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REPORT OF THE ICES-IOC WORKING GROUP ON HARMFUL ALGAL BLOOM DYNAMICS (WGHABD)

3-6 APRIL 2006

GDYNIA, POLAND

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive Summary

The **ICES-IOC Working Group of Harmful Algal Bloom Dynamics** meeting was hosted by the Institute of Oceanography of the University of Gdansk, in Gdynia, Poland from 3–6 April 2006. 26 scientists from thirteen countries participated. This was a very successful meeting with a challenging set of terms of reference to deal with in the time available. Nevertheless, the group made 35 presentations under the terms of reference and this report is a summary of these presentations and discussions.

Over the three and a half days, the group dealt with:

- Progress in the detection of harmful algal blooms and their dynamics by remote sensing techniques.
- Reviewed the section on Phytoplankton Monitoring in the Report of the Joint FAO/IOC/WHO Ad Hoc Expert Consultation.
- Reviewed the outcome of the Workshop on New and Classical Techniques in Enumeration of Phytoplankton.
- Reviewed the progress and analyses that REGNS North Sea Group has made.
- Discuss new findings that pertain to harmful algal bloom dynamics.
- Reviewed the on-line format of HAEDAT submission form.
- Reviewed the structure and composition of the decadal HAE maps.
- Collated and assessed National reports.
- Discussed potential contributions to the ecosystem overview.

These are dealt with in detail in the report (Sections 5 to 15).

New Findings

Eight presentations were made by the group to report new findings in the area of HAB dynamics. These included the summary of a three year project on HAB oceanography in Ireland (BOHAB), The use of Flowcam™ in phytoplankton enumeration, A summary of Spirolides and Microcystin chemistry, The detection of Azaspiracid in crabs, a summary of the seasonality of *Dinophysis* in the Swedish Skagerak. Additionally, there were three notable, unusual blooms brought to the groups attention: *Alexandrium fundyense* in the Gulf of Maine, *Alexandrium* in the Bay of Fundy, and an exceptional bloom of *Karenia mikimotoi* in Ireland. More details of these presentations are given in the New Findings section of this report (Section 10)

The group also had the opportunity to have a half day joint session with the WGGIB (Working Group on GEOHAB implementation in the Baltic). Presentations by this group included reports on New Nodularin analogs in the Baltic, Phosphorus dynamics in the Baltic during a cyanobacterial bloom, satellite methods in Baltic system monitoring, Ecosystem effects and health hazards of Cyanotoxins, Nodularin concentrations in Southern Baltic sediments, mussels and Flounder, and latest news on BMAA neurotoxin in the Baltic Sea. These are reported in detail in the WGGIB report.

National Reports

One of the most useful functions provided by **WGHABD** is an annual opportunity for international delegates to compare international trends in HAB events. At the 2006 workshop twelve countries presented national reports for discussion, of which there are ten reported in this document. 2005 saw several noteworthy or exceptional HAB events.

- The **USA** experienced one of its most intense blooms of *Alexandrium fundyense*, which caused PSP all along the coast of New England. A second unusual HAB was the bloom of *Karenia brevis* which lasted all through 2005 in the Florida area, killing fish, mammals and birds, and causing respiratory problems in humans.

