of Oslo, P.O. Box 1069, Blindern, N-0316, Oslo 3, Norway.

Light and dark carbon fixation by the marine dinoflagellate genera *Dinophysis* and *Ceratium*.

The marine dinoflagellate genus *Dinophysis* includes commercially important species that are the causative agents of Diarrhetic Shellfish Poisoning (DSP). Since it has not been possible to maintain *Dinophysis* species in culture, it may be that they are mixotrophic, utilizing dissolved or particulate organic matter as their carbon, nutrient or vitamin source. We have investigated inorganic carbon fixation (^{14}C-method) in several species of *Dinophysis*, and compared their fixation rates with those of common phytoplankton species belonging to the genus *Ceratium*, known to be autotrophic. Experiments were conducted in the Gullmarfjord (Swedish Skagerrak coast) in August 1991 during a period of mixed diatom-dinoflagellate plankton. Nutrient enriched (to ensure that carbon uptake was not nutrient limited) surface water samples were incubated in 1.5 l polycarbonate bottles with a high amountof inorganic ^{14}C (1 µCi/ml) in a tank with natural illumination. Individual cells of the desired species were manually isolated under a microscope and transferred to scintillation vials. Autotrophic *Ceratium*-species (*C. macroceros*, *C. furca* and *C. tripos*) showed net ^{14}C-uptake only during light periods, while in darkness there was a decrease in cell carbon. For *Dinophysis acuminata* and *D. norvegica*, however, net carbon uptake occurred with light and dark periods. Biomass specific rates of carbon uptake ($pgC \cdot pgC^{-1} \cdot h^{-1}$) in darkness for the *Dinophysis* species were significantly higher than for *Ceratium* species ($p<0.05$ Mann-Whitney U test). When exposed to light, *Ceratium macroceros* and *Dinophysis acuta* had the highest specific carbon uptake, up to 0.02 $pgC \cdot pgC^{-1} \cdot h^{-1}$. All other species had light fixation values below 0.01 $pgC \cdot pgC^{-1} \cdot h^{-1}$. Although *Dinophysis*-species did not show a systematically lower carbon fixation in light compared to *Ceratium*-species, the positive dark carbon fixation in *Dinophysis* suggest a mixotrophic mode of nutrition. This could involve uptake of dissolved organic substances released directly from the phytoplankton assemblage or as a result of grazing, or phagotrophy (ingestion of bacteria or phytoplankton that accumulated the ^{14}C label).

Poster No. 29

Happey-Wood, C.M.
School of Biological Sciences, University College of North Wales, Bangor, Gwynedd, LL57 2UW, United Kingdom

Bacteria and phytoplankton interactions: effects on the productivity of "new" carbon by picoplankton.

Measurement of picoplankton primary production in Llyn Padarn, an upland lake, using ^{14}C-methodology has shown that the contribution of the smallest cell-sized algae, the picophytoplankton <2µm, is important. This contribution varies between 2 and 68% of the total production per day and may reach higher levels, up to 80% of the total primary production for short periods, particularly towards the end of the day. Determinations of picophytoplankton production depend on measurement of ^{14}C incorporated into cells <3µm - >0.2µm retained on Nuclepore filters and thus include "new organic carbon" incorporated into minute autotrophic algae and "^{14}C-labelled extracellular carbon" released from the entire phytoplankton population which has been taken up by bacteria during the incubation period. Recent investigations have demonstrated that such bacterial uptake of EOC varies during the day and contributes an average of 60% of the "new" carbon incorporated into picoplankton over 24h in August and September. Maximum rate of uptake of ^{14}C EOC by bacteria occurred between 15-18h in September at 4m depth when this bacterial contribution to particulate picoplankton production was 14 mgC m^{-3} h^{-1}. This rate of production was eight times greater than that of photosynthetic picoplankton, and was equivalent to almost 70% of the total particulate phytoplankton production. Thus accepted values of picophytoplankton production in aquatic ecosystems are overestimations and should be corrected for the impact of the bacterial contribution to picoplankton carbon production via recycling of EOC from the phytoplankton.

Poster No. 30

Hartig, P. & Pahl-Wostl, C.
Swiss Federal Institute of Technology Zurich, Umweltphysik, c/0 EAWAG, Ueberlandstrasse 133, CH-8600 Dübendorf, Switzerland

Response of phytoplankton photosynthesis to fluctuating light regimes.

In order to simulate the effect of vertical mixing on the light environment of phytoplanktonic algae, algae derived from natural populations and from cultures were exposed to fluctuating light regimes with a time scale of 10 s to 60 min in a newly developed photosynthetron. These fluctuating light regimes were set to correspond to situations involving different values of the ratio of euphotic depth to mixing deoth, including values less than and greater than unity. Light fluctuations were simulated mechanically by a computer-controlled servo-system. Carbon fixation rates were estimated using the ^{14}C method.
Despite the high variability of the light intensity during the experiments (zero to 3000 µmol quanta$\cdot m^{-2}\cdot s^{-1}$), the temperature remained constant to within ± 0.5°C. Another great advantage of the new photosynthetron is that productivity rates can be measured simultaneously under 6 different light regimes with 4 parallel experiments for each regime, thus allowing a statistically meaningful comparison of algal production rates under the same physiological conditions.
Experimental data obtained from photosynthetron experiments were used to verify the dynamic model DYPHORA (Pahl-Wostl and Imboden, 1990). This model accounts for the dynamic response of algal photosynthesis on two time scales: induction phenomena occur on a time scale of minutes, effects of inhibition occur on a time scale of hours.
The difference in the efficiency of the utilization of light quanta as a function of different light regimes is explained by taking into account the dynamic behaviour of photosynthesis.

Poster No. 31

Häse, C. & Tilzer, M.M.
Limnologisches Institut, Universität Konstanz, Postfach 5560, D-7750, Konstanz 1, Germany

Photosynthesis-irradiance parameters in phytoplankton: implications for productivity estimates in Lake Constance.

In Lake Constance, parallel measurements of primary production were carried out in situ and in an incubator during the years 1986-88. The experiments allowed the prediction of only one of the parameters of the P-vs-E-curves with satisfactory accuracy: the light-saturation-parameter P^B_{max} could be estimated after calculation of a Q_{10} for temperature-correction based on the data set. However, the prediction of the light-limitation-parameter, the initial slope α^B of P-vs-E-curves requires further investigation. Use of the incubator values resulted in an average underestimation of primary production of about 20%. More detailed experiments will enable us to separate the influence of light harvesting and quantum yield of photosynthesis.

Poster No. 32

Hoepffner, N., Barker, T. & Schlittenhardt, P.
Commission of the European Communities, Joint Research Center (JRC), Institute for Remote Sensing Applications, I-21020 Ispra (Va), Italy.

Marine productivity in the Northeast Atlantic: estimation from satellite data.

As part of the JRC marine research activities, a model of phytoplankton productivity has been implemented and applied to an area off Northwest Africa, characterized by a strong upwelling activity.
In the model, the daily rate of photosynthesis in the water column is computed through its known dependence on available light and biomass. Irradiance at sea surface is computed from a spectral atmospheric radiative model, adapted for oceanographic applications. The model takes into account the spectral composition of the underwater light field, as well as the vertical distribution of biomass which is derived from Coastal Zone Colour Scanner (CZCS) data. Results are obtained in terms of new and total production.
The advantages and the reliability of such type of model to monitor phytoplankton productivity in highly dynamic coastal areas are discussed.

Poster No. 33

Khondker, M.
Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh.

Phytoplankton production in a well mixed column of water from the humid sub-tropical Bangladesh.

Studies on the estimation of daily primary productivity by phytoplankton of a well mixed pond have been conducted for one year. Light mediated photosynthesis, depth profiles of temperature, chlorophyll *a*, productivity and vertical attenuation coefficient and Secchi depth and euphotic depth were measured and presented graphically over the four major seasons of Bangladesh. From the data of daily productivity, an estimation of its annual figure has been done.
Studies on the phytoplankton primary productivity in Bangladesh are still confined in freshwater sectors. However, the research technique which has been developed here can be applied to the marine habitats of the country with little changes.

Poster No. 34

Koblentz-Mishke, O.
Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia.

Quantum yield (QY) of photosynthesis of marine phytoplankton measured in natural conditions.

More than 400 data on QY were obtained in joint Russian-Polish expeditions to Baltic and Black Seas using results of measurements of primary production *in situ*, underwater light energy and its absorption by pigments. Light dependence of QY was analysed separately for stations accomplished in mesotrophic and eutrophic waters. In both cases QY decreased by roughly one order of magnitude in passing from the lower boundary of the euphotic layer to the sea surface. In the middle part of this layer QY was about constant, being twice higher in mesotrophic waters than in eutrophic ones both under the conditions of threshold and under the conditions of inhibiting light.
The results obtained are useful for evaluation of errors of methods, for ecological analysis of productivity process, as well as for working out methods for evaluation of primary production both from ships and from space.

Poster No. 35

Kononen, K., Grönlund, L. and Lahdes, E.
Finnish Institute of Marine Research, P.O. Box 33, SF-00931, Helsinki, Finland.

Evaluation of the nutrient control hypothesis of the filamentous cyanobacteria blooms in nutrient recycling ecosystem in the central Gulf of Finland, Baltic Sea.

Filamentous, nitrogen-fixing cyanobacteria bloom development was followed in July-August 1990 in a hydrographically defined, stratified basin in the central Gulf of Finland, Baltic Sea. Hydrography, dissolved inorganic, particulate and total nutrients, chlorophyll *a*, phytoplankton, ^{32}P-uptake and alkaline phosphatase activity were measured twice a week. The study period was characterized by two major wind-induced mixing events followed by remarkable nutrient pulses, the first one with DIN:DIP ratio 19 and the second without phosphorus. Different plankton community responses were resulted from these events. Most of the inorganic phosphorus uptake was in the smallest plankton size fraction (<2μm) and the phosphorus pulse was mainly accumulating into the DOP fraction. The results allow us to revise the hypothesis according to which surplus inorganic phosphorus in the upper mixed layer after the vernal phytoplankton bloom is the triggering factor for cyanobacterial blooms in the Gulf of Finland. The bloom of filamentous, nitrogen-fixing cyanobacteria *Aphanizomenon flos-aquae* was found to be primarily a result from the temporal uncoupling of the physically forced nutrient pulse and the ability of the microbial loop to adapt to the new level of nutrient cycling and to lesser extent the ability of the species for nitrogen-fixation.

Poster No. 36

Kromkamp, J.
Delta Institute for Hydrobiological Research, Vierstraat 28 4401, EA Yerseke, The Netherlands.

The influence of vertical mixing on the photosynthesis and primary production of a marine diatom: a culture study.

Vertical mixing in a light-limited continuous culture was simulated by means of computer controlled "Venetian blind" system. The cultures of *Skeletonema costatum* were submitted to equal daily light doses, but the way in which they received the light was different, i.e. one of the cultures received a sinusoidal light climate, whereas another culture had superimposed on this light regime a pattern of vertical mixing through a steep light gradient. As a result, the cultures showed different photosynthetic characteristics and light harvesting capabilities. For instance, the absorption cross section (m^2 mg chl^{-1}) and α per unit chlorophyll was higher i the culture which simulated vertical mixing, whereas this culture showed a lower photosynthetic unit size. No change in photosynthetic parameters were observed in the culture with only the sinusoidal light climate. The culture simulating vertical mixing on the other hand showed changes in some P/I-characteristics.
The results are discussed with reference to estimates of measurements of primary production in a vertically mixed water column.

Poster No. 37

Krupatkina, D.K.
Institute of Biology of South Sea, Ukranian Academy of Sciences, Sevastopol, Ukraine.

The influence of frontal zones of east tropical Atlantic upon the vertical distribution of chlorophyll and primary production.

The vertical distribution of chlorophyll and primary production was determined at 35 stations within the areas of seven frontal zones of various origin in September to November 1989. Maximum values of chlorophyll (60-73 $mg \cdot m^{-2}$) and production (1.7-1.8 $gC \cdot m^{-2} \cdot d^{-1}$) were found to be within the frontal zones at Cape Blanc and Angola cyclonic rotation. Two typical chlorophyll profiles are shown within the frontal zones: the feebly marked chlorophyll maximum in surface layer and the deep chlorophyll maximum (DCM) at the upper border of thermocline where the average light intensity was 5-12% of surface illumination. Also marked are two typical profiles of production: the first, with maximum production (P_{max1}) in the layer of 0-10 m only and the second, within which, parallel to P_{max1}, there is also P_{max2} at the upper border of thermocline, twice as great as P_{max1}. Under the influence of the frontal zones, the DCM usually rises to more illuminated layers, its thickness decreases, and the concentration of chlorophyll in it increases. The influence upon the production shows itself in minimum production (P_{min}) going down to less illuminated layers (0.5% of light intensity), increase of P_{max1}/P_{min} proportion, and appearance of diatom bloom in the layers whose contribution to production is maximum one (60-90%).

Poster No. 38

Kyewalyanga, M.
Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1.

Ocean primary production calculated by spectral and broad-band models.

Water-column primary production was determined by the *in situ* method during the spring bloom in the North Atlantic Ocean. For the same samples, the parameters of the photosynthesis-light (*P-I*) curve were determined in broad-band light, and in narrow spectral bands for construction of the action spectrum. Using these parameters, with information on the vertical distribution of chlorophyll, measurements of light absorption by particulate materials, and data on surface irradiance, water-column production was calculated using four different production models.
When compared to *in situ* primary production measurements, the results show that the spectral model, Model 1, is the best estimator of water-column primary production. Model 2 which used broad-band α^B (the initial slope of *P-I* curve, normalized to biomass *B*) with light integrated over wavelength, and Model 4 (broad-band α^B and broad-band light), consistensly underestimated production by about 25% and 60% respectively. However, Model 3 (in which light is computed using a depth-averaged attenuation coefficient, $\overline{K}$, and in which α^B is assumed to be wavelength-independent) gave water-column primary production estimates not significantly different from *in situ* values.
It is recommended that the spectral model should be applied, whenever possible, in the computations of water-column primary production. If, however, broad-band α^B has to be used in the calculations, it is suggested that light at depth be computed if possible using $\overline{K}$. The use of the full broad-band model, Model 4, is not recommended. This is because the model gave strongly biased estimates of water-column primary production relative to the observed values.

Poster No. 39

Latala, A.
Institute of Oceanography, University of Gdansk, Pilsudskiego 46, 81-378 Gdynia, Poland.

The characteristic of photosynthetic activity of Baltic phytoplankton.

At the base of different ecosystem productivity lie the specific photosynthetic activities of individual plant species as well as plant communities. The determination of irradiance-photosynthesis curves enables the precise characteristic of these activities.
The irradiance-photosynthesis curves in net phytoplankton and nanoplankton collected from the surface water of the Gulf of Gdansk in the period of April to December were determined by the microvolumetric method. The measurements of the gas exchange rates were carried out in the laboratory, 2-3 hours after sample collection and at the same temperature as in the field. All measurements were performed in 4 replicates. If necessary, the zooplankton species were removed from the samples of biomass about 0.5 mm^3. Then the samples were fixed with Lugol solution to examine their species composition and calculate the biomass using geometric formulas. In June and July when nanoplankton made a relatively great part of phytoplankton samples, the irradiance-photosynthesis curves were determined also for nanoplankton. Photosynthesis and respiration were expressed in $\mu l\ O_2 \cdot h^{-1}\ mm^{-3}$ and $\mu l\ O_2 \cdot h^{-1}\ \mu g^{-1}C$, respectively. The measurements of PAR irradiance were carried out in the microrespirometer using the LI-COR 185 quanta meter and expressed in $\mu E \cdot m^{-2} \cdot s^{-1}$.
Photosynthesis was saturated at about 120-150 $\mu E \cdot m^{-2} \cdot s^{-1}$ and in autumn at about 60 $\mu E \cdot m^{-2} \cdot s^{-1}$. The highest light intensities used (ca. 725 $\mu E \cdot m^{-2} \cdot s^{-1}$) strongly inhibited the photosynthetic rates. The seasonal changes in compensation point (min. in December: 3.5 $\mu E \cdot m^{-2} \cdot s^{-1}$, max. in July-August: 40 $\mu E \cdot m^{-2} \cdot s^{-1}$), E_k value (min. in December: 25 $\mu E \cdot m^{-2} \cdot s^{-1}$, max. in June-July: 95 $\mu E \cdot m^{-2} \cdot s^{-1}$), maximum photosynthetic rate (min. in November: 0.67 $\mu l\ O_2 \cdot h^{-1}\ mm^{-3}$, max. in May-June: 4.22 $\mu l\ O_2 \cdot h^{-1}\ mm^{-3}$) and respiration (min. in November-December: -0.06 $\mu l\ O_2 \cdot h^{-1}\ mm^{-3}$, max. in August: -2.06 $\mu l\ O_2 \cdot h^{-1}\ mm^{-3}$) were determined. The photosynthesis and respiration rates in nanoplankton were about 10 times higher than in net phytoplankton. The above mentioned changes of photosynthesis and respiration are discussed against a background of phytoplankton species composition.

Poster No. 40

LeBouteiller, A.
ORSTOM, B.P. A5, Noumea, New Caledonia

Distribution of phytoplankton in the largest productive system of the world ocean: The Pacific equatorial upwelling.