- Farther north in **Canada**, it was a fairly unexceptional year with the usual round of closures experienced both on the east and west coasts from PSP.
- On the other side of the Atlantic, **Norway** did not record ASP toxicity even following a dense bloom of 16 million *Pseudo-nitzschia* cells/L recorded. Small events of DSP and PSP toxicity were recorded with levels exceeding the quarantine levels at only a few monitoring stations. AZA was detected for the first time in Crabs.
- **Estonia** recorded exceptionally low levels of Nodularia when compared to the annual trends,
- **Poland** also reported 2005 as being a "moderate" year for *Nodularia*.
- **Denmark** did not experience any PSP or DSP, however ASP was detected for the first time in mussels from Danish waters.
- The **UK** reported the presence of *Alexandrium* spp. presence in moderate levels in England at 1.8 million cells/L and low levels in Scotland > 1300cells/L. These did not coincide with PSP in shellfish. Low levels of *Dinophysis* were also reported. *Pseudo-nitzschia* were more widespread and persistent than previous years but the concentrations were not particularly high. The *Karenia* bloom that affected the Republic of Ireland did not extend into UK waters.
- **Ireland** did in contrast, however, experience a high number of HAB related problems in 2005. For the first time a major ASP event was recorded in both samples of *M.edulis* and *C.gigas* associated with a bloom of *Pseudo-nitzschia*. Extensive DSP toxicity was detected through the summer months in all areas and then quarantine levels of AZA, lasted right through the following autumn and winter months. Low levels of *Alexandrium* were detected through the summer without any toxicity, apart from a small PSP outbreak in Cork in June. Finally a bloom of *Karenia mikimotoi* wreaked havoc on the benthic and pelagic communities during June and July.
- **The Netherlands** reported a bloom of *Phaeocystis* in February which is earlier than normal, resulting eventually in a 10 million cell/L bloom. In May this peaked at 138 million cells/L. Moderate levels of *Dinophysis* were recorded which resulted in levels slightly above quarantine level of DTX-3 as recorded by LCMS.
- In **Spain,** a very intense *Gymnodinium catenatum* bloom (after 10 years of absence!) occurred from October to December affecting all the production areas in the Rías Baixas and some areas in the Northen Galician coast. Maximum *G. catenatum* concentration was $1.7 \cdot 10^{5}$ cell·l^{-1} and maximum level of accumulated toxins 4080 µg STXeq·100 g^{-1} meat.

Full text of these National reports and the other Terms of Reference are given in the body of the report.

1 Welcome and opening of the Meeting

Following a welcome by the Chair, the Deputy Director of the Institute of Oceanography, Dr Hanna Mazur-Marzec, opened the meeting on the 3 April 2005. The participants were introduced with respect to their names, institute, national affiliation and fields of expertise. The agenda was agreed and Dr Pat Tester and Dr Eileen Bresnan elected as joint Rapporteur. The list of participants is presented in Annex 1. The meeting agenda is presented in Annex 2.

The Chair invited comments and review from the outgoing Chair of WGHABD, Dr Jennifer Martin relating to the WGHABD report presented to ICES Oceanography Committee from the 2005 meeting. She reported to the group that the oceanography committee felt the report was well organized, informative and the meeting well attended. While primarily concerned with HABs, the WG was not just addressing the dynamics but also more general areas of HAB science. An example of this was the co-ordination of the Intercomparison Workshop on New and Classic Techniques for the Determination of Numerical Abundance and Biovolume of HAB-Species Evaluation of the Cost, Time Efficiency and Intercalibration Methods (WKNCT) held in Kristineberg, Sweden 22–27 August 2005.

Being a joint ICES-IOC working group, the IOC in most years announces the possibility for its Member Countries outside the ICES area to attend WGHABD and offers travel support. In 2006 however, the IOC were not in a position to offer this support due to other demands on their budget. The IOC did support the intercomparison workshop (WKNCT). The IOC also supports the general aims of WGHABD, and continues valuable interaction regarding data collection and management of HAB data through the development of the HAEDAT database.

The Terms of Reference for 2005 were reviewed and adopted.

2 Terms of Reference

At the 92nd Statutory Meeting (2005), Aberdeen, Scotland, the Council approved the WGHABD (2005) Terms of References:

The **ICES-IOC Working Group on Harmful Algal Bloom Dynamics [WGHABD]** (Chair J.Silke Ireland) will meet in Gdynia, Poland, from 3–6 April 2006 to:

a) Review progress in the detection of harmful algal blooms and their dynamics by remote sensing techniques and examining results from new sensors and algorithms as well as validation procedures used for HAB observations.

b) Review the section on Phytoplankton Monitoring in the Report of the Joint FAO/IOC/WHO Ad Hoc Expert Consultation for Codex Alimentarius on Biotoxins in Bivalve Molluscs (Oslo 26 September 2004).

c) Review the outcome of the WKNCT Workshop on New and Classical Techniques in Enumeration of Phytoplankton.

d) Review progress towards the joint theme session between WGHABD and WGPBI for the ICES ASC in 2006 titled "Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge".

e) Review progress and analyses that REGNS North Sea Group have done on data-sets submitted by members of WGHABD (to meet in the interim).

f) Discuss new findings that pertain to harmful algal bloom dynamics. Bring new findings in phytoplankton population dynamics models, with emphasis on loss processes, to the attention of WGHABD for discussion.