At 165°E in April 1988, in the presence of a relatively low phytoplankton biomass (chlorophyll *a*=14.5 $mg \cdot m^{-2}$ in the euphotic zone), primary production of the equatorial upwelling was 1.6 $gC \cdot m^{-2} \cdot day^{-1}$ on the average (8 days of intensive *in situ* measurements, PROPPAC 2 cruise). This mean value was corroborated by other direct or indirect estimates of the production which were obtained in similar biological and environmental conditions.
Then, a crucial question is the following one: is the situation described during PROPPAC 2 representative of the whole Pacific equatorial upwelling? To answer this question, a wide study of the distribution of phytoplankton and physical and chemical properties was performed during ALIZE II cruise stretching all

along the equator from 95°W to 165°E (January and February 1991).
As previously observed, the equatorial enrichment area covered a belt more than 11000 km long, with surface nitrate concentration up to 11 µM near the Galapagos, decreasing westward and disappearing beyond 167°E.
In spite of this zonal gradient, the amount of surface chlorophyll *a* (Chl*a*) did not change significantly from one end of the upwelling to the other, and was very low everywhere: Chl*a* = 0.22 $mg \cdot m^{-3}$ in the east (n=55 profiles) and Chl*a* = 0.22 $mg \cdot m^{-3}$ in the west (n=31). These values are quite similar to those observed at 165°E during the 6 transects of the PROPPAC abd SUBTROPAC programmes which have crossed the equatorial upwelling since 1988: Chl*a* = 0.23 $mg \cdot m^{-3}$ (n=57).
During the ALIZE I cruise in 1965, covering the same area as ALIZE II, the equatorial upwelling presented nearly the same distribution. The mean surface Chl*a* was 0.19 $mg \cdot m^{-3}$ in the east (n=17) and 0.19 $mg \cdot m^{-3}$ in the west (n=13).
Similarly to surface Chl*a*, the mean Chl*a* content of the euphotic layer was respectively 13.1 and 13.8 $mg \cdot m^{-2}$ in the eastern and western parts of the Pacific in 1991, and 14.3 $mg \cdot m^{-2}$ at 165°E.
More surprisingly, the size structure of chlorophyll *a* was also nearly constant from 95°W to 167°E: Chl*a*>3µm represented 27% and 28% of total Chl*a* in the east and west respectively, and Chl*a*<1µm=39% on the average all along the equator. These size distributions are not different from those observed at 165°E in the western equatorial upwelling.
Besides, counts of cells by epifluorescence microscopy performed by Jean BLANCHOT at 48 hydrocasts revealed that the euphotic zone contained on the average 4.2×10^{11} cyanobacteria per m^2 and 2.1×10^{11} eucaryotic microalgae per m^2, without any bloom anywhere.
Schematically, in spite of the typical longitudinal gradients of temperature and nutrients showed by the equatorial transects of both ALIZE I and ALIZE II cruises, all the biomass indexes available today clearly indicate that an extreme monotony characterizes the distribution of phytoplankton all along the enrichment area due to the equatorial upwelling, covering 11 million Km^2 for mean conditions.
Hence, primary production could also be extremely monotonous within the whole system.

Poster No. 41

Legendre, L., Klein, B., Mingelbier, M. & Tamigneaux, E.
GIROQ, Département de biologie, Université Laval, Québec, Canada, G1K 7P4
(FAX:418-656-2339; OMNET:l.legendre)

Measuring primary production at sea: Potential problem with 24-h incubations using the ^{14}C method.

In *JGOFS Core measurement protocols*, it is recommended to conduct 24-h dawn-to-dusk incubations for estimating daily rates of primary production by the ^{14}C method. However, given the constraints of navigation, it is not always possible to start *in situ* or simulated *in situ* incubations at dawn, especially when an extensive grid of stations must be sampled. If phytoplankton production is estimated from changes in oxygen concentration in light and dark bottles, values should be the same irrespective of the time of the day when the incubation started. This is not the case, however, if primary production is estimated from the uptake of ^{14}C. Thsi is because the amount of labelled organic compounds lost during the dark hours will vary, for an identical rate of exudation and respiration, from maximum when the incubation is started at dawn to almost nil if the incubation is started at dusk. The significance of this potential problem was assessed at sea, and practical solutions are proposed for field incubations.

Poster No. 42

Legrand, C.[1] & Malinsky-Rushansky, N.Z.[2,3]
[1]Centre de Recherche en Ecologie Marine et Aquaculture de l'Houmeau (CNRS-IFREMER), B.P. 5, L'Houmeau, France 17137.
[2]Israel Oceanographic & Research, Kinneret Limnological Laboratory, P.O. Box 345, Tiberias, Israel 14105.
[3]Department of Life Sciences, Bar Ilan University, Ramat Gan, Israel.

Organic production and excretion by different phytoplankton size classes.

Excretion rates of photosynthetic products by different classes of phytoplankton are difficult to compare, partially because of different assay techniques or laboratory instruments. The purpose of this research is to compare the carbon fluxes between nano- and picoplanktonic eukaryotic algae from salt ponds and lake water respectively, using identical techniques and laboratory equipment. Photosynthetic particulate organic carbon assimilation (POC) and excretion of dissolved organic compounds (DOC) by the algae as well as the subsequent bacterial assimilation and respiration were measured by the ^{14}C technique using differential filtration. The percentage of extracellular release (PER) of dissolved organic compunds was lower (3.3-5.0%) for larger algal cells than for the picoeukaryotes (10.9%). PER of a natural mixed salt pond phytoplankton population was intermediate (9.7%), while maximal values for the picoplanktonic natural freshwater fraction was 8%. Bacterial assimilation of the DOC released by the algae under these growth conditions seems to be related more to algal species than to biovolume, although there may also be an effect of the different and specific bacterial assemblages. The remineralisation of the total DOC respired to CO_2 was higher for the freshwater (18.3%) than for the salt pond (7.3-16.3%) populations. Great variations were found in the respiration rates of natural bacteria from DOC excreted by the freshwater picoalgae (94%) and from these excreted by the nanoplanktonic salt pond algae (0-59%). Our results show that bacterial assimilation and mineralisation of DOC contributes actively (irrespective of phytoplankton biovolume) to the carbon flux in freshwater and in marine environments. Higher bacterial respiration rate and higher picoplankton excretion rates were observed in freshwater, suggesting a relatively higher flux of carbon by this pathway in freshwater than in salt water. Our results also show that assimilation of CO_2 by algae, measured by the ^{14}C technique, can be misevaluated if the amounts of extracellular release, as well as the percentage of bacterial assimilation and mineralisation are ignored.

Poster No. 43

Levasseur, M.E. & Demers, S.
Institut Maurice-Lamontagne, Ministére des Pêches et des Océans, C.P. 1000, Mont-Joli, Québec, Canada G5H 3Z4

The fate of silicate-limited diatom blooms: sinking or grazing?

We tested the hypothesis that silicate-limited diatom blooms sink rapidly out of the photic zone. The sampling was conducted in the St. Lawrence Estuary during a period of low silicate concentrations and high diatom biomass. We determined at 4-h intervals the biomass and physiological characteristics of plankton collected: 1) with a GO-FLOW water bottle at 3 m depth in a water mass followed with a buoy, 2) with sediment traps moored at 8 m depth in the water mass, and 3) in 3 m water pumped to an onboard 200 l tank (control for sinking and grazing by macrozooplankton). In the awter mass, chlorophyll *a*

concentrations in the >5 μm size fraction (mostly diatoms) decreased from 10 to 1 μg l^{-1} during the 3-day sampling period. In spite of the low ambient silicate level, no relationship was found between the chlorophyll *a* sedimentation rate and the nutritional status of particles (internal nutrient pools, C:N ratio) collected at 3 m and in the traps. The decrease in chlorophyll *a* level was accompanied by an increase in paheopigment concentrations, suggesting that the diatom bloom was mostly grazed *in situ* by copepods. In the absence of sinking and grazing pressure (results from the tank), the abundance of diatoms increased regularly and diatoms became silicate-deficient (low P^B_{max} and high C:N ratios). These results indicate that zooplankton grazing may prevent Si-limitation in diatom populations by decreasing their biomass and their silicate demand.

Poster No. 44

Marra, J.
Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964, USA

Verification of a simple optical model for the estimation of daily primary production: examples from various ocean environments.

A model based on the absorption properties of phytoplankton and the quantum yield is used to evaluate optical predictions of daily primary production in coastal, temperate and subarctic marine environments. The primary source of variation among these is in the parameterization of the quantum yield with respect to irradiance.

Poster No. 45

McGlade, J.[1], Bauer, P.[2], Gaito, S.[1], Marshall, J[1]. & Winter, D.[1]
[1] Theoretical Ecology Group, Forschungszentrum Jülich, Germany.
[2] German Aerospcae Research Establishment, Space Systems Analysis Group, DLR, HA-SR, Köln, Germany.

Modelling primary production in the mid north Atlantic: a comparison of model simulations of phytoplankton growth with NOAA AVHRR images.

A 2-dimensional spatial model of phytoplankton growth is compared to the development of a plankton bloom observed in the mid north Atlantic in May 1990 via satellite images and shipboard measurements. The model consists of a 2-dimensional spatial PDE extension of a simple ODE model of the interaction of phytoplankton, zooplankton and bacterial populations. The ODE model is based on a simple nitrogen budget which uses separate nitrate, ammonium and DON compartments, a variable mixed layer depth and an incident PAR which varies with cloud cover, time of day/year and latitude. The 2-dimensional PDE model models the effects of simple diffusion, turbulent (well mixed) diffusion and current flow. The effect of cloud cover , small scale turbulence (local mixing) and uniform currents are compared to the behaviour of the bloom observed via NOAA AVHRR satellite in April-June 1990.

Poster No. 46

Minier, C.[1], Galgani, F.[1] & Robert, J.M.[2]
[1]IFREMER, Rue de l'Ile d'Yeu, 44037 Nantes, cedex, France
[2]Laboratoire de biologie marine, Faculté des Sciences et Technologies, 2 Rue de la Houssiniére, 44072 Nantes, cedex 03, France

***In vivo* characterisation of esterase activity in *Synechococcus* PCC 7601, *Haslea ostrearia* and *Prorocentrum micans*.**

Esterase enzymatic activity can be measured *in vivo* by the fluorescein diacetate (FDA) method as a tool for evaluating cell metabolic activity (Thoren, 1989; Dorsey, 1989). This method associated with a 96-well microtiter plate reader confers rapidity and statistical accuracy (Galgani, 1991; Gilbert, 1991).
Consequently basic biochemical and physiological properties of the esterase activity can be evaluated under natural conditions. In our study the properties of the enzyme have been determined for *Synechococcus* PCC7601, *Haslea ostrearia* and *Prorocentrum micans*.
First, kinetic-parameters (k_m and V_{max} per cell) were determined using different methods, including iterative determinations, Lineweaver-Burk and Eadie-Hofster transformations.
Then, the link between enzyme reaction and the physical and metabolic state of the cell has been evaluated. Specific activity on relation with the growth, circadian rhythms, influenceof parameters such as temperature and the presence of different compounds in the culture medium were investigated.
The results show the adequacy of such measurements as a tool for evaluating metabolic state of the three species. The oceanographic and environmental implications of such results are discussed.

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Poster No. 47

Moncoiffe, G. & Savidge, G.
The Queen's University of Belfast, Marine Biology Station, The Strand, Portaferry, Co. Down, BT221PF, Northern Ireland, UK.

Seasonal variation of metabolic rates from size-fractionated planktonic communities by in-bottles oxygen method.

Since April 1991, a routine study of planktonic coomunities metabolism has been carried out at a fixed station in the Ria de Vigo (northwest of Spain). Twice a week, net production and respiration rates of size fractionated community have been estimated in situ, over 24 hours, using the oxygen light:dark bottles technique. Oxygen measurements have been performed by an automated microprocessor controlled Winkler titrator system.
The study will be achieved in November 1991, but from April to September it has covered several phytoplankton blooms correlated with north wind occurrences well known to generate deep water upwelling on the Galician shelf in spring and summer. Nutrient pulses in the ria confer on it high production levels. In unfractionated samples, the mean net production value in surface was 41 µmol $O_2 \cdot l^{-1} \cdot d^{-1}$ with maxima obtained in May and September: 130 and 120 µmol $O_2 \cdot l^{-1} \cdot d^{-1}$. September high production corresponded with red tide characteristics: green-brown water colour, high chlorophyll *a* concentration (18 $\mu g \cdot l^{-1}$) and toxin alert in the ria. The mean respiration value in surface was 16 µmol $O_2 \cdot l^{-1} \cdot d^{-1}$ and maxima were obtained in summer (43 µmol $O_2 \cdot l^{-1} \cdot d^{-1}$) and in September (40 µmol $O_2 \cdot l^{-1} \cdot d^{-1}$). In average, 65% of the whole community respiration were attributable to the <10 µm size fraction and 96% of the net production to the fraction >10 µm.
Backed up with hydrographic and phytoplankton taxonomic observations, the data will be treated with special reference to metabolic differences between contrasting phytoplanktonic populations (diatoms or dinoflagellates dominated) which succession is established by superimposition of seasonal and upwelling cycles.

Poster No. 48

Partensky, F.[1], Hoepffner, N.[2] & Li, W.K.W.[3]
[1]Station Biologique, BP74, 29682 Roscoff cedex, France
[2]Institute for Remote Sensing Applications, Centro Comune di Ricerca, 21020 Ispra, Italy
[3]Bedford Institute of Oceanography, Biological Oceanography Division, Dartmouth, Nova Scotia, B2Y 4A2, Canada

Photoacclimation of marine *Prochlorococcus* sp. (Prochlorophyta) in culture.

Several unialgal strains of the marine prochlorophyte *Prochlorococcus* sp., one (MED strain) isolated from the Mediterranean Sea and two (SARG and NATL-1 starins) from the North Atlantic Ocean, were grown under a range of white light irradiances (I_g). All three strains contained divinyl-chlorophylls *a* and *b*, a chlorophyll c-like pigment, zeaxanthin and α-carotene. They all responded to decreasing I_g: 1) by an increase of their div.-chl *a* and *b* contents, 2) by an increase of their div.-chl *b* to *a* ratio and 3) by a decrease of their zeaxanthin content. However, the MED strain always had a low div.-chl *b* to div.-chl *a* ratio, varying between 0.14 at 7.5 $\mu E \cdot m^{-2} \cdot s^{-1}$ and 0.08 at 133 $\mu E \cdot m^{-2} \cdot s^{-1}$. In contrast, Atlantic strains had a high div.-chl *b* to div.-chl *a* ratio varying between 0.97-1.26 at low light and 0.41-0.53 at high light. Photosynthesis-irradiances curves were obtained for all strains using a photosynthetron. All strains showed photoinhibition of photosynthesis at high white irradiances (i.e. P^B decreased beyond I_{max}), but it was less pronounced in the MED strain than in the Atlantic strains. The MED strain had a P^B_{max} of 4.78 µg C(µg Chl)$^{-1}$ when grown at 67 $\mu E \cdot m^{-2} \cdot s^{-1}$, an intensity which seemed to saturate photosynthesis, while at the same I_g, SARG and NATL-1 strains had P^B_{max} of 2.47 and 1.36 µg C(µg Chl)$^{-1}$ respectively and were not light saturated (P^B_{max} was 5.58 and 2.27 µg C(µg Chl)$^{-1}$, respectively at 133 $\mu E \cdot m^{-2} \cdot s^{-1}$).

The large discrepancies in photoacclimational responses observed between isolates suggest that *Prochlorococcus* is a polygenetic complex. However, to determine whether such differentiation between populations results from geographical, seasonal and/or bathycal isolation needs further investigation.

Poster No. 49

Pazos, Y. & Figueiras, F.G.
Instituto de Investigacions Mariñas, CSIC. Eduardo Cabello, 6, 36208-Vigo, Spain.

Photosynthetic responses in relation to species composition and the environmental conditions in the Ria de Arousa.

A seasonal sequence of the photosynthetic response of natural phytoplankton populations has been studied through P-I curves and their derived parameters in relation to species composition and oceanographic conditions.
Samples were taken, from May to October 1989, at a station in the centre of the Ria de Arousa. The same sample was used to make ^{14}C incubations, chlorophyll analyses, phytoplankton counts, temperature, salinity, nutrients and elemental composition. Light profiles were determined by a LICOR sensor LI-190SZ.
Until now all P-I curves were fitted with r^2=0.99. The ranges of the derived parameters are:
α - (0.01-0.04) mgC [mgChl*a*]$^{-1}$ h^{-1} μE^{-1} m^{-2} s^{-1}
P_{max} - (5-10) mgC [mgChl*a*]$^{-1}$ h^{-1}
I_k - (180-700) μE m^{-2} s^{-1}
θ_{max} - (0.01-0.04) mol C assimilated [mol PAR absorbed]$^{-1}$
These results allow us to differentiate between populations dominated by red tide organisms from others dominated by diatoms. Both populations are described as characteristic of different physicochemical conditions in the medium.
We analyse the significance of these photosynthetic responses in relation to species composition and their living conditions in the medium.

Poster No. 50

Rodriguez, E.G.
Instituto de Estudos do Mar Alte Paulo Moreira, Rua Kioto, 253-28910-Arraial do Cabo-RJ, Brasil.

Yearly variation in primary productivity of marine phytoplankton from Cabo Frio (RJ, Brazil) region.

Light saturation curves of natural assemblages of phytoplankton at 4 stations in Cabo Frio coastal waters were examined and related to changes in environmental conditions. The study was based on 263 experiments carried out weekly during a two-year period. No differences in the specific productivity of saturating light (P^B_m) between stations were detected. Global mean value of P^B_m was 4.7 mgC•mgChl*a*$^{-1}$•h^{-1}, with a range from 0.50 to 24.8. Significant seasonal variations were not observed due to great variability. Correlation and regression analysis attributed most of P^B_m variation to temperature, salinity and the phaeopigment:chlorophyll *a* ratio.

Poster No. 51

Schmuck, G.[1], Schlittenhardt, P.[1], Van der Linde, D.[1] & Moya, I.[2]
[1] Commission of the European Communities, Joint Research Center (JRC), Institute for Remote Sensing Applications, Advanced Technologies, I-21020 Ispra (Va), Italy.
[2] LURE, University Paris, Orsay Ville.

Fluorescence induction of algae (*Scenedesmus obliquus*) as an indicator of photosynthetic activty.

The estimation of the primary production of the ocean by remote sensing requires carefully performed sea-truth measurements of the rate of photosynthesis. Up to now these studies were performed via the ^{14}C method and via oxygen measurements.
In our contribution we describe the comparison between oxygen electrode photosynthesis measurements on laboratory cultures of *Scenedesmus obliquus* with chlorophyll fluorescence signals detected with a modulated pulse amplitude fluorometer. This system allows the application of the saturation pulse method which reveals information in addition to that given by the standard "Kautsky curves", and which allows to work at steady state illumination. Several fluorescence parameters were confronted to the oxygen evolution in order to clarify the fluorescence/photosynthetic activity relationships. Our studies seem to prove that the O_2-methods can be replaced by the new fluorescence technique. The first results about the influence of the actinic light on the photosynthetic activity of algae will be presented (light saturation curves via fluorescence), followed by a discussion about modifications of the measuring system to be able to detect fluorescence signals from natural algae concentrations.

Poster No. 52

Stone, L. & Berman, T.
Israel Oceanographic & Limnological Research Ltd., The Yigal Allon Kinneret Limnological Laboratory, P.O. Box 345, Tiberias 14102, Israel.

A model for carbon flux in pelagic ecosystems.

A model which describes the fate and flux of photosynthetically fixed carbon throughout a simplified pelagic food web is described. Primary producers are divided into those which are directly grazed by metazoan zooplankton or fish and those which pass into a detrital pathway. Components of the microbial loop (bacteria, flagellates, ciliates) as well as herbivorous and predacious zooplankton and fish are included. A computer program for this model has been developed and examples with data from Lake Kinneret will be given. Despite its obvious oversimplicity, we submit that this model can be useful for examing the fate of carbon fixed by phytoplankton, relative importance of trophic relationships between planktonic organisms and the various patterns of carbon flux in aquatic ecosystems.

Poster No. 53

Van Spaendonk, A.
Delta Institute for Hydrobiological Research, NL-4401 EA Yerseke, The Netherlands.

Phytoplankton primary production in the Westerschelde Estuary, the Netherlands.

Data collected in 1989 show that phytoplankton primary production in the Westerschelde Estuary is controlled by the "column irradiance". From the 12 locations visited in 1989, 3 representative stations were selected for an intensive study of diurnal (light) and tidal (salinity) influences on photosynthetic characteristics. In May, June and September 1990 a five-day survey was made. At 3 locations (20, 25 and 30 ppt salinity) a 1m submerged drogue was followed during the day to investigate the diurnal cycle. On the remaining 2 days cross sections were sampled to study the tidal cycle.
The results demonstrate a clear diurnal variation, with decreasing α's and assimilation numbers in the afternoon. The cross section data show that phytoplankton populations, with different photosynthetic performance, can be very local. These findings have consequences for the calculation of daily primary production.

Poster No. 54

Vaulot, D., Partensky, F. & Casotti, R.
Station Biologique, BP74, 29682 Roscoff cedex, France

Application of flow cytometric and microfluorimetric DNA measurements to phytoplankton studies.

We have developed methods to measure cellular DNA in single phytoplankton cells using either flow cytometry or image analysis coupled with epifluorescence microscopy (microfluorimetry). These techniques have several applications.
1) Species/strain discrimination. Significant discrepancies in DNA contents have been detected among closely related species (e.g. *Gyrodinium* cf. *aureolum* and *Gymnodinium nagasakiense*) or strains (e.g. Prochlorophytes, *Phaeocystis pouchetti*).
2) Sexuality. In *Phaeocystis*, DNA measurements have allowed us to establish the sexual nature of the "microswarmer" stage of the life cycle. In contrast, colony formation was apparently not linked to sexuality. In *Gyrodinium* cf. *aureolum*, "small" cells, which coexist with normal-sized cells have been shown to be vegetative rather than sexual.
3) Limiting factor. By determining the distribution of cells of natural Prochlorophytes in the different stages of the cell cycle before and 24h after addition of traces of nitrates or ammonium, we have been able to establish the impact of nitrogen limitation on these populations in the Mediterranean Sea in winter.
4) Division rates. Daily time series of Prochlorophyte cell cycle distributions have allowed us to estimate *in situ* division rates in the Mediterranean Sea.

Poster No. 55

Vignault, C.[1], Demers, S.[2], Roy S.[1] & Gagnon, R.[2]
[1]INRS-Océanologie, 310 Allée des Ursulines, Rimouski, Québec, Canada, G5L 3A1
[2]Institut Maurice-Lamontagne, B.P. 1000, Mont-Joli, Québec, Canada, G5H 3Z4

Photo-protection in marine phytoplankton: implication of xanthophyll cycle and influence on algal fluorescence.

In marine phytoplankton, changes in pigments involved in the xanthophyll cycle and rapid fluorescence variations have been associated with photo-protection mechanisms. These adaptations potentially allow algae to accomodate rapid changes in the light field and permit cells to elaborate longer-term mechanisms of photo-protection such as regulation of pigment content and composition. In the present study, different species were tested in order to determine the light level threshold at which cells start up the photo-protective mechanism and the time course of the reaction. Cells were acclimated to 3 different light conditions and tested at 11 light levels. The results suggest that the threshold is a function of the light acclimation and the species involved.

Poster No. 56

Weichart, G.
Bundesamt für Seeschiffahrt und Hydrographie, Postfach 30 12 20, 2000 Hamburg 36, Germany

Estimation of primary production in the open sea from changes of O2, CO2 and nutrients in the upper mixed layer.

In spring 1976, the International "Fladen Ground Experiment (FLEX '76)" was carried out in the northern North Sea. During most of the observation time, when the research vessel was keeping close to the central position, the influence of patchiness and advection by currents was relatively small. Under such favourable conditions it was possible to follow the temporal changes and processes in the same water body during the first phase of the spring phytoplankton bloom. After 19 April, a distinct thermocline developed. At the same time the nutrient and CO_2 concentrations in the upper mixed layer began to decrease, due to the uptake by the growing phytoplankton. During periods with high irradiance a remarkable diurnal rhythm of the CO_2 concentration in the surface water could be observed. From the changes of CO_2 and phosphate the mean net primary production (gross primary production of the phytoplankton minus respiration of all organisms) during the first 12 days of the phytoplankton bloom was calculated. It was 1.9 ± 0.2 $g \cdot m^{-2} \cdot d^{-1}$ C.

In spring 1986, the International "Patchiness Experiment (PEX '86)" was carried out in the eastern Baltic Sea, south of Gotland. During the whole time of the experiment the weather conditions were very favourable for the phytoplankton growth. As a result, the concentrations of O_2, CO_2 and nutrients in the water column changed rapidly. So, in spite of the patchiness, the increase of O_2 and the decrease of CO_2 and nutrients (phosphate and nitrate) could be used for the estimation of net primary production (gross primary production of the phytoplankton minus respiration of all organisms). from the O_2 change a net primary production of 0.8 to 1.0 $g \cdot m^{-2} \cdot d^{-1}$ C was obtained (uncorrected for the O_2 release to the atmosphere). The values calculated from the changes of CO_2 and nutrients varied between 1.1 and 1.4 $g \cdot m^{-2} \cdot d^{-1}$ C. The error was ±10% to ±15%. The O_2 release to the atmosphere was 30% of the O_2 produced by photosynthesis, the CO_2 uptake from the atmosphere was ca. 1% of the CO_2 consumed by photosynthesis.

In the time from 1972 to 1979 the net primary production of the German Bight was estimated from changes of the CO_2 concentration. Between the beginning of the spring phytoplankton bloom in the middle of April 1974 and 26/27 May 1974, the net primary production was ca. 20 $g \cdot m^{-2} \cdot C$, in one water body (25 km diameter) 30 to 40 $g \cdot m^{-2}$ C.

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Poster No. 57

Zernova, V.V. & Domanov, M.M.
Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia.

Seasonal changes of the nearshore Antarctic phytoplankton and abiotic factors in the Admiralty Bay, King George Island, South Shetland Islands.

During the year 1987-1988, the type of seasonal changes of the quantity of cells and biomass of phytoplankton, as well as of chlorophyll *a* concentration and primary production was almost the same and connected with the hydrobiological, hydrochemical and climatic factors. Main peak of phytoplankton was reached in summer, in February, the smallest values were found in the middle of winter (June, July). Annual average data of phytoplankton give the opportunity to consider Admiralty Bay as mesotrophic region. The ratio Si/P was a good indicator of different water masses (Weddel Sea Si/P=43, Bellinsgausen Sea Si/P=24). The correlation between Si/P and total phytoplankton biomass was low (r=0.3; n=42). So the seasonal periodicity of phytoplankton biomass in Admiralty Bay was connected more with the climatic factors and the biology of local algae, than with the inflow of different water masses from Brandefild Sound.

Poster no58

Brunet, C., Gentilhomme V. and Brylinski J.M.
C.N.R.S. - U.R.A. 1363, Station Marine, BP 80, 62930 Wimereux, France

Primary productivity along an inshore - offshore in the French part of the Eastern English Channel

In the French area of the Eastern English Channel, the coastal waters 3 or 4 miles wide are separated from offshore waters by a coastal front. The phytoplanktonic biomass (B) and production (P) are higher in coastal waters. The P/B ratio (Productivity) is high in both inshore and offshore waters. Some local variations of this ratio are observed from coast to open sea. In spring tide, an or more increases of phytoplanktonic biomass in subsurface appear on the transect. These biomass (B) accumulations correspond to a fall of productivity (P/B). These ones indicate the presence of interface between some water masses parallel to the coast. The pigment pool displays some modifications which linked to biomass accumulations.

Poster no 59

Herman J., Gons & Machteld Rijkeboer

Netherlands Institute of Ecology, Centre for Limnology, Rijksstraatweg 6, 3631 AC Nieuwersluis, The Neterlands

Diel productivity of cyanobacteria : when does it show in surface spectral reflectance ?

Changing contribution of the energy in the wavelengths around 685 nm to the upwelling light due to variable chlorophyll a fluorescence may provide information on productivity of phytoplankton by passive remote sensing. Effects of incident light were studied using cultures of the filamentous cyanobacterium Oscillatoria limnetica in laboratory scale enclosure (LSE). The LSE (volume 130 l ; depth 2 m) is a physical model of the water column in shallow, optically deep lakes. Culture conditions were a subsurface irradiance of 430 μE m-2 s-1 (400-700 nm from high-intensity daylight lamps), a 16:8 h light dark cycle, a temperature of 20°C, and a diffusivity of 26 cm2 s-1 (i.e. "full mixing").
Increasing fluorescence with subsurface irradiance ranging 150 to 900 μE m-2 s-1 was shown in the surface reflectance spectra of fully mixed, phosphorus-limited O. limnetica suspension. With suspensions of light-limited O. limnetica a much weaker increase was found when the light was varied from 200 to 1700 μE m-2 s-1 the fluorescence decreased. In still water conditions at a subsurface irradiance of 1000 μE m-2 s-1 the fluorescence appeared to be quenched within 15 min after interrupting the mixing.

ANNEX IV

National Reports of the Occurrence of Harmful Algal Blooms 1991

a) Canada
b) France
c) Poland
d) Sweden
e) United Kingdom - Scotland
f) United States

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: Bay of Fundy

2. Date of Occurrence: No shellfish harvesting areas were closed due to unacceptable levels of domoic acid in the Bay of Fundy during 1991.

3. Effects: None. Extractions for domoic acid were done at the Department of Fisheries and Oceans Inspection Laboratory in Black's Harbour, New Brunswick, and analyses were carried out in Halifax, Nova Scotia.

4. Management Decision: None required. However, when levels of domoic acid in tissues exceed 20 ppm, shellfish harvesting areas are closed. The Bay of Fundy is normally closed to harvesting of blue mussels throughout the year due to persistent PSP contamination.

5. Causative Species: *Nitzschia pseudodelicatissima.* (Highest concentrations observed during 1991 were 78,340 cells/L in mid-June.)

6. Environment:

Temperature range:	8 - 12°C
Salinity:	32 ppt
Water column:	mixed inshore, stratified offshore

7. Advected Population or In Situ Growth: Both.

8. Previous Occurrences: Areas were closed to harvesting during 1988 due to unacceptable levels of domoic acid. Although closures are not an annual occurrence in the Bay of Fundy, we do detect levels of domoic acid in plankton tows each summer. *Nitzschia pseudodelicatissima* occurs annually in the region but not at levels detected during 1988.

9. Individual to Contact:

Jennifer Martin
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick
Canada E0G 2X0
(506) 529-8854 (Voice)
(506) 529-4274 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: Bay of Fundy

2. Date of Occurrence: Shellfish harvesting areas were closed at various locations in the southwest between June and August.

3. Effects: Unacceptable levels of PSP toxins were detected in shellfish tissues. Extractions were done at the Department of Fisheries and Oceans Inspection Laboratory in Black's Harbour, New Brunswick.

4. Management Decision: Shellfish harvesting beds were closed to harvesting during the time when soft-shell clams had levels of PSP toxins above 80 µg/100 g. The Bay of Fundy is closed to harvesting of blue mussels throughout the year.

5. Causative Species: *Alexandrium fundyense*

6. Environment:

Temperature range:	8 - 12 °C
Salinity:	32 ppt
Water column:	mixed inshore, stratified offshore

7. Advected Population or In Situ Growth: Advected.

8. Previous Occurrences: Closures of shellfish harvesting areas due to unacceptable levels of PSP toxins are an annual occurrence in the Bay of Fundy.

9. Individual to Contact:

Jennifer Martin
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick
Canada E0G 2X0
(506) 529-8854 (Voice)
(506) 529-4274 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: Southern coast of Nova Scotia: Mahone Bay.

2. Date of Occurrence: May - June.

3. Effects: Low but detectable levels of DSP toxins were found in cultured mussels (*Mytilus edulis*). A 50:50 ratio of okadaic acid:DTX-1 was found at the peak of the bloom, but then became predominantly DTX-1 two weeks later as levels began to drop. Levels in mussels became undetectable by early July. Plankton samples exhibited no detectable DSP toxins using ADAM/HPLC analysis, but the biomass of phytoplankton was low by the time samples were collected for chemical analysis.

4. Management Decision: The low levels of DSP toxins found did not justify an official closure of mussel harvesting, but the mussel growers in the area voluntarily stopped harvesting for about a two month period as a precautionary measure.

5. Causative Species: *Dinophysis norvegica*.

6. Environment: Water temperature: 6 - 12°C.

7. Advected Population or In Situ Growth: Not known.

8. Previous Occurrences: *Dinophysis norvegica* and DTX-1 in mussels were previously found at the same location in early August, 1990.

9. Additional Comments: The presence of *Dinophysis* in the May - June bloom seemed to be a good indicator of DSP in mussels, contrary to the September - October bloom of *Dinophysis* which showed no DSP in plankton or mussels at the same location. *Prorocentrum lima* growing on the surface of mussels was isolated into culture, and was shown to produce DTX-1; the abundance of *P. lima* on mussel surfaces was low.

10. Individual to Contact:

Dr. Anthony de Freitas
Institute for Marine Biosciences
National Research Council of Canada
1411 Oxford St.
Halifax, Nova Scotia
Canada B3H 3Z1
(902) 426-8263 (Voice)
(902) 426-9413 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: Southern coast of Nova Scotia: Mahone Bay.

2. Date of Occurrence: Late September - November.

3. Effects: A concentrated sample of plankton, composed almost uniquely of *Dinophysis norvegica*, exhibited no detectable DSP toxins using ADAM/HPLC analysis.

4. Management Decision: None required.

5. Causative Species: *Dinophysis norvegica*. Cell concentrations ranged from 10,000 - 40,000 cells/L during the bloom period.

6. Environment: Water temperature: 15 - 19°C in September, declining to 10 - 12°C in October. There was no strong thermocline.

7. Advected Population or In Situ Growth: Not known.

8. Previous Occurrences: *Dinophysis norvegica* and DTX-1 in mussels were previously found at the same location in early August, 1990.

9. Additional Comments: The plankton biomass used for the chemical analysis was high (about 10 g), so there is little question about the absence of detectable DSP toxins in the sample. Studies are continuing to determine why DSP toxins are apparently absent in mussels during the early winter bloom, but are present during the early summer blooms.

10. Individual to Contact:

Dr. Anthony de Freitas
Institute for Marine Biosciences
National Research Council of Canada
1411 Oxford St.
Halifax, Nova Scotia
Canada B3H 3Z1
(902) 426-8263 (Voice)
(902) 426-9413 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: Gulf coast of Nova Scotia: St. Georges Bay west to Pictou.

2. Date of Occurrence: June.

3. Effects: Concentrated samples of net plankton, composed mainly of *Dinophysis* species, exhibited no DSP toxins using ADAM/HPLC analysis.

4. Management Decision: None.

5. Causative Species: A concentrated band of phytoplankton, containing about 95% *Dinophysis* species, was found close to the pycnocline at about 12 m depth. *Dinophysis* species found in order of abundance: *D. norvegica*, *D. acuminata*, and *D. acuta*.

6. Environment: Temperature: 11.5°C. Salinity: 29 ppt. There was some stratification, with a pycnocline at about 12 m depth.

7. Advected Population or In Situ Growth: *Dinophysis* cells were found both inside and outside of the bay. It is possible (but not known) that this population was advected from the Northumberland Strait to the west.

8. Previous Occurrences: *Dinophysis* is known to be a major component of the summer phytoplankton in the St. Georges Bay area from surveys carried out since the 1970's.

9. Additional Comments: St. Georges Bay is an important nursery area for larval invertebrates and fish species of commercial value. There are therefore potentially important food web implications if DSP is produced by the *Dinophysis* populations. The bay and adjacent waters will continue to be monitored in the future.

10. Individual to Contact:

Dr. John C. Smith
Department of Fisheries and Oceans
Gulf Fisheries Centre
P.O. Box 5030
Moncton, New Brunswick
Canada E1C 9B6
(506) 851-3827 (Voice)
(506) 851-2079 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: North coast of Prince Edward Island: Malpeque and Cascumpec bays.