g) Review the on-line format of HAEDAT submission form and evaluate the amendments made to update historical submissions and links to mapping.

h) Review the structure and composition of the decadal HAE maps for the ICES region with special reference to clarifying the distinction between harmful algal blooms and the harmful affects that are reported on the maps. In particular, the registration of cyanobacterial blooms in brackish and marine waters should be re-visited from the emerging perspective of their known toxicity and implicit harmful effects.

i) Collate and assess National reports and update the decadal mapping of harmful algal events for the IOC/ICES harmful algal database, HAE-DAT (Country Reps).

j) Discuss and report on potential contributions to the ecosystem overview of the advisory reports describing the quantity and quality of marine habitat and/or the health of the marine ecosystem, and to consider and report on potential indicators of significant change in these ecosystem attributes.

k) Review and update sub-regional data tables and where necessary include new data (parameters) and/or existing data (parameters) updated where relevant. The data tables will be subject to thematic assessment to be undertaken at a REGNS thematic assessment workshop.

3 Summary and Conclusions

Techniques for analysis and prediction of the population dynamics of HABs are not well developed and measures of species-specific growth rates and mortality rates are very difficult. Monitoring is an important aspect of HAB research and the WG needs to interact with monitoring programme designs and data interpretation. For example, more environmental data is often needed and sampling should be rationalised with local hydrography such as mixed layer depth, circulation patterns, frontal dynamics, etc. Historical data and time series data from sediment and climate studies are important in looking for historical occurrences of HABs. Increase and decrease in population size is important to bloom dynamics.

The importance of the WG approach and focus on population dynamics of specific HAB species and not on phytoplankton ecology in general was emphasized. The economic, resource and environmental effects of HABs are included within the WGHABD. In addition, phytoplankton ecology models often rely on biomass, nutrient, and carbon cycling and in many cases, cannot define, explain or predict HAB dynamics. In the past we have had joint meetings with modellers to try and incorporate physics and HAB dynamics into models.

The WG felt that the existing ToR were related, and were important to dynamics.

Term of Reference a) Review progress in the detection of harmful algal blooms and their dynamics by remote sensing techniques and examining results from new sensors and algorithms as well as validation procedures used for HAB observations.

Five presentations were made, including a review of current technology followed by presentations of data from Sweden, USA (2) and Canada.

Space – or airborne remote sensing of the sea, sometimes termed EO (Earth Observations) is often motivated with the aim of observing harmful algal blooms. Initiatives including the GMES (Global Monitoring for the Environment and Safety), the MERSEA program and its application to Operational Oceanography and HAB detection in real time will be reviewed. New satellites and sensors have become operational the last years, i.e., the MERIS sensor on the European satellite ENVISAT and the US satellites AQUA and Terra with the sensor MODIS. Older sensors include the SeaWIFS that has reached its end of life. Earth observations have limitations regarding HAB observations which include that only high biomass blooms are detected, and only surface water is monitored etc.

In general the only HAB-product available is chlorophyll a. Also cloud cover is a problem for the technique. New sensors with higher spatial and spectral resolution as well as new algorithms for data processing hold promise for resolving signals for HAB-species or algal groups, e.g., cyanobacteria. There is a great need to review the results from the new sensors and algorithms and the validations procedures used.

The conclusions of these discussions were:

- Use remote sensing data for detection and monitoring of possible harmful algal blooms is possible but should include verification observations with *in situ* data (traditional, buoys, SOOP, ferrybox, etc.);
- Combination of results with meteorological and oceanographic forecasting models to predict impact;
- Near real time monitoring is useful;
- It is vital to spread the information beyond the science community: to authorities, stakeholders and to the public and the information should be presented in a simple, understandable way.

Term of Reference b) Review the section on Phytoplankton Monitoring in the Report of the Joint FAO/IOC/WHO Ad Hoc Expert Consultation for Codex Alimentarius on Biotoxins in Bivalve Mollusks (Oslo 26 September 2004).

This report was in response to requests from countries for updated guidelines for biotoxin analysis methods and regulator thresholds and plankton monitoring

The draft report was distributed at last year's WGHABD for comments and Per Anderson presented a summary of the guidelines in the report.

Term of Reference c) Review the outcome of the WKNCT Workshop on New and Classical Techniques in Enumeration of Phytoplankton.