2. Date of Occurrence: Late October to early November.

3. Effects: One sample of mussels (*Mytilus edulis*) from Lennox Island in Malpeque Bay reached 18 µg/g on October 28, but this was an outlier; most of the samples contained less than 5 µg/g. Cascumpec Bay mussels and oysters (*Crassostrea virginica*) contained less than 3 µg/g.

4. Management Decision: As a precaution due to levels nearing the federal limit of 20 µg/g, the following areas were closed to the harvesting of molluscan shellfish from October 31 to November 4: Lennox Channel, Darnley Basin, Malpeque Bay, Bideford River, and Conway Narrows.

5. Causative Species: *Nitzschia pungens* f. *multiseries*. Cell concentrations ranged from 15,400 to 39,200 cells/L, depending on the station in Lennox Channel, on October 31. Cell numbers thereafter dropped to undetectable.

6. Environment: Temperature range during the bloom period: 9 - 16°C. Salinity: about 27 ppt. The water column was well mixed.

7. Advected Population or In Situ Growth: Most probably, the population originated within the bays.

8. Previous Occurrences: Low numbers of *Nitzschia pungens* but no domoic acid had previously been detected in Malpeque Bay, but this is the first year that the bay was closed to harvesting due to domoic acid contamination.

9. Additional Comments: Contrary to 1987 - 1989, but similar to 1990, no bloom of toxic *N. pungens* f. *multiseries* occurred in the Cardigan Bay region of eastern Prince Edward Island. Also, as in 1990, there was a bloom (600,000 cells/L) of non-toxic *N. pungens* f. *pungens* in October.

10. Individual to Contact:

Dr. John C. Smith
Department of Fisheries and Oceans
Gulf Fisheries Centre
P.O. Box 5030
Moncton, New Brunswick
Canada E1C 9B6
(506) 851-3827 (Voice)
(506) 851-2079 (Fax)

HARMFUL ALGAL BLOOMS IN 1991 - CANADA

1. Location: North coast of Prince Edward Island: New London Bay

2. Date of Occurrence: Mid-September to mid-October.

3. Effects: Domoic acid levels in mussels (*Mytilus edulis*) were 17 µg/g on September 27, and rose to 29 µg/g on September 28. Domoic acid was also found in oysters (*Crassostrea virginica*) at levels generally below 5 µg/g, but one sample contained 12 µg/g.

4. Management Decision: Because levels exceeded the federal limit of 20 µg/g, New London Bay was closed to the harvesting of molluscan shellfish from September 30 to October 31.

5. Causative Species: *Nitzschia pungens* f. *multiseries*. Cell concentrations ranged up to 800,000 cells/L near the peak of the bloom.

6. Environment: Temperature range during the bloom period: 9 - 16°C. Salinity ranged narrowly around 27 ppt. The water column was well mixed.

7. Advected Population or In Situ Growth: Most probably, the population originated within New London Bay.

8. Previous Occurrences: *Nitzschia pungens* and low levels of domoic acid have been detected in New London Bay since 1988, but this is the first year that the bay was closed to harvesting due to domoic acid contamination.

9. Additional Comments: Contrary to 1987 - 1989, but similar to 1990, no bloom of *N. pungens* f. *multiseries* occurred in the Cardigan Bay region of eastern Prince Edward Island. Also, as in 1990, there was a bloom (600,000 cells/L) of non-toxic *N. pungens* f. *pungens* in October.

10. Individual to Contact:

Dr. John C. Smith
Department of Fisheries and Oceans
Gulf Fisheries Centre
P.O. Box 5030
Moncton, New Brunswick
Canada E1C 9B6
(506) 851-3827 (Voice)
(506) 851-2079 (Fax)

QUEBEC FISHERIES REGION (CANADA)
Diarrheic Shellfish Poisoning, 1991

1. Locations: Northern and southern shore of the Gaspé peninsula and northwestern Gulf of the St. Lawrence.

2. Dates: Generally in late June, late August at one station.

3. Effects: None observed.

4. Management Decisions: No action taken.

5. Causative Species:
–*Dinophysis acuminata* (dominant dinophysoid species), *D. norvegica* and *D. rotundata* observed between June 6 and September 22.
–Maximum concentration of *Dinophysis spp.:* 3 632 cells/liter recorded June 25.

6. Environment:
–temperature range: 0–18°C (11–14°C during the bloom)
–salinity range: 7–30°/₀₀ (24–28°/₀₀ during the bloom)

7. Advected population or in situ growth: *Dinophysis spp.* can be found throughout the region at low concentrations. It can represent an endemic population although exogenous transport by the Gaspé current could be important in some areas.

8. Previous occurrence: Concentrations of *Dinophysis spp.*, particularly *D. acuminata*, are found each year in St. Lawrence. No diarrheic intoxications have been reported.

9. Additionnal comments: *Dinophysis spp.* concentrations recorded in 1991 are low compared to the two previous years of the monitoring program.

10. Individual to contact: Dr. Maurice E. Levasseur or Béatrice Huppertz

Maurice Lamontagne Institute
Fisheries and Oceans
P.O. Box 1000
Mont–Joli (Québec) Canada
G5H 3Z4
(418) 775–0500
FAX: (418) 775–0542

QUEBEC FISHERIES REGION (CANADA)
Paralytic Shellfish Poisoning, 1991

1. Locations: South shore of the Gulf of St. Lawrence (49°13'N, 65°43'O) and north shore of the St. Lawrence estuary (48°08'N, 69°42'O).

2. Dates: Late July – early August, 1991.

3. Effects: –No human illness reported.–No water discoloration reported.
–Soft–shell clams (*Mya arenaria*) and blue mussels (*Mytilus edulis*) accumulated toxins. Highest levels observed: 74 (*M. arenaria*) and 159 (*M. edulis*) µg STX eq/100g, according to the AOAC mouse bioassay.

4. Management Decisions: Harvesting of shellfish periodically prohibited. Due to recurring mussel intoxications along the northern Gaspé penninsula, certain zones remained closed without PSP analysis.

5. Causative Species: –*Alexandrium excavatum.*
–First occurence May 6, 196 cells/liter observed.
–Maximum concentration: 28 274 cells/liter recorded July 21.

6. Environment: –temperature range: 0 –15°C (10 –13°C during the bloom)
–salinity range: 8–30°/₀₀ (23°/₀₀ during the bloom)

7. Advected population or in situ growth: The *Alexandrium* bloom found along the northern shore of the lower St. Lawrence estuary may represent an endemic population since high concentrations of motile cells have previously been observed in the water column. In contrast, blooms along the southern shore of the Gulf represent exogenous transport from the northern side by the Gaspé current. The residual circulation pattern provides a plausible mechanism for the transport of blooms accross the estuary.

8. Previous occurrences: *Alexandrium* bloom is a annual event reported since 1984; PSP toxic incidents known for more than 100 years in the region.

9. Additionnal comments: Contrarily to the previous two years, concentrations of *Alexandrium* and toxicity levels in mussels remained low in 1991.

10. Individual to contact: Dr. Maurice E. Levasseur or Béatrice Huppertz

Maurice Lamontagne Institute
Fisheries and Oceans
P.O. Box 1000
Mont–Joli (Québec) Canada
G5H 3Z4
(418) 775–0500
FAX: (418) 775–0542

Harmful Algal Blooms in 1991 - Canada

1. Location: West coast of Vancouver Island - Barkley Sound and Clayoquot Sound region

2. Date: Mid August to mid September

3. Effects: No penned fish losses recorded.

4. Management decision: None

5. Causative species: *Heterosigma akashiwo*. Concentrations recorded: $8x10^5$ cells.L^{-1} on 5 September; $2.9X10^6$ cells.L^{-1} on 20 September (both counts from Tofino area).

6. Environment: No data

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

8. Previous occurrences: At this time of year: 1990, 1989, 1988 and presumably sporadically in previous years.

9. Additional comments: Occurred in Barkley Sound during August; in Clayoquot Sound (Tofino area) during September.

10. Individual to contact:

Mr. J.R. Forbes
Department of Fisheries and Oceans
Institute of Ocean Sciences
P.O. Box 6000, Sidney, B.C., Canada
V8L 4B2

604 363 6443
604 363 6390 (Facs.)

Harmful Algal Blooms in 1991 - Canada

1. Location: Strait of Georgia - Sunshine coast, Campbell River/Desolation Sound, Saltspring Island, Departure Bay, Burrard Inlet.

2. Date: Mid June to late September

3. Effects: Low cell numbers, insufficient to cause penned fish losses.

4. Management decision: None

5. Causative species: *Heterosigma akashiwo*

6. Environment: No data

7. Advected population or *in situ* growth: Most likely combination of *in situ* growth and advection from central Strait of Georgia.

8. Previous occurrences: At this time of year: 1990, 1989, 1988, 1986 and presumably sporadically in previous years.

9. Additional comments: Many small blooms recorded within the area, in some cases presumably as a result of advection from offshore.

   Specifics: Sunshine coast - mid June to late July
   Campbell River/Desolation Sound - Mid June, mid to late September
   Saltspring Is., Burrard Inlet and Departure Bay - mid to late August

10. Individual to contact:

Mr. J.R. Forbes
Department of Fisheries and Oceans
Institute of Ocean Sciences
P.O. Box 6000, Sidney, B.C., Canada
V8L 4B2

604 363 6443
604 363 6390 (Facs.)

Harmful Algal Blooms in 1991 - Canada

1. Location: Northern Strait of Georgia - Campbell River/Desolation Sound region

2. Date: Late April to early May.

3. Effects: Low cell numbers, insufficient to cause penned fish losses.

4. Management decision: None

5. Causative species: *Chaetoceros convolutus* and/or *C. concavicornis*

6. Environment: No data

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

8. Previous occurrences: In spring in this area: 1989, 1988 and presumably sporadically in previous years.

9. Additional comments: Occurred within mixed diatom bloom.

10. Individual to contact:

Mr. J.R. Forbes
Department of Fisheries and Oceans
Institute of Ocean Sciences
P.O. Box 6000, Sidney, B.C., Canada
V8L 4B2

604 363 6443
604 363 6390 (Facs.)

Harmful Algal Blooms in 1991 - Canada

1. Location: East coast of the Strait of Georgia - Sunshine coast region and northern Strait of Georgia - Campbell River/Desolation Sound.

2. Date: Late May to mid June

3. Effects: Low cell numbers, insufficient to cause penned fish losses.

4. Management decision: None

5. Causative species: *Chaetoceros convolutus* and/or *C. concavicornis*, with cell concentrations to 200 cells.L^{-1}.

6. Environment: Secchi reading at Hoskin Channel: 2.5m

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

8. Previous occurrences: At this time of year: 1990, 1989, 1988 and presumably sporadically in previous years.

9. Additional comments: Occurred initially on the east coast of the Strait of Georgia, and later to the north. Occurred within mixed diatom bloom.

10. Individual to contact:

Mr. J.R. Forbes
Department of Fisheries and Oceans
Institute of Ocean Sciences
P.O. Box 6000, Sidney, B.C., Canada
V8L 4B2

604 363 6443
604 363 6390 (Facs.)

Harmful Algal Blooms in 199· - Canada

1. Location: Eastern and northern Strait of Georgia, east side Queen Charlotte Strait, Simoom Sound.

2. Date: Mid October to mid November

3. Effects: Some penned fish losses in Sutil Channel (west side of Cortes Is.), Teakerne Arm (W. Redonda Is.) and in Homfray Channel (south side of E. Redonda Is.), all in northern Strait of Georgia area.

4. Management decision: None

5. Causative species: *Chaetoceros convolutus* and/or *C. concavicornis*, Cell concentrations recorded in late October included $2x10^5$ cells.L^{-1} in Homfray Channel, 7 - $8x10^4$ cells.L^{-1} in Teakerne Arm, and 1.8 - $3.0x10^4$ cells.L^{-1} along east side of Queen Charlotte Strait (Simoom Sound, Sir Edmund Bay and Cypress Harbour).

6. Environment: No data

7. Advected population or *in situ* growth: Most likely *in situ* growth at the various locations.

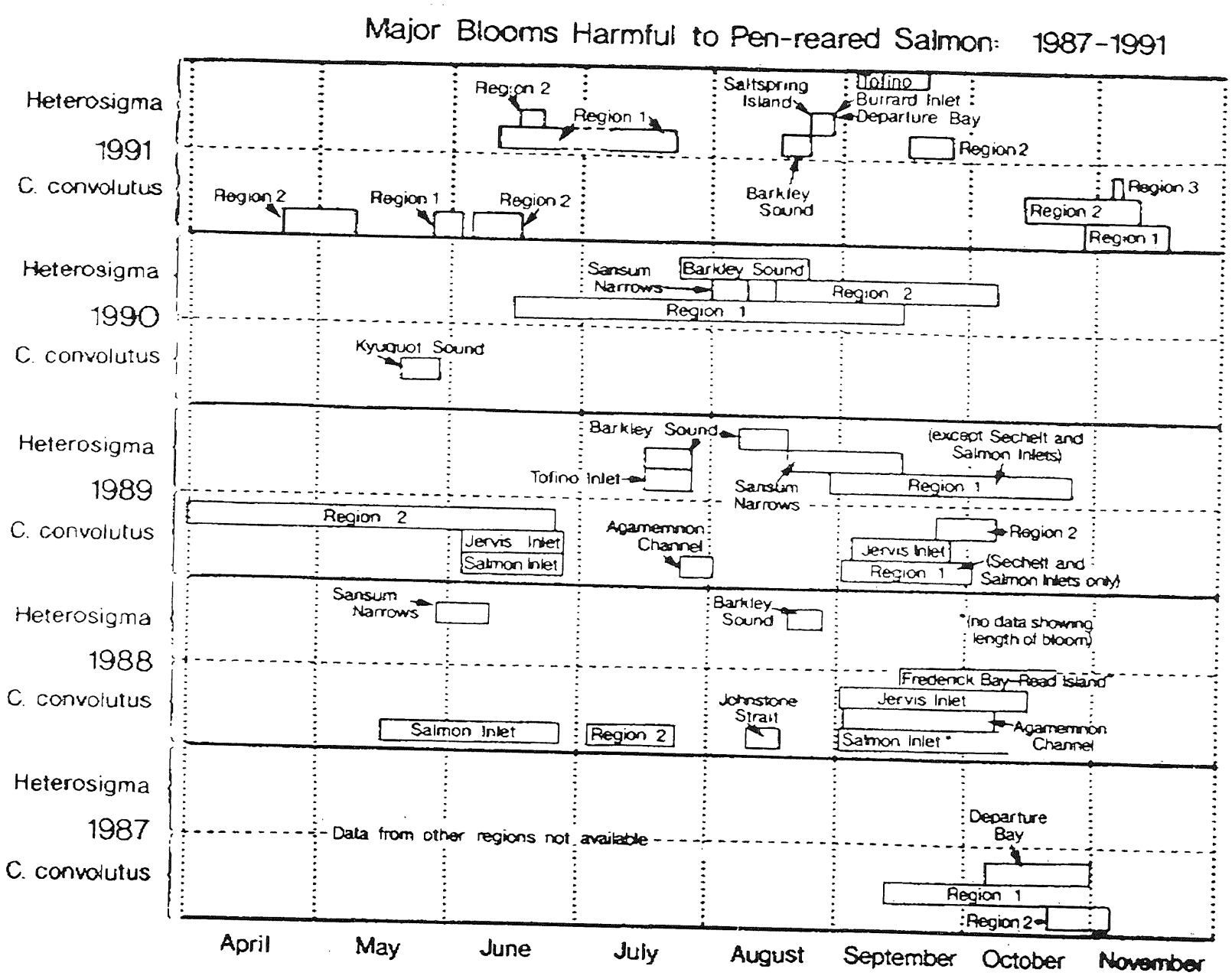
8. Previous occurrences: This species occurs typically in Autumn in this region (including 1989, 1988 and 1987), but has usually disappeared by the beginning of November.

9. Additional comments: Occurred initially in northern Strait of Georgia area, and only later to the north and south.

10. Individual to contact:

Mr. J.R. Forbes
Department of Fisheries and Oceans
Institute of Ocean Sciences
P.O. Box 6000, Sidney, B.C., Canada
V8L 4B2

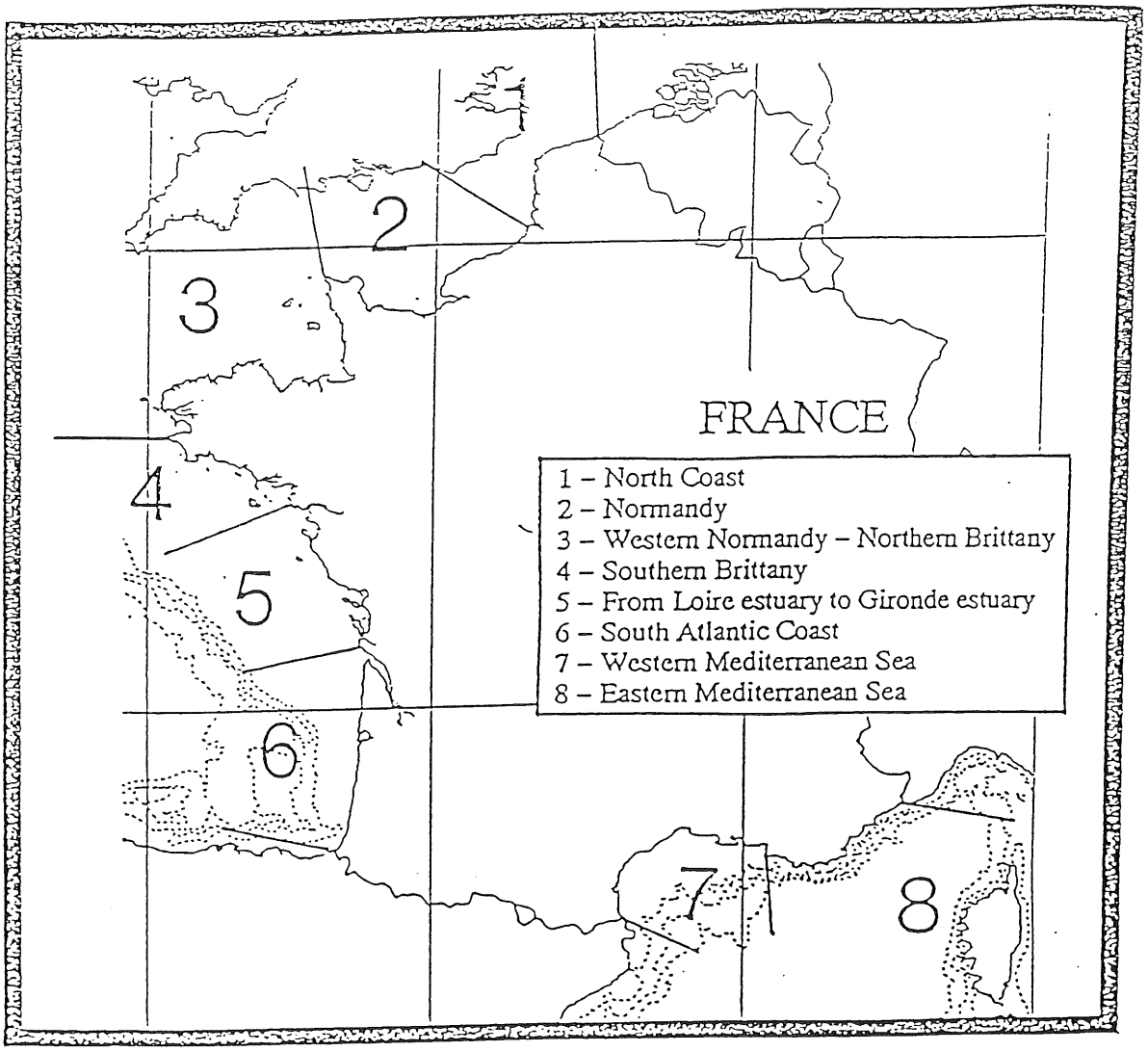
604 363 6443
604 363 6390 (Facs.)



Region 1 = Sunshine Coast, Reg. 2 Campbell River/Desolation Sd.

FRANCE – ALGAL BLOOM REPORTS – 1991

Catherine BELIN *



The French coast is separated into 8 areas for description of harmful events caused by phytoplankton.

* IFREMER, B.P. 1049, 44037 Nantes cedex, France

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

NORTH COAST (area 1)
Zone affected : Dunkerque - Calais

2. DATE OF OCCURRENCE

March 28, 1991

3. EFFECTS

Discolored water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Chaetoceros armatum (17 460 000 cells.l^{-1})

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS
   NORTH COAST (area 1)
   Zone affected : Boulogne

2. DATE OF OCCURRENCE
   October 02, 1991

3. EFFECTS
   Brown water

4. MANAGEMENT DECISIONS
   Continued surveillance

5. CAUSATIVE SPECIES
   Asterionella glacialis (80.10^6 cells.l^{-1})

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH
   No data available

8. PREVIOUS OCCURRENCES
   1989 (300.10^6)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS
   NORTHERN BRITTANY (area 3)
   Zone affected : Abers

2. DATE OF OCCURRENCE
   May 09 to July 26, 1991

3. EFFECTS
   Reddish to red water

4. MANAGEMENT DECISIONS
   Continued surveillance

5. CAUSATIVE SPECIES
   Asterionella glacialis

6. ENVIRONMENT

Temperature :	16.4 to 17°C
Salinity :	22 to 28 ‰
Turbidity :	1.5 to 14 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH
   No data available

8. PREVIOUS OCCURRENCES
   No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Jean-Claude LE SAUX
IFREMER
3, rue de Kerfraval
29600 MORLAIX
FRANCE
(Régional Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

NORTHERN BRITTANY (area 3)
Zone affected : Elorn river

2. DATE OF OCCURRENCE

June 06, 1991

3. EFFECTS

Very green water – Extent : about 1 km

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Eutreptiella sp. (90.10^6 cells.l^{-1})

6. ENVIRONMENT

Salinity : 15 ‰
Turbidity : 10 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Jean-Claude LE SAUX
IFREMER
3, rue de Kerfraval
29600 MORLAIX
FRANCE
(Régional Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

NORTHERN BRITTANY (area 3)
Zone affected : Douarnenez bay

2. DATE OF OCCURRENCE

June to October, 1991

3. EFFECTS

DSP toxicity above safety level (maximum recorded : very high toxicity)

4. MANAGEMENT DECISIONS

Ban of shellfish marketing, from July 04 to October 17

5. CAUSATIVE SPECIES

Dinophysis spp. maximum cell counts : 6 900 cells.l^{-1}

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

1983, 1984 (1 600 cells.l^{-1}), 1985 (8 900), 1986 (18 300), 1987 (6 100), 1988 (2 800), 1989 (2 700), 1990 (1 100)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Audierne bay

2. DATE OF OCCURRENCE

April 11, 1991 and November 12, 1991

3. EFFECTS

Green-brown to brown water. A sheet about 500 m in April

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Chaetoceros armatum (4 840.10^3 cells.l^{-1} in April, 26 240.10^3 cells.l^{-1} in November)

6. ENVIRONMENT

Temperature : 10.8°C (April), 12.5°C November
Salinity : 32.4 ‰ (April), 35 ‰ (November)
Turbidity : 37.5 N.T.U. (April), 11 N.T.U. (November)

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably in situ growth

8. PREVIOUS OCCURRENCES

1989 (510.10^6.cells l^{-1}), 1990 (x.10^6)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Elisabeth NEZAN
IFREMER
13, rue de Kérose
29900 CONCARNEAU
FRANCE
(Régional Contatc)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Concarneau bay

2. DATE OF OCCURRENCE

May 08 to May 13, 1991

3. EFFECTS

Green-brown to blackish water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Prasinophyceae (perhaps *Halosphera* or *Pyramimonas*) 420.10^6 cells.l-1

6. ENVIRONMENT

Temperature : 13.3°C
Salinity : 34 ‰
Turbidity : 15 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

No

9. ADDITIONNAL COMMENTS

This discolored water was followed by a red water (*Mesodinium rubrum*)

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Elisabeth NEZAN
IFREMER
13; rue de Kérose
29900 CONCARNEAU
FRANCE
(Régional Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Concarneau bay

2. DATE OF OCCURRENCE

May 13 to May 20, 1991

3. EFFECTS

Very red water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Mesodinium rubrum (x.10^5 cells.l^{-1})

6. ENVIRONMENT

Temperature : 13.3°C
Salinity : 34 ‰
Turbidity : 15 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

1990 (?)

9. ADDITIONNAL COMMENTS

This discolored water was preceded by a brown water (*Prasinophyceae*)

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Elisabeth NEZAN
IFREMER
13; rue de Kérose
29900 CONCARNEAU
FRANCE
(Régional Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Etel river

2. DATE OF OCCURRENCE

April 22 to May 13, 1991

3. EFFECTS

Discolored water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Chaetoceros sp. (190 000 cells.l-1)

6. ENVIRONMENT

Temperature : 10.8 to 12.2°C
Salinity : 32.6 to 33 ‰
Turbidity : 0.6 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably in situ growth

8. PREVIOUS OCCURRENCES

No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS
   SOUTHERN BRITTANY (area 4)
   Zone affected : Etel river

2. DATE OF OCCURRENCE
   May 28 to June 17, 1991

3. EFFECTS
   Discolored water.

4. MANAGEMENT DECISIONS
   Continued surveillance

5. CAUSATIVE SPECIES
   Rhizosolenia sp. (142 000 cells.l^{-1})

6. ENVIRONMENT

Temperature :	14.6 to 15.7°C
Salinity :	33.8 to 35.3 ‰
Turbidity :	0.6 to 3.1 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH
   Probably in situ growth

8. PREVIOUS OCCURRENCES
   No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS
   SOUTHERN BRITTANY (area 4)
   Zone affected : Etel river

2. DATE OF OCCURRENCE
   April 11, 1991

3. EFFECTS
   Discolored water.

4. MANAGEMENT DECISIONS
   Continued surveillance

5. CAUSATIVE SPECIES
   Glenodinium sp. (1.10^6 cells.l^{-1})

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH
   Probably in situ growth

8. PREVIOUS OCCURRENCES
   No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS
   SOUTHERN BRITTANY (area 4)
   Zone affected : Vilaine bay

2. DATE OF OCCURRENCE
   April 22, 1991

3. EFFECTS
   Discolored water

4. MANAGEMENT DECISIONS
   Continued surveillance

5. CAUSATIVE SPECIES
   Prorocentrum micans (?)

6. ENVIRONMENT
   Temperature : 10.9°C
   Salinity : 29.7 ‰

7. ADVECTED POPULATION OR IN SITU GROWTH
   No data available

8. PREVIOUS OCCURRENCES
   No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Vilaine Bay, Croisic roads

2. DATE OF OCCURRENCE

June to late July, 1991

3. EFFECTS

DSP toxicity above safety level (maximum recorded : high toxicity in Vilaine bay and Croisic roads)

4. MANAGEMENT DECISIONS

Ban of shellfish marketing, from June 20 to July 26 (Vilaine bay), from June 14 to July 12 (Croisic roads)

5. CAUSATIVE SPECIES

Dinophysis spp. maximum cell counts : 2 500 cells.l^{-1} (Vilaine bay), 6 200 cells.l^{-1} (Croisic roads)

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably both

8. PREVIOUS OCCURRENCES

1983, 1984 (x.10^3 cells.l^{-1}), 1986 (Vilaine : 2 400, Croisic : 1 300), 1987 (Vilaine : 10 700), 1988 (Vilaine : 20 400), 1990 (Vilaine : 24 400, Croisic : 2 100)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

SOUTHERN BRITTANY (area 4)
Zone affected : Croisic roadstead

2. DATE OF OCCURRENCE

August 13 to September 12, 1991

3. EFFECTS

Green water. Mortalities of young soles (August 19) probably by anoxia.

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Gymnodinium sp. ($4\ 275.10^3$ cells.l^{-1})

6. ENVIRONMENT

Temperature : 19.3°C
Salinity : 36 ‰

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably in situ growth

8. PREVIOUS OCCURRENCES

1986 (3.10^6), 1988 (40.10^6), 1989 (?)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

FROM LOIRE ESTUARY TO GIRONDE ESTUARY (area 5)
Zone affected : Loire estuary, Yeu island

2. DATE OF OCCURRENCE

June to July, 1991

3. EFFECTS

DSP toxicity above safety level (maximum recorded : high toxicity in Loire estuary, middle toxicity in Yeu island)

4. MANAGEMENT DECISIONS

Ban of shellfish marketing, from June 14 to July 12 (Loire estuary), from June 20 to July 26 (Yeu island)

5. CAUSATIVE SPECIES

Dinophysis spp. maximum cell counts : 1 100 cells.l^{-1} (Loire estuary), 700 (Yeu island)

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably advected population

8. PREVIOUS OCCURRENCES

1988 (Yeu : 200 cells.l^{-1}), 1990 (Loire : ?, Yeu : 2 100)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

FROM LOIRE ESTUARY TO GIRONDE ESTUARY (area 5)
Zones affected : Olonne coast

2. DATE OF OCCURRENCE

September 04, 1991

3. EFFECTS

Green water. Some shellfish mortalities (anoxia ?)

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Gymnodinium sp.

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably both

8. PREVIOUS OCCURRENCES

1985 ?, 1988 (18.10^6)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

FROM LOIRE ESTUARY TO GIRONDE ESTUARY (area 5)
Zones affected : North of Ré Island, Aiguillon bay, Chatelaillon

2. DATE OF OCCURRENCE

September 10 and 11, 1991

3. EFFECTS

Green water.

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Gymnodinium sp. (186 000 cells.l^{-1})

6. ENVIRONMENT

Temperature : 20.4 to 21.9°C
Salinity : 35.2 to 36 ? ‰
Turbidity : 2.6 to 16 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

Probably both

8. PREVIOUS OCCURRENCES

1985 (3.10^6 cells.l^{-1}), 1986 (7.10^6), 1988 (18.10^6)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

SOUTH ATLANTIC COAST (area 6)
Zone affected : coast above Arcachon basin

2. DATE OF OCCURRENCE

May 26 to May 28, 1991

3. EFFECTS

Red-violine water. A sheet at about 800 m offshore

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Leptocylindrus sp. (902 000 cells.l^{-1})

6. ENVIRONMENT

Salinity : 34 ‰

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

Nadine MASSON
IFREMER
Quai du Cdt Silhouette
33120 ARCACHON
FRANCE
(Régional Contatc)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

WESTERN MEDITERRANEAN SEA (area 7)
Zone affected : Roussillon coast

2. DATE OF OCCURRENCE

August to October, 1991

3. EFFECTS

DSP toxicity above safety level (maximum recorded : very high toxicity)

4. MANAGEMENT DECISIONS

Ban of shellfish marketing, from August 22 to October 10

5. CAUSATIVE SPECIES

Dinophysis spp. maximum cell counts : 300 cells.l^{-1}

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

1987 (1 200 cells.l^{-1}), 1989 (2 600), 1990 (2 400)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

WESTERN MEDITERRANEAN SEA (area 7)
Zones affected : Languedoc and Camargue coasts

2. DATE OF OCCURRENCE

July 15 to July 28, 1991

3. EFFECTS

White to yellow-brown water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Protoceratium reticulatum (12.10^7 cells l^{-1})

6. ENVIRONMENT

Temperature : 24°C

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

No

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE 1991

1. LOCATIONS

WESTERN MEDITERRANEAN SEA (area 7)
Zones affected : Camargue coast and Fos gulf

2. DATE OF OCCURRENCE

July to August, 1991

3. EFFECTS

DSP toxicity above safety level (maximum recorded : very high toxicity in Camargue coast, high toxicity in Fos gulf)

4. MANAGEMENT DECISIONS

Ban of shellfish marketing, from July 19 to August 27 (Camargue coast), from July 05 to August 22 (Fos gulf)

5. CAUSATIVE SPECIES

Dinophysis spp. maximum cell counts : 4000 cells.l^{-1} (Camargue coast), 1 000 cells.l^{-1} (Fos gulf)

6. ENVIRONMENT

7. ADVECTED POPULATION OR IN SITU GROWTH

No data available

8. PREVIOUS OCCURRENCES

1985 (Fos : 4 700 cells.l^{-1}), 1987 (Fos : 1 400), 1989 (Camargue : 1 650, Fos : 9 400), 1990 (Fos : 1 200)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

ALGAL BLOOM REPORTS - FRANCE
1991

1. LOCATIONS

WESTERN MEDITERRANEAN SEA (area 7)
Zone affected : Berre Lake

2. DATE OF OCCURRENCE

March 20 to May 31, 1991

3. EFFECTS

Brown water

4. MANAGEMENT DECISIONS

Continued surveillance

5. CAUSATIVE SPECIES

Prorocentrum minimum ($43\ 400.10^3$ cells.l^{-1})

6. ENVIRONMENT

Temperature : 11.8 to 16.4°C
Salinity : 7.9 to 15.1 ‰
Turbidity : 1.5 to 20 N.T.U.

7. ADVECTED POPULATION OR IN SITU GROWTH

In situ growth

8. PREVIOUS OCCURRENCES

1986 (660.10^3), 1987 (7.10^6), 1988 (9.10^6), 1989 (25.10^6)

9. ADDITIONNAL COMMENTS

10. INDIVIDUAL TO CONTACT :

Catherine BELIN
IFREMER
BP 1049
44037 NANTES cédex 01
FRANCE
(National Contact)

J.Jacques CONSOLE
IFREMER
BP 330
83507 LA SEYNE/MER cédex
FRANCE
(Régional Contatc)

ALGAL BLOOM REPORTS - POLAND (1991)

1. Location:

Gulf of Gdańsk (Southern Baltic)

2. Date of occurence:

End of April, 1991

3. Effects:

Brown water

4. Management Decisions:

5. Causative species:

Gonyaulax catenata, maximum cell counts: 1950 * 10^3 l^{-1} - April 30

6. Environment:

Temperature: 8.0 degrees C.

Salinity: 6.63 ppt.

7. Advected population or in situ growth:

Probably both

8. Previous occurrences:

1987, 1990

9. Additional comments:

10. Individual to contact:

Tomasz Mackiewicz
Sea Fisheries Institute
ul. Kołłątaja 1
81-332 Gdynia, Poland

ALGAL BLOOM REPORTS - POLAND (1991)

1. Location:

Southern Baltic, offshore and gulf areas.

2. Date of occurence:

First days of August, 1991.

3. Effects:

A lot of green to yellow patches on the surface of sea water.

4. Management Decisions:

5. Causative species:

Aphanizomenon flos-aquae $12 * 10^{6}$ ugC/l

Nodularia spumigena $3 - 105 * 10^{5}$ ugC/l

6. Environment:

Temperature: 19.9 - 20.2 ^{o}C

Salinity: 7 ppt.

Oxygen: 6.4 ml/l.

7. Advected population or in situ growth:

8. Previous occurrences:

Blooms nearly every summer. Last Cyanophyceae - Nostocales bloom of especial intense, took place in 1988. The summer bloom consist of Cyanophyceae - Chroococcales (Microcystis reinboldii, Aphanothece clathrata, Gomphosphaeria spp.) is observed annually in Southern Baltic.

9. Additional comments:

Bloom started to develope: - in the open sea, offshore:
- in the surface layer (ca. 1m), where temperature was very high.

10. Individual to contact:

Janina M. Bralewska
Sea Fisheries Institute
ul. H.Kollataja 1
PL-81-332 Gdynia, Poland

SWEDEN 1991

LOCATION	The Baltic Sea. Aprox. between N 57° and N 59° and E 16° and E 22°
DATES	End of July, beginning of August
EFFECTS	No serious effects reported. Considerable public concern
MANAGEMENT DECISION	Recommendation not to bathe
CAUSATIVE SPECIES	Nodularia spumigena and Aphanizomenon flos-aquae
TOXIN	Hepatotoxins found in some but not all samples
ENVIRONMENT	
PREVIOUS OCCURRENCES	Blooms nearly every year in large parts of the Baltic Sea
ADDITIONAL COMMENTS	
INDIVIDUAL TO CONTACT	Lars Edler, SMHI, Doktorsg. 9D, S-262 52 Ängelholm Sweden, tel 46 431 80854, fax 46 431 83167. Bertil Håkansson, SMHI, S-601 76 Norrköping, Sweden, tel.46 11 158385, fax 46 11 158350

HARMFUL ALGAL BLOOMS 1991 - SCOTLAND

1. Location: West coast of Scotland: north of Ardnamurchan and including the Inner Hebrides.

2. Date of Occurrence: Mid-May until end September 1991.

3. Effects: PSP toxins detected in bivalve molluscs and crustacea. Maximum toxin level found in mussels was 3670MU in Loch Kishorn on 2nd July 1991. Maximum level detected in 3162MU in queen scallops from Loch Toscaig in early July 1991.

4. Management Decision: Warning notices posted along coast from Mallaig to Cape Wrath and around the Isle of Skye. Mollusc fisheries closed from Kyle of Lochalsh to Torridon on mainland and in Lochs Eishort and Dunvegan, round Skye. Closure placed on velvet crab fishery in Loch Broom - Gairloch area.

5. Causative Species: Possibly Alexandrium sp.

6. Environment

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

8. Previous occurrences: 1991 PSP outbreak not as widespread on west coast as that of 1990. Maximum levels of toxin detected were lower than those recorded in 1990.

9. Additional comments:

10. Individual to contact:

Elspeth Macdonald/Godfrey Howard
SOAFD
Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB9 8DB.

HARMFUL ALGAL BLOOMS 1991 - SCOTLAND

1. Location: East coast of Scotland.

2. Date of Occurrence: Late April to mid July 1991.

3. Effects: PSP toxins detected in bivalve molluscs and crustaceans. Maximum toxin level found was 7447MU (1490 µg/100 g tissue) in mussels from the Firth of Forth, in May.

4. Management Decision: Warning notices posted along coast from Scottish border to Buckie. Firth of Forth closed for 3-4 weeks in May.

5. Causative Species: Possibly Alexandrium.

6. Environment:

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

8. Previous occurrences: Common event in this area since first recorded in 1968.

9. Additional Comments:

10. Individuals to contact:

Elspeth Macdonald/Godfrey Howard
SOAFD
Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB9 8DB.

HARMFUL ALGAL BLOOMS 1991 - SCOTLAND

1. Location: Orkney Islands, Scotland.

2. Date of occurrence: July 1991 - January 1992.

3. Effects: PSP toxins detected in bivalve molluscs and crustaceans. Maximum toxin level found in molluscs was 7488MU in queen scallops from Stronsay in mid August. Highest level found in crustacea was 2513MU recorded in velvet crabs from Rousay in early September.

4. Management Decision: Shellfisheries all around the Orkney Islands were subject to various closure notices during the outbreak.

5. Caustative Species: Possibly Alexandrium.

6. Environment:

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

8. Previous occurrences: This area was not sampled for PSP previous years. in

9. Additional Comments: Toxicity persisted in velvet crabs throughout the winter, into January 1992.

10. Individual to contact:

Elspeth Macdonald/Godfrey Howard SOAFD
Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB9 8DB.

HARMFUL ALGAL BLOOMS 1991 - SCOTLAND

1. Location: Loch na Keal, Isle of Mull. Scottish west coast.

2. Date of Occurrence: 23-25 April 1991.

3. Effects: Mortalities of caged Salmo salar, especially smolts.

4. Management Decision: Not known.

5. Causative species: Thought to be *Heterosigma akashiwo.*

6. Environment: Calm weather; Secchi disc depth 2.5 m instead of normal 5-6 m.

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

8. Previous occurrences: Not previously reported in this area.

9. Additional Comments:

10. Individual to contact:

Elspeth Macdonald
SOAFD
Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB9 8DB.

Richard Gowen
DANI
Aquatic Science
Research Div.
Newforge Lane
Belfast BT9 5PX.

CODE DESIGNATIONS FOR

BLOOM REPORTING

AREAS 4, 5, AND 6

ALGAL BLOOM REPORTS - UNITED STATES - 1991

Locations:
Northern coast of Massachusetts (Area 4)
Georges Bank (offshore, Area 6)

Date of Occurrence:
June and July

Effects:
Low toxicity levels; reached only 120 µg/100g in coastal soft-shell clams (Mya arenaria) in June and started to decline in July.
No human deaths or illnesses occurred.
Toxins that accumulated in 1990 persisted in Georges Bank surf clams (Spisula solidissima) at several hundred µg/100g, with possible slight increase in toxin levels occurring in July 1991.
No toxicity (PSP) reported along southern coast (Area 6) in 1991.

Management Decision:
Shellfish closure along northern coast of Massachusetts
Continuation of the closure of Georges Bank to shellfishing

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

Environment:

Advected Population or In Situ Growth:
Advection from the North is the most likely cause of toxicity. The cause of the offshore toxicity and its linkage with inshore toxicity remains to be clarified.

Previous Occurrences:
Annual event since 1972, usually in May/June

Additional Comments:
The important offshore scallop fishery has not been affected by the PSP toxicity problem because this fishery utilizes only the adductor muscle, which remains toxin free, or nearly so. Low levels of domoic acid have also been detected in shellfish in inshore and offshore waters of Massachusetts.

Individual to Contact:
Dr. Alan White
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, MA 02543
Tel: 508-548-5123 Fax: 508-648-5124

AREA 8

ALGAL BLOOM REPORTS - UNITED STATES - 1991

1. **Locations:** Peconic Bay system (N.Y.) from Flanders Bay to Gardiners Bay. Highest densities in Flanders Bay (westernmost area) and West Neck Bay (Shelter Island).

2. **Dates of Occurrence:** May through September with peak concentrations (2×10^6 cells/ml) in mid June.

3. **Effects:** Deleterious effects on various shellfish species have been documented. Water column discoloration (brown) and reduced transparency. Secchi depth <1.0 m during peak bloom period.

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

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

6. **Environment:** Temperature: 115 - 29.7°C
   Salinity: 20.96 - 30.02 ppt
   Water column stability - mixed

7. **Advected Populations 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 cell density occasionally exceeding 10^6 cells/ml. Cell numbers declined through 1988 and 1989 and were generally undetectable during 1990 except for 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

    Tel: (516) 852-2082

AREA 9

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: Sandy Hook Bay (component of Hudson-Raritan estuary), NJ.

2. Date of Occurrence: About July 20 to August 1; peak July 30

3. Effects: brown water, subsequent flocculent deposits, especially in south shore vicinity (Keansburg to Atlantic Highlands)

4. Management Decision: increase surveillance by the Monmouth County Health Dept. in liaison with NJDEP

5. Causative Species: diatoms: dominant species *Thalassiosira nordenskioldii*, *Chaetoceros sociale*, *Leptocylindrus minimum*, *Cyclotella* sp.; concentrations of individual species to 5×10^4 ml^{-1}, chlorophyll *a* > 50 mg l^{-1}

6. Environment: warm, clear; water clear but becoming turbid; generally shallow (< 5m); slight stratification in deeper areas

7. Advected Population or In Situ Growth:

   primarily in-situ, possibly from adjacent neritic waters

8. Previous Occurrences:

   Summer diatom blooms have occurred in this area for the past several years.

9. Additional Comments:

10. Individual to Contact:

Paul Olsen
New Jersey Dept. of Environmental Protection and Energy
Bureau of Water Monitoring
CN029 Trenton, NJ 08625 USA

AREA 9

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: Shark River, NJ

2. Date of Occurrence: about July 25 to August 1, peak July 30

3. Effects: patches of green water, dark green near head of tide to light green near inlet to Atlantic Ocean

4. Management Decision: Surveillance by the Monmouth County Health Dept. in liaison with NJDEP

5. Causative Species: Prorocentrum redfieldi, P. minimum, Gyrodinium sp., Euglena sp., Katodinium rotundatum, Chroomunas sp. (flagellates) Thalassirosira sp. (diatom) ; concentrations of dominant species to 2 X 10^4 cells ml^{-1}

6. Environment: (See Sandy Hook Bay summer diatom blooms)

7. Advected Population or In Situ Growth:

   Probably in-situ but possibly advected near the inlet by tidal action (different species were dominant here than in upper estuary.

8. Previous Occurrences: nuisance blooms have occurred only occasionally (usually localized) on this relatively small estuary*

9. Additional Comments: Concurrent with the diatom bloom in Sandy Hook Bay.

10. Individual to Contact:

Paul Olsen
New Jersey Dept. of Environmental Protection and Energy
Bureau of Water Monitoring
CN029 Trenton, NJ 08625 USA

* Occasional red tides in the adjacent coastal waters, dominated by Prorocentrum micans/redfieldi, have had greater adverse impact (i.e. complaints of respiratory irritation by bathers); occurrences were in 1968, 1972 and 1980-82.

AREA 9

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: Hudson-Raritan estuary, New York/New Jersey

2. Date of Occurrence: May 20 - June 1; peak about May 25

3. Effects: red water in estuary, especially in Sandy Hook Bay south shore area

4. Management Decision: Continued monitoring by NJDEP/USEPA

5. Causative Species: Prorocentrum minimum; maximum concentration about 2.5×10^4 cells ml^{-1}

6. Environment: (See Sandy Hook Bay, summer diatom bloom)

7. Advected Population or In Situ Growth: in-situ population

8. Previous Occurrences: has been subdominant in annually recurring red tides in the NJ northern estuarine and coastal region; reported as dominant red tide species in adjacent Long Island

9. Additional Comments: (NY) south shore embayments; bloom in NJ occurred somewhat earlier than in previous years; Katoedinium rotundatun, which had been the dominant red tide species, conspicuously not abundant in 1991.

10. Individual to Contact:

Paul Olsen
New Jersey Dept. of Environmental Protection and Energy
Bureau of Water Monitoring
CN029 Trenton, NJ 08625 USA

AREA 9

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: Barnegat Bay, NJ

2. Date of Occurrence: early June to early September; peak in early July

3. Effects: yellow brown water discoloration, virtually summer-long; possible ecological damage in eelgrass mortality

4. Management Decision: ongoing surveillance (NJDEP/USEPA), entrophication study (NJDEP)

5. Causative Species: Nannochloris atomus; peak concentration approaching 10^6 cells ml^{-1}, chlorophyll a > 22 mgl^{-1}; blooms at times almost monospecific

6. Environment: data may be available from NJOEP Division of Science & Research

7. Advected Population or In Situ Growth: in-situ growth

8. Previous Occurrences: chronic blooms at least since 1985; N. atomus presence first discovered on Barnegat Bay 1965

9. Additional Comments: N. atomus is ubiquitous in the region, but maximum concentrations elsewhere (e.g. Raritan Bay) have been less than half those on Barnegat Bay

10. Individual to Contact:

Paul Olsen
New Jersey Dept. of Environmental Protection and Energy
Bureau of Water Monitoring
CN029 Trenton, NJ 08625 USA

AREA II

ALGAL BLOOM REPORTS - UNITED STATES

Content

Reports should be restricted to a presentation of episodes that have either clearly resulted in problems related to public health or aquaculture or are of an "exceptional" nature.

Categories to include (with explanatory test where appropriate)

1. Locations: Pamlico River (6 stations), Taylor Creek, Lee Brothers Aquaculture Aurora Facility, Nense River (2 stations). Also: NC Maritime Museum (all fish species in holding tank), Jan, 1992, and National Marine Fisheries Service, Beaufort (Menhaden tank), Feb, 1992.

2. Date of occurrence: 15 May, 4 Aug, 10(?) Sep, 7-20 Oct, 15 Dec, 1991.

3. Effects:

   - separate fisheries and public health effects: Massive kills of finfish (menhaden, flounder, striped bass) & shellfish (e.g., blue crabs), etc.
   - general human and marine organisms, shellfish, or finfish epidemiology: massive subcutaneous lesions and hemorrhaging; neurotoxic symptoms and apparent suffocation
   - and pathology (include size, age of affected stock)

   - toxin assay results (include details on extraction and assay procedures;
   - include chronology of toxin scores when relevant) - give
   - reference and laboratory: Underway with guidance/assistance from D. Baden, S. Hall:
   - water colouration: Usually no change but on 2 occasions, milky/pale tan.

4. Management Decision: (e.g. quarantine details etc.) Sampling protocol to detect and verify presence of the toxic dinoflagellate, directed by J. Burkholder and E. Noga (NCSU).

5. Causative Species:

   - Tentative - Species (probably new) within genus Alexandrium
   - concentration of suspected species and co-occurring species
   - where deemed relevant (sampling method brief description) Must be sampled (for toxic vegetative cells) while a kill is in process; quickly encysts and settles out once fish are dead.
   - steps taken to identify (Confirmation if necessary or sought): Plate formula undertaken with help from K. Steidinger; cyst characteristics (for systematics) with help from D. Anderson, B. Dale.

- chlorophyll measurements when available

6. Environment:

- temperature range: 12°C - 28°C = fish kills confirmed with lab bioassays, (Burkholden) SEM.

- salinity range: 0/ppt (with water or high in Ca^{++})--35/ppt = kills as documented by Burkholder

- water column stability (mixed/unmixed): Unmixed, in shallow, turbid conditions

- oxygen concentrations from low (approx. 2/ppm) to approx. 10/ppm

7. Advected population or in situ growth

- describe physical location: Various tributaries and acquaculture facilities as described previously.

8. Previous Occurrences: Suspected but not documented.*

9. Additional Comments: *

10. Individual to Contact: (1) J. Burkholder, Depart. of Botany, Box 7212, NCSU, Raleigh, NC, 27695--for confirmation of the alga and its toxicity; (918)515-2726. (2) E. Noga, NCSU, School of Veterinary Medicine for fish disease/pathology and if live specimens are available (919) 829-4236.

* Approximately 25% of fish kills in these estuaries have been associated with "sudden death" of fish spp. (many) and shellfish which exhibited neurotoxic symptoms--but no cause could be determined until we were at the scene of a massive menhaden kill and caught the organism "swarming" in the water (cell conc. approx. 2000/ml) while fish were dying. However, within several hours after fish death, there were only approx. 20 cells/ml remaining because the alga had encysted and settled [back] to the sediments. Since May, 1991, Burkholder and Noga have ~~dis~~associated this organism with approximately 25% of the fish kills which have occurred in the Pamlico and Nense Estuaries. Toxin appears to be water-soluble; we suspect a saxitoxin. Alga--may be a new species within genus Alexandrium (K. Steidinger is helping to get the plate formula for formal speciation).

**Finfish--this far confirmed (lab bioassay) as resceptible to this dinoflagellate--striped bass, eel, menhaden, spot, croaker, mullet, flounder, clownfish, tlapia (Zipp.), goldfish, guppies (=all spp. tested so far)

Shellfish thus far confirmed as susceptible--blue crab, clam, bay scallops, mud crab.

AREA 21

HUMAN INTOXICATIONS - CALIFORNIA 1991

MONTH	AREA code	COMMENTS
AUGUST	21	Sea mussels collected at Salt Point, Sonoma County Eleven people affected; three severly, one critically were air-lifted from park area to two hospitals in in Santa Rosa. Eight developed mild and transient symptoms and refused medical help. By August 8, 1991 all were discharged from the hospital. Mussels taken from the people by state park personnel contained 2000 µg of PSP.

Ref: State of California Department of Health Services (SCDHS)
Shellfish Monitoring Program 1991

AREA 21

MORTALITY OF FISH AND OTHER MARINE ORGANISMS

CALIFORNIA 1991

MONTH	AREA code	COMMENTS
Sept.	21	Report to the California Department of Fish and Game of an unusual number of sick and dying brown pelicans and Brandt's cormorants in the Santa Cruz area. Ten samples submitted to the Sanitation and Radiation Laboratory of the Department of Health Services. Two of the ten samples tested slightly positive for PSP. Observed bioassay symptoms quite different from those associated with PSP toxins. The symptoms more closely resembled those reported for domoic acid, another shellfish toxin. Samples of the birds submitted to the National Research Council in Canada, whose Institute of Marine Biosciences positively identified domoic acid. Concentrations in the stomach contents assayed 100-200 ppm, in body parts 50-60 ppm. This is the first documented occurrence of domoic acid in California. Plankton samples collected in Santa Cruz contained the diatom Nitzschia pseudoseriata (Pseudonitzschia australis). Analyses of the plankton samples by IMB confirmed the presence of domoic acid.

Ref: State of California Department of Health Services (SCDHS)
Shellfish Monitoring Program 1991

'RATION OF PSP TOXIC EPISODES CALIFORNIA COUNTIES and SHELLFISH AFFECTED 1991

	J	F	M	A	M	J	J	A	S	O	N	D	max tox µg/100g
:LNOR	ns	43	<42	<42	<42	<42	<43	<42	68	86	ns	44	86
'MBOL	<42	<42	<42	<41	<42	<42	<41	48	79	49	<42	<40	79
'NDOC	<42	<43	ns	<41	<41	<42	930	3300	59	54	<42	42	3300
:NOMA	<42	44	47	43	57	50	3300	2000	77	ns	110	70	3300
					WASHINGTON CLAM	(body)	100	ns	ns	ns	ns	ns	
						(siphon)	660	ns	ns	130	ns	170	
						(viscera)	1400	ns	ns	47	ns	68	
					BASKET COCKLE		130	ns	ns	ns	ns	ns	
RIN	170	80	<42	44	<41	110	1900	870	ns	ns	48	<42	10000
						(SSM)	10000	2900	84	71	50	<42	
						(WBM)	4100	2100	ns	73	ns	ns	
						(CBM)	2400	2000	<41	<43	ns	ns	
						(SBM)	ns	ns	<43	49	58	<43	
						(CPO)	2200	1300	43	69	52	<41	
						(SPO)	1200	130	<42	ns	ns	ns	
					MANILA CLAM		110	45	ns	ns	ns	ns	
					GAPER CLAM	(siphon)	<44	ns	ns	ns	ns	ns	
						(viscera)	2500	210	ns	ns	ns	ns	
NFRA	ns	ns	ns	ns	ns	41	69	46	ns	ns	<41	<43	69
NMAT	43	69	<41	43	65	173	390	<42	<42	80	66	<41	390
NCRU	<42	<42	<42	45	65	99	85	48	45 50	43	56	55	99
'NTER	ns	ns	ns	80	<43	46	64	60	ns	47	63	<42	64
BISP	<42	<42	<41	<42	<41	45	45	68	48	<42	<42	<42	68
NBAR	41	<42	<40	<41	44	47	77	52	<42	<42	47	62	77
:NTUR	<43	45	<43	<42	56	53	64	<41	<42	<42	<42	60	64
'SANG	<42	63	<43	94	55	66	78	<42	<42	ns	<42	<42	94
?ANGE	ns	<42	ns	44	50	49	<38	<41	<42	<41	<42	<42	50
NDGO	ns	ns	ns	ns	<42	<42	<42	<42	<42	43	<42	<42	43

ld Sea Mussel (WSM)
:ntinel Sea Mussel (SSM)
ld Bay Mussel (WBM)
iltured Bay Mussel (CBM)
·ntinel Bay Mussel (SBM)
:ltured Pacific Oyster (CPO)
·ntinel Pacific Oyster (SPO)

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

DOMOIC ACID TOXIN DATA - CALIFORNIA COUNTIES AND SHELLFISH AFFECTED 1991

	Nov.	Dec.	Shellfish
DEL NORTE	<10	nd	WSM
HUMBOLDT	5.6	nd	WSM
	nss	29.0	Razor Clam
MENDOCINO	1.1	nd	WSM
SONOMA	2.4	nd	WSM
MARIN	2.0	nss	SSM
	nd	1.1	CPO
SAN FRANCISCO	<10*	nss	WSM
SAN MATEO	<10	<1.0**	WSM
SANTA CRUZ	15.0	23.6	WSM
MONTEREY	47.0	10.1	WSM
	nss	1.2	CPO
SAN LOUIS OBISPO	<10	nd	WSM
	<10	nd	WBM
	<10	nd	CPO
SANTA BARBARA	1.1	nd	WSM
VENTURA	<10	nss	WSM
LOS ANGELES	<10	nss	WSM
ORANGE	<10	nd	WSM
SAN DIEGO	<10	nss	WSM

Analyses by the Department of Health Services Sanitation and Radiation Laboratory (SRL)

SRL Detection Limits:
* AOAC (acid) Extraction (10 µg/g)
** Methanolic Extractions (0.3 µg/g)

WSM (wild sea mussel)
SSM (sentinel sea mussel)
WBM (wild bay mussel)
CPO (cultured Pacific oyster)

nd (not detectable)
nss (no sample submitted)

MARIN COUNTY 1991 PARALYTIC SHELLFISH POISON DATA

AREA	SHELLFISH	TOXICITY µg/100g	MONTH
	CULTURED PASIFIC OYSTERS		
Drakes Estero/Bed #12		45	Jan
" " #12		92	Feb
" " #15		90	
" " #12		2200	July
" " # 8		1400	
" " # 3		290	
" " #26		95	
Tomales Bay/Lease #M430-11		1500	
" " -02		1100	
" " -02B		320	
" " -10		1100	
" " -14		290	
" /Marconi Cove		48	
HIOC WetStorage		45	
Tomales Bay/Lease #430-02		490	Aug
" " -02B		350	
" " -11		270	
" " -14		48	
" /Lawson's Landing		120	
Drakes Estero/Bed #08		830	
" " #12		1300	
" " #03		240	
" " #12		43	Sep
" " #12		74	Oct
" " #22		42	
Tomales Bay/Lease #M430-11		59	
Drakes Estero/Bed # 8		43	Nov
" " #12		52	
	SENTINEL PACIFIC OYSTERS		
Drakes Bay/Chimney Rock LBS		1200	July
Drakes Bay/Chimney Rock LBS		130	AUG

AREA	SHELLFISH	TOXICITY µg/100g	MONTH
	WILD SEA MUSSELS		
Stinson Beach/south rocks		170	Jan
" "		73	Feb
" "		110	June
" "		990	July
Rodeo Beach		46	
Kehoe Beach		45	
Stinson Beach/south rocks		1900	July
Kehoe Beach		870	Aug
Stinson Beach/south rocks		46	Nov
Kehoe Beach		48	
	SENTINEL SEA MUSSELS		
Drakes Bay/Chimney Rock LBS		42	Jan
" "		80	Feb
" "		46	June
" "		10000	July
Tomales Bay/Lawson's Landing		3600	
Drakes Bay/Chimney Rock LBS		2900	Aug
Tomales Bay/Lawson's Landing		110	
Drakes Bay/Chimney Rock LBS		83	Sep
Tomales Bay/Lawson's Landing		84	
Drakes Bay/Chimney Rock LBS		71	Oct
" "		50	Nov
Tomales Bay/Lawson's Landing		44	
	WILD BAY MUSSELS		
Drakes Estero/Bed #12		40	Apr
Tomales Bay/Lease #M430-10		63	July
Drakes Estero/Bed #12		4100	
" "		1700	Aug
" "		73	Oct
	CULTURED BAY MUSSELS		
Tomales Bay/Marconi Cove		53	July
" /Lease #430-11		2400	
" " -10		710	
" " -14		78	
Tomales Bay/marconiCove		40	Aug
" /Lease #430-11		2000	
" " -14		120	
" " -10		250	
	SENTINEL BAY MUSSELS		
Drakes Estero/Bed #12		49	Oct
Drakes Estero/Bed #12		58	Nov
	MANILA CLAM		
Tomales Bay/Lease #430-11		110	July
" " -10		45	Aug
	GAPER CLAM		
Tomales Bay/Clam Island	viscera	2500	July
" "		210	Aug

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: DEL NORTE COUNTY, CALIFORNIA areas and shellfish affected: Point St. George (Wild Sea Mussels)

2. Date of Occurrence: September, October, December, no sample was submitted in November.

3. Effects: Through the months of September and December measurable but below the alert toxin levels were recorded in wild sea mussels. In October the concentration of toxin in the mussels rose to 86 µg/ 100g of shellfish meat.

4. Management Decisions: California annual quarantine was in effect to October 31

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: Most likely an in situ growth

8. Previous Occurrences: 1981

9. Additional Comments: The shellfish in this area were for the most part of 1991 free of toxicity.

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991- UNITED STATES

1. Locations: HUMBOLDT COUNTY, CALIFORNIA areas and shellfish affected: Shelter Cove/ Abalone Pt., Trinidad Pier, Humboldt Bay/USCG Station (Wild Sea Mussels); Humboldt Bay/Bird Island, Indian Island Ch., USCG Station, Trinidad Pier (Sentinel Sea Mussels)

2. Date of Occurrence: August, September, October

3. Effects: Concentrations of paralytic shellfish toxins persisted in high measurable levels but below the alert concentration.

4. Management Decisions: The California Annual Mussel Quarantine was in effect throughout this period.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: Since no collection data for this area are available the most likely growth population occurs in situ.

8. Previous Occurrences: 1969, 1971, 1973, 1989

9. Additional Comments: Most of 1991 the shellfish were free of toxins

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: MENDOCINO COUNTY, CALIFORNIA areas and shellfish affected: Westport/Bruhel Pt., Fort Bragg/Virgin Creek and Ten-Mile River, Anchor Bay (Wild Sea Mussels)

2. Date of Occurrence: July, August, September, October, December

3. Effects: July paralytic shellfish toxin concentrations assayed at 930 µg/100g mussel tissue. The toxin concentrations escalated to 3300 µg/100g of shellfish meat. In September, October and December the levels decreased to high measurable but below alert levels.

4. Management Decisions: The Annual Quarantine was in effect however it was extended indefinitely by the state health director as a precautionary measure.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: Most probably an in situ growth population.

8. Previous Occurrences: 1932, 1962, 1966, 1967, 1969, 1975, 1982, 1984, 1989, 1990

9. Additional Comments: The toxin levels increased rapidly from no detectable concentrations to extremely high levels. The continuous close monitoring of all shellfish is of the greatest importance.

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: SONOMA COUNTY, CALIFORNIA areas and shellfish affected Salt Point State Park, Bodega Head, Sea Ranch, Mussel Point, Doran Rocks (Wild Sea Mussels); Bodega Harbor/Doran Park, Bodega Harbor/Inner, Bodega Bay, Bodega Head, Bodega Harbor/ USCG Dock (Washington Clam); Bodega Bay (Basket Cockle)

2. Date of Occurrence: July, August, October, November, December

3. Effects: During July, August paralytic shellfish toxin levels assayed reached a high of 3300 µg/100g of wild sea mussels decreasing to below alert concentration and in November the level increased to 110 µg. During the rest of the 1991 the wild sea mussel levels were in the high measurable but below the alert of 80 µg. The PSP toxin levels in Washington Clam whole body (July 100 µg), siphon (July 660 µg, October 130 µg, December 170 µg), viscera (July 1400 µg) however, no samples were submitted during the rest of the year. A sample of Basket Cockle from Bodega Bay in July assayed at 130 µg/100g but no other samples were submitted in 1991.

4. Management Decisions: Although the California Annual Quarantine was in effect a special quarantine was established by the Director of Health Services on July 25 to include all bivalve shellfish taken by sport harvesters.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: Both advected population and in situ growth. The bloom of the dinoflagellate traced to Mendocino County.

8. Previous Occurrences: 1927, 1929, 1930, 1932, 1937, 1954, 1962, 1968, 1969, 1970, 1971, 1976, 1980, 1981, 1982, 1984, 1987, 1989, 1990

9. Additional Comments: On August 7, 1991 several people became ill eating sea mussels collected at Salt Point ignoring the quarantine in effect. Three severly ill people were air lifted to hospitals, one in critical condition. Eight others reported feeling nausiated and slightly ill refused medical help. No fatalities occurred.

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: MARIN COUNTY, CALIFORNIA areas and shellfish affected: Stinson Beach/south rocks, Rodeo Beach, Kehoe Beach (Wild Sea Mussels); Drakes Bay/Chimney Rock, Tomales Bay/Lawson's Landing (Sentinel Sea Mussels); Drakes Estero/Bed #12, Tomales Bay/Lease #M430-10 (Wild Bay Mussels, Sentinel Bay Mussels); Tomales Bay/Marconi Cove and Leases #M430-10,11,14 (Cultured Bay Mussels); Drakes Bay/Chimney Rock LBS (Sentinel Pacific Oysters); Drakes Estero/Beds 3, 8, 12, 22, Tomales Bay/Marconi Cove, Lawson's Landing, Leases =M430-02, 02B, 10, 11, 14, HIOC Wet Storage (Cultured Pacific Oysters); Tomales Bay/Lease #M430-10, 11 (Manila Clam); Tomales Bay/Clam Island (Gaper Clam)

2. Date of Occurrence: January, February, June, July, August, September high above alert levels; March, October, November high measurable but below alert concentration

3. Effects: Sentinel Sea Mussel toxin content recorded wass 10,000 µg/100g, Wild Sea Mussels' concentration 1900 µg, Wild Bay Mussels 4100 µg, Cultured Bay Mussels 2400 µg, Gaper Clam viscera 2500 µg, Manila clam 110 µg, Sentinel Pacific Oysters 1200 µg, Cultured Pacific Oysters 2200 µg. These high concentrations occurred during the months of July and August.

4. Management Decisions: The magnitude and geographical extent of the toxic Alexandrium catenella bloom resulted in the issuance of a special quarantine order by the Director of Health Services on July 25, 1991 to include all bivalve shellfish taken by sport harvesters. On July 26 Drakes Bay and the entire Estero were closed to commercial harvesting. The annual quarantine on sport harvested mussels, due to expire on October 31, 1991 was extended indefinitely by the state health director.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: Both advected population from the northern coastal areas and in situ growth most likely contributed to the bloom condition.

8. Previous Occurrences: 1927, 1929, 1932, 1954, 1962, 1963, 1964, 1965, 1966, 1970, 1971, 1976, 1980, 1981, 1982, 1984, 1986, 1987, 1988, 1989, 1990

9. Additional Comments: This is the area where most of the shellfish aquaculture industries have their leases. Monitoring of these beds for toxin levels becomes imperative since concentrations can increase rapidly above alert levels.

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: SAN MATEO COUNTY, CALIFORNIA areas and shellfish affected: Pescadero State Beach, Linda Mar, Moss Beach, Bean Hollow State Beach (Wild Sea Mussels)

2. Date of Occurrence: January, February, April, May, June, July, October, November

3. Effects: In June Pescadero State Beach wild sea mussel samples assayed 173 µg PSP; July wild sea mussel samples from Ben Hollow State Beach reached 390 µg/100g and at Linda Mar 110 µg, while the Pescadero State Beach samples remained at 100 µg; October samples from Pescadero Beach rose to the alert level of 80 µg/100g. The rest of the months measurable below the alert concentrations persisted.

4. Management Decisions: The California Annual Mussel Quarantine was in effect.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

7. Advected Population or In Situ Growth: This appears to be an in situ population

8. Previous Occurrences: 1970, 1971, 1982, 1983, 1984, 1986, 1987, 1988, 1989, 1990

9. Additional Comments: This area needs to be monitored more closely for the presence of toxic dinoflagellates and their cysts

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

AREA 21

HARMFUL ALGAL BLOOMS IN 1991 - UNITED STATES

1. Locations: SANTA CRUZ COUNTY, CALIFORNIA areas and shellfish affected: Natural Bridges, San Mateo/Santa Cruz Co. Line (Wild Sea Mussels)

2. Date of Occurrence: April, May, June, July, August, September, October, November, December

3. Effects: The Wild Sea Mussels from San Mateo/Santa Cruz Co. Line assayed 99 µg/100g of meat and from Natural Bridges 85 µg in June and July respectively. Throughout the other months the levels of toxin reported were in high measurable but below the alert concentration.

4. Management Decisions: The California Annual Mussel Quarantine was in effect.

5. Causative Species: Alexandrium catenella

6. Environment: No data available

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

8. Previous Occurrences: 1971, 1984, 1989

9. Additional Comments: This could be an area of a possible toxic dinoflagellate bloom. Because of the reports of an unusual number of sick and dying brown pelicans and Brandt's cormorants in this area the birds stomachs were analyzed for PSP. Two of the ten samples tested slightly positive, the concentrations were much below the alert level of 80 ug/100g tissue and the observed bioassay symptoms were quite different from those associated with PSP toxins. The symptoms more closely resembled those reported for another shellfish toxin, domoic acid. Samples submitted to the National Research Council Canada, whose Institute for Marine Biosciences (IMB) positively identified domoic acid and California Fish and Game announced the first documented occurrence of domoic acid on the west coast. Plankton samples collected in Santa Cruz contained the diatom Nitzschia pseudoseriata analysis of which by IMB confirmed presence of domoic acid.

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

AREAS 19 + 20

CALIFORNIA COUNTIES 1991 PSP LEVELS

SAN FRANCISCO COUNTY - June, July, August measurable but below the alert level; no samples submitted on regular basis
Previous occurrences - 1970, 1971, 1980, 1983, 1984, 1986

MONTEREY COUNTY - April 80 µg; June, July, August, October, November measurable but below the alert levels
Previous occurrences - 1988, 1989

SAN LOUIS OBISPO COUNTY - June, July, August, September medium to high mesurable concentrations below the alert level
Previous occurrences - 1979, 1989, 1990

SANTA BARBARA COUNTY - January, May, June, July, August, November, December high measurable levels below the alert concentration
Previous occurrences - 1978, 1985, 1989

VENTURA COUNTY - February, May, June, July, December paralytic shellfish toxin concentration high measurable below the alert level
Previous occurrences - 1980, 1989

LOS ANGELES COUNTY - April 94 µg; February, May, June, July high measurable toxin concentration just below the alert level
Previous occurrences - 1970, 1971, 1972, 1983, 1985, 1986, 1987, 1988, 1989

ORANGE COUNTY - April, May, June measurable below alert levels
Previous occurrences - 1974, 1976, 1980, 1984, 1985, 1989

SAN DIEGO COUNTY - October low measurable PSP
Previous occurrences - 1985

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

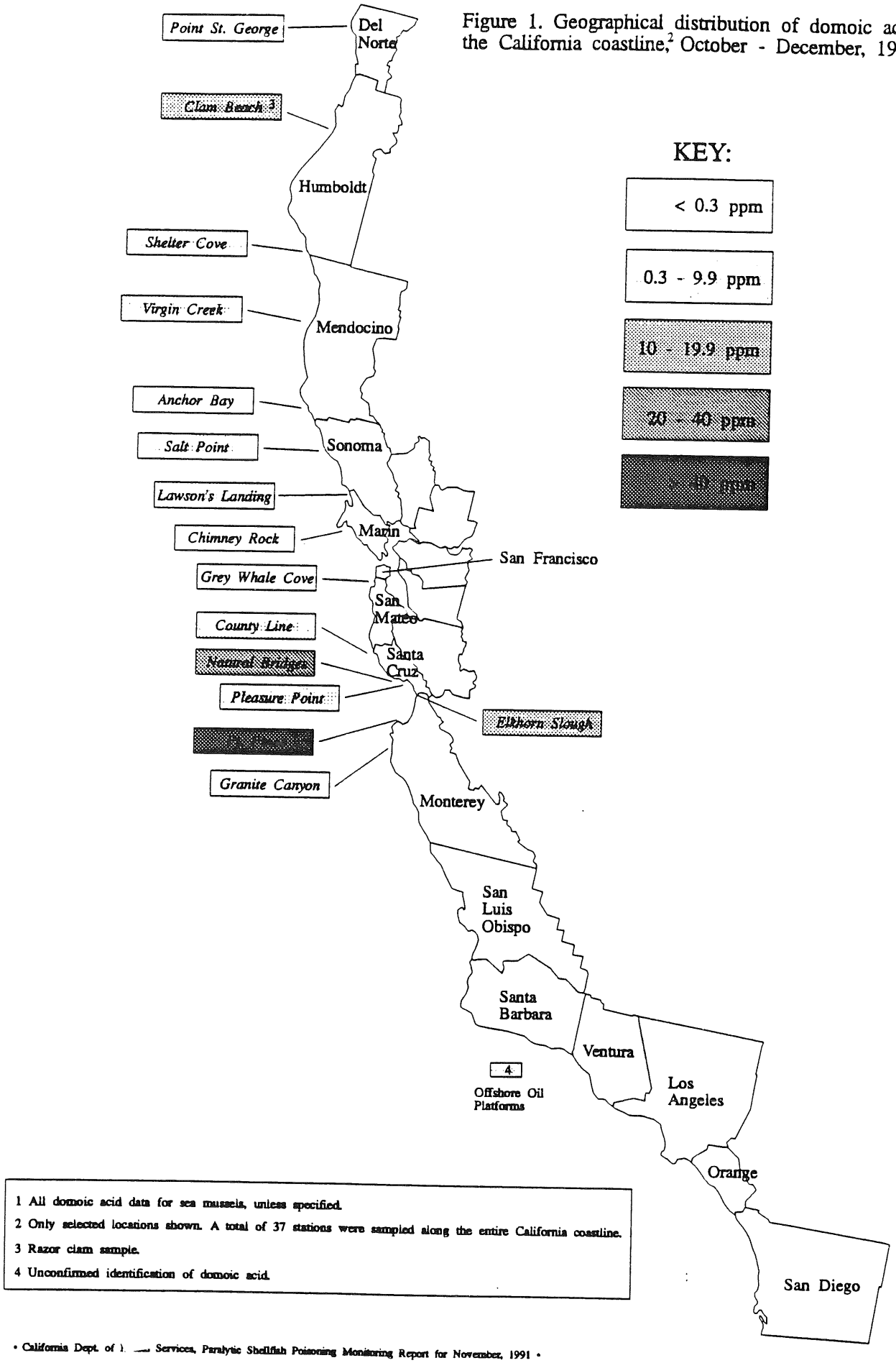


Figure 1. Geographical distribution of domoic acid[1] along the California coastline,[2] October - December, 1991.

1 All domoic acid data for sea mussels, unless specified.

2 Only selected locations shown. A total of 37 stations were sampled along the entire California coastline.

3 Razor clam sample.

4 Unconfirmed identification of domoic acid.

• California Dept. of [illegible] Services, Paralytic Shellfish Poisoning Monitoring Report for November, 1991 •

AREA 22+23

HARMFUL ALGAL BLOOMS IN THE UNITED STATES -- 1991

1. Location:

Pacific coasts of Oregon and Washington

2. Date of Occurrence:

Probably Oct-Nov 1991

3. Effects:

Caused razor clams and Dungeness crabs to become intoxicated with domoic acid
28 human illnesses reported, all very mild
Toxin assays done by U.S. Food and Drug Administration and National Marine Fisheries Service using acid or methanol extraction followed by HPLC (same method used in Canadian studies)

4. Management Action:

Closure of commercial and recreational harvest of razor clams on Oregon/Washington beaches; closed commercial fishery for Dungeness crabs from northern California to northern Washington for nearly a month; spring, 1992, recreational harvest for razor clams probably cancelled because clams are still toxic

5. Causative Species:

Presumed to be Pseudonitzschia australis Frenguelli; cultures from Oregon and Washington have not yet produced domoic acid; few phytoplankton samples are available, cell concentrations not known

6. Environment:

Not known, but there are indications that water temperature is higher than usual

7. Advected Population or In Situ Growth:

Not known, but may be part of a similar bloom in central California

8. Previous Occurrences

Not known, few historical phytoplankton or clam samples available, but some frozen clams collected in 1985 and 1986 contained low levels of domoic acid; no literature references to this species being here in the past

9. Additional Comments:

Razor clams are still toxic in mid-March 1992 with domoic acid levels of 30-60 ppm (regulatory closure level is 20 ppm); most toxin was found in the edible parts of the clams rather than in the viscera, but in crabs, most toxin was found in the viscera with low level contamination in the meat probably from cooking/cleaning process

10. Individual to Contact:

Rita Horner
School of Oceanography, WB-10
University of Washington
Seattle, WA 98195 USA

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)
1991	OR	22										X	X	X	124 ppm razor clams
1991	WA	2 23										X	X	X	154 ppm razor clams
1991	OR	22												X	24 ppm crab guts and muscle
1991	WA	23												X	89 ppm crab guts; 4 ppm crab meat

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

HUMAN INTOXICATIONS

YEAR	MONTH	AREA (CODE)	COMMENTS
1991	Nov-Dec	23	About 28 people reported symptoms within 24 hr of eating razor clams; illnesses were relatively mild, mostly gastrointestinal problems, but a few mild neurological problems, e.g. headache, disorientation, mild memory loss. Recovery from all symptoms was rapid. People got sick at relatively low toxin levels - around 20ppm; epidemiological study suggested first-time clam eaters were more likely to get sick than people who had eaten them before. Degree of illness depended on person, e.g., within one family, some members got sick, others didn't, older family members not necessarily affected more than younger ones.

MORTALITY OF FISH AND OTHER MARINE ORGANISMS

YEAR	MONTH	AREA (CODE)	COMMENTS
1991	Oct-Dec	22,23	Not known; none reported

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)
1991	.35						X								suspect ASP toxicity
	25						X								" "
	25						X								" "
	25						X								" "
	26							X							2244 ug/100g (butter clams)
	25							X							suspect ASP toxicity
	26							X							" "
	25								X						" "
	25													X	Unknown

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

HUMAN INTOXICATIONS

YEAR	MONTH	AREA (CODE)	COMMENTS
1991	June	26	Suspect PSP (butterclams 2104+2244 µg/100 g)
1991	Dec.	25	UNKNOWN CAUSE TO SYMPTOMS
			PREVIOUSLY TOX RESULTS FOR PSP TOXIN
			[illegible] — STILL [illegible]
			NEGATIVE FOR PSP BY U.S. [illegible]
			[illegible]

AREA 25

ALGAL BLOOM REPORTS - UNITED STATES

(60° 37' N.
146° 00' W.)

1. Locations: Sheep Point, N. shore of Orca Bay, 10 miles NW of Cordova, AK.

2. Date of Occurrence: 4/22 - 4/23 /91

3. Effects: Water coloration

4. Management Decision:

5. Causative Species: Suspect Noctiluca

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences:

9. Additional Comments:

10. Individual to Contact:

Michael T. OSTASZ
Alaska DEPT. OF ENVIRN. CONSERVATION
3600 "C" ST. Suite 1324
Anchorage, AK 99503
907-563-0318

ACE 5703902

AREA 25

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: 60° 37'30" N, 145° 55'00" W
Simpson Bay on NE shore of ECCA Bay, 18 miles NW of CORDOVA, ALASKA

2. Date of Occurrence: 5/7-5/8/91

3. Effects:
Water coloration

4. Management Decision: Statewide press Release to warn about shellfish harvesting in unapproved (non certified) areas.

5. Causative Species:
Suspect Noctiluca

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences:

9. Additional Comments:

10. Individual to Contact:

Michael J. Ostasz
Alaska Dept. of Env. Conservation
3600 C St. Suite 1324
Anchorage, AK 99503
907-563-0315

ACE 5703900

AREA 25

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: (60°37'30"N
(145°57'30"W.
ALICE Cove, on N. Shore of CROIA Bay, 9 miles NW of Cordova, AK.

2. Date of Occurrence: 5/7- 5/15/91

3. Effects: WATER Coloration

4. Management Decision: STatewide Press Release to warn about harvesting in Unapproved/Uncertified Areas

5. Causative Species: Suspect Noctiluca

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences:

9. Additional Comments:

10. Individual to Contact:
MICHAEL J. OSTASZ
ADEC, 3600 "C" ST. Suite 1324
ANCHORAGE, AK 99503

ACE 5703901

AREA 25

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: Simpson Bay, U-shaped, 8 mile long on NE shore of Orca Bay, 8 miles NW of Cordova, AK. 60° 37' 30" N, 145° 45' 00" W.

2. Date of Occurrence: 6/4/91

3. Effects: WATER discoloration (red)

4. Management Decision: Sample indigenious product (mussels, for background levels. Sample taken by Alaska Dept. of Fish + Game, Sports Division Cordova, AK

5. Causative Species: Suspect Noctiluca

6. Environment: Popular sport clam harvesting area for residents of Cordova. Area is not commercially certified.

7. Advected population or in situ growth:

8. Previous Occurrences: Previous occurrences with suspect Noctiluca have been reported

9. Additional Comments: Mussel sample showed < 32 Mg/100 for PSP level

10. Individual to Contact:

Michael J. Ostasz
Alaska Dept. of Environmental Conservation
3601 "C" St. Suite A
Anchorage, AK 99503
907 563-0318
FAX 907-562-4208

ACE 5703903

AREA 26

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: Sheep Island located on the ~~W~~ east side of Kodiak Island immediately east of the Village of Old Harbor, Alaska. Island is 0.4 mile long in Sitkalidak Strait, at mouth of Midway Bay, between Sitkalidak I., + S.E. coast of Kodiak Island. 57° 13' 00' N., 153° 14' 20" W.

2. Date of Occurrence: 6/11/91

3. Effects: 4 people had symptoms (3 cases); 3 people were ill. 2 other suspect cases (not confirmed at this time).

4. Management Decision: Samples of butter clams + others to be analyzed for PSP.

5. Causative Species: Suspect PSP

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences: Unknown. Previous shellfish samples in 10/90 showed butter clams as 56 Mg/100gr and mussels as 36 Mg/100gr of PSP.

9. Additional Comments: Samples being processed for PSP. Area not certified. Harvest for ~~Subst~~ Subsistence purposes. No commercial harvest.

10. Individual to Contact:

Michael J. Ostasz
Alaska Dept. of Environment Conservation
3601 "C" St. Suite A
Anchorage AK 99503
907-563-0318
FAX 907-562-4208

ACE 5703904

AREA 26

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: Nelson Lagoon, 20 miles long, 20 miles west of Port Moller, on Alaska Peninsula. 56° 00'N., 161° 00'W.

2. Date of Occurrence: 6/13/91

3. Effects: ONE individual ate cockles and soon felt tingling in face + lips. Product had been fryed.

4. Management Decision: Sample of product attempted to be analyzed for PSP. Problems with congealing solution.

5. Causative Species: Cockles

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences: Unknown

9. Additional Comments: Awaiting PSP results if test can be performed. SEE #4.

10. Individual to Contact:

Michael J. Ostasz
Alaska Dept. of Env. Conservation
3601 "C" St. Suite 1324
Anchorage, AK 99503
907-563-0318
FAX 907-[illegible]-4018

ACE 5703905

Woods Hole Oceanographic Institution
Woods Hole, MA
02543

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: TATITLEK (60°52'45"N., 146°41'00"W) on NE shore of Tatitlek NARROWS, 1 mile NE of Bligh Isl. and 40 miles NW of Cordova, AK

2. Date of Occurrence: 6/20/91

3. Effects: Discoloration of water - orange/red

4. Management Decision: Sample background species of mussels for PSP

5. Causative Species: Suspect *Noctiluca*

6. Environment: NOT A commercially certified area

7. Advected population or in situ growth:

8. Previous Occurrences: Not previously Reported

9. Additional Comments:

10. Individual to Contact:

Michael J. OSTASZ
ADEC
3601 "C" ST. Suite 1324
Anchorage, AK 99503

ACE 5703906

907-563-0318

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: AFOGNAK ISLAND (50 miles ACROSS) NORTH OF KODIAK ISLAND. LOCATION 58° 15'N, 152° 30'W.

2. Date of Occurrence: June 29, 1991

3. Effects: Reddish-brick color to water.

4. Management Decision: N/A

5. Causative Species: Suspect Noctiluca

6. Environment:

7. Advected population or in situ growth:

8. Previous Occurrences: NONE REPORTED

9. Additional Comments: N/A

10. Individual to Contact:

Michael J. OSTASZ
ADEC
3601 "C" ST. Suite 1324
Anchorage, AK 99503

ACE 5703915
-/C

Woods Hole Oceanographic Institution
Woods Hole, MA
02543

1991

ALGAL BLOOM REPORTS - UNITED STATES

1. Locations: South of Knowles Head
60° 41'
146° 37' 30"

2. Date of Occurrence: 7/19/91

3. Effects: Orange discoloration to water

4. Management Decision: None - Area not classified for shellfish.

5. Causative Species: Suspect Noctiluca

6. Environment: 100 yards long

7. Advected population or in situ growth:

8. Previous Occurrences: None Reported

9. Additional Comments:

10. Individual to Contact:
Michael J. Ostasz
ADEC
3601 "C" St. Suite 1324
Anchorage, AK 99503
907-563-0318 FAX 907-562-4208

ACE 5703908

AREA 25

HARMFUL ALGAL BLOOMS IN THE UNITED STATES -- 1991

1. **Location:** Ketchikan, Alaska

2. **Date of Occurrence:** 12/12/91

3. **Effects:** One person reported nausea, "buzzing in legs" tingling in hands, twitching in arms and legs, (seizure-like jerking), mild floating ~~[illegible]~~ feeling, and expressive aphasia. Unknown cause to symptoms (epidemiology report).

4. **Management Action:** Resampled lot of littleneck clams. Negative for PSP + Domoic Acid.

5. **Causative Species:** N/A

6. **Environment:** From Blashke Island (approved oyster and clam harvest area)

7. **Advected Population or In Situ Growth:** In protected bay area in Southeast Alaska. Previous summer sampling for PSP had rejected some littlenecks for sale for human consumption.

8. **Previous Occurrences** ~~[illegible]~~ >

9. **Additional Comments:** All product (littlenecks) were negative for PSP on orginal sampling program.

10. **Individual to Contact:**

Michael T. Ostasz
ADEC
800 E. Dimond Blvd. Suite 3-455
Anchorage, AK

ANNEX V

ALGAL BIOASSAYS: A TOOL FOR ENVIRONMENTAL MONITORING

Dr S. Maestrini, Centre de Recherche en Ecologie Marine et Aquaculture de L'Houmeau (CNRS-IFREMER).

The principle of a bioassay is very simple: if one cultivates algae under conditions in which only one factor (or group of factors) is varied, and the response is proportional, then that factor (or group) is considered to be limiting. Growth thus obtained is the summation of all variables, measurable or not by other methods, that have any direct or indirect influence on growth. This approach is in principle very close to that of the conventional biological assay, which uses the response of an organism to measure the concentration or activity of a particular metabolite that cannot be measured by chemical means, for example, the vitamin assay of body fluids or the standardization of antibiotics. However, although experimental procedures are often similar, the objectives differ.

The term bioassay does not refer to a unique well-defined method, but rather to a large assemblage of protocols varying in practical details with every author. It is possible to evaluate a method only in relation to the objectives and questions posed, because the method is all-embracing and some information or measurements will always be precluded. Therefore, before undertaking a bioassay it is absolutely necessary to establish exactly what one wants to know. The bioassays able to provide an estimation of the capacity of a given body of water to support algal growth (i.e., Algal Growth Potential (AGP)) are concerned less with measuring the actual concentrations of compounds than estimating comparative nutritional capacity. They are based on the measure of the total algal yield in an unenriched water sample by means of a well-defined protocol. Because the water being assayed is used without modification, the experimental techniques are aimed at protecting the alga from grazing and creating conditions of illumination and temperature that will allow its growth to be a reflection of the "quality" of the water, inasmuch as that quality depends on the quantity of nutrient elements or of toxic substances inhibiting utilization of these nutrients.

The practical realization of this assay follows from the actual definition of AGP. It consists in cultivating the test algae under suitable conditions of light and temperature in a filtered sample of the sea water and measuring the maximum biomass produced.

This approach is particularly useful for making comparisons between different waters in terms of the growth of a chosen organism. For this it suffices simply to set up all the samples at the same time with the same test alga in identical conditions. Besides providing comparisons between the samples, the responses also allow one to compare AGPs obtained with other sets, provided of course that experimental conditions and test alga are identical.

A "species yield index" has been further used as being more representative than raw AGP of the unknown properties of a water mass. Based on the fact that it takes a nearly constant quantity of each nutrient (the subsistence quota, *sensu* Droop) to produce a given algal biomass, the "species yield index" is defined as the ratio of biomass produced by a test alga *versus* the nutrient apparently taken up (i.e., analysed-nutrient disappearance). Hence, when all chemical forms of a nutrient are analysed, the yield index meets a species constant, whereas when all forms which were taken up by the cells were not analysed, the ratio increases. Therefore, while AGP only allows one to say generally whether the water is poor or rich respecting the mineral nutrients, by contrast, the species yield index can indicate reduced or increased availability of any one of those nutrients and or the uptake of other unsuspected chemical species.

Bioassays undertaken with unenriched water are simple, but they are very limited and somewhat imprecise. In the first place, the large number of simultaneous samples required presents the experimenter with the difficult choice between adequate sample volume and adequate frequency of measurement. Too small a sample is likely to be unrepresentative and moreover does not permit the most sensitive methods of biomass estimation, while at least daily measurements are needed to ensure that the biomass peak is not missed. Another criticism of the method concerns the usual methods of storage and preservation of the seawater samples. Certainly the problems posed by differing treatment of the samples are not confined to the fertility (AGP) test, although with that test it is virtually impossible to achieve uniformity. In fact, if one wants to compare waters of different origin, except in the rare case when samples are collected rapidly by air, they must be preserved until all have been collected. This is why, in order to determine the effects of storage, it was recommended that, whenever possible, three series of nutrient analyses should be made: one at the time of taking the samples, one immediately after thawing and before inoculation with the test algae, and finally one at the end of the algal growth.