This workshop was a complex activity requiring algal cultures, field material and a variety of different methodologies, with the objective of providing valuable results on the comparison of different microscope based techniques and some advanced molecular techniques for the identification and quantification of harmful microalgae. The WGHABD was instrumental in initiating this process and established a steering committee. The steering group presented a summary of the report from the workshop and discussed its dissemination.

Term of Reference d) Review progress towards the joint theme session between WGHABD and WGPBI for the ICES ASC in 2006 titled "Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge".

An update on this theme session was provided by one of the co-conveners with input from the working group.

Term of Reference e) Review progress and analyses that REGNS North Sea Group have done on datasets submitted by members of WGHABD (to meet in the interim).

The REGNS study group has requested that the WGHABD prepare to provide data, information and indicators. A delegate from the WGHABD reported on the outcome of the REGNS meeting in May 2005 and on the progress of the assembly and analysis of the data.

Term of Reference f) discuss new findings that pertain to harmful algal bloom dynamics. Bring new findings in phytoplankton population dynamics models, with emphasis on loss processes, to the attention of WGHABD for discussion

The working group received nine presentations on new findings and events, from the participants. These included the Summary of a project on the Biological Oceanography of HABs in Ireland, A review of a *Nodularia* model, review of the FlowCam system in cell enumeration, Spirolide Neurotoxins from *Alexandrium ostenfeldi*,. An exceptional bloom of *Karenia mikimotoi* in Ireland, The 2005 New England *Alexandrium fundyense* bloom, Azaspiracid in crabs, Dinophysis in the Swedish Skagerak and *Alexandrium* cell abundance in the Bay of Fundy.

Modelling exercises aimed at understanding HAB population dynamics have suffered from poor estimates of biological loss terms. Current knowledge on selected HAB loss processes (e.g., grazing, viruses, parasitism, and programmed cell mortality) is limited. Improved knowledge on the dynamics of these loss processes and their relative contribution is essential to improve models for HAB dynamics. Of the presentations received dealing with population dynamics of HABs there still was a concentration on the onset of blooms rather than their fate, there appears to be little information being generated on the loss processes.

Term of Reference g) The new online format of the HAE-DAT submission form was demonstrated and discussed. The suggestions from last year's discussions at WGHABD have been mostly incorporated and the dataset is in a format where better analyses can be conducted. This new format replaces the previous where data was entered manually into the HAE-DAT dataset (which was in Access97 format). This new electronic format (with the same information as previous forms) is available online for submission directly into the database. Monica Lion (IOC-IEO-SCCHA, Vigo, Spain) has gone through potential problems for the conversion of all the old historical records into the new form.

Term of Reference h) Review progress in computerized production of decadal maps from country reports, including the revision of reports already in the database covering the last 10 years Decadal maps are currently being updated manually. A new Decadal maps product which uses both ArcView and Flash softwares, and allows updating of maps from a MySQL database is being explored. The use of the MySQL database both in the new HAEDAT format and in the new decadal maps will open future technical options for linking these two datasets that will be studied during this year. The capability of linking the maps has been and continues to be extended to additional countries. Most ICES member countries have provided divisions of coastlines and coordinates to enable the linkages. Further opportunities to develop the links will be explored inter-sessionally.

Term of Reference i) Collate and assess National reports and update the decadal mapping of harmful algal events for the IOC/ICES harmful algal database, National reports were presented for, USA, Germany, Denmark, Canada, Norway, Estonia, Latvia, Poland, Netherlands, Great Britain, Ireland, Spain. Maps were circulated for updating for inclusion to the decadal maps. Information was requested for input on the new online database in the required format for HAEDAT.

Term of Reference j) It was concluded that that the role of phytoplankton with regard to the ecosystem approach, is a far wider issue than could be addressed by WGHABD, whose main role is to investigate the dynamics of functional sub-group of phytoplankton. If the Oceanographic Committee wish any specific advice on this matter the group would be happy to discuss this inter- sessionally.

Term of Reference k) Dealt with under ToR e).

4 Term of Reference a)

4.1 Monitoring possible harmful algal blooms from satellite - review of recent developments and applications

Martin Hanson from the Swedish Meteorological and Hydrological Institute - SMHI Oceanographic Unit, Göteborg, Sweden opened this term of reference with a review of orbiting sensors and their application in the HABs area.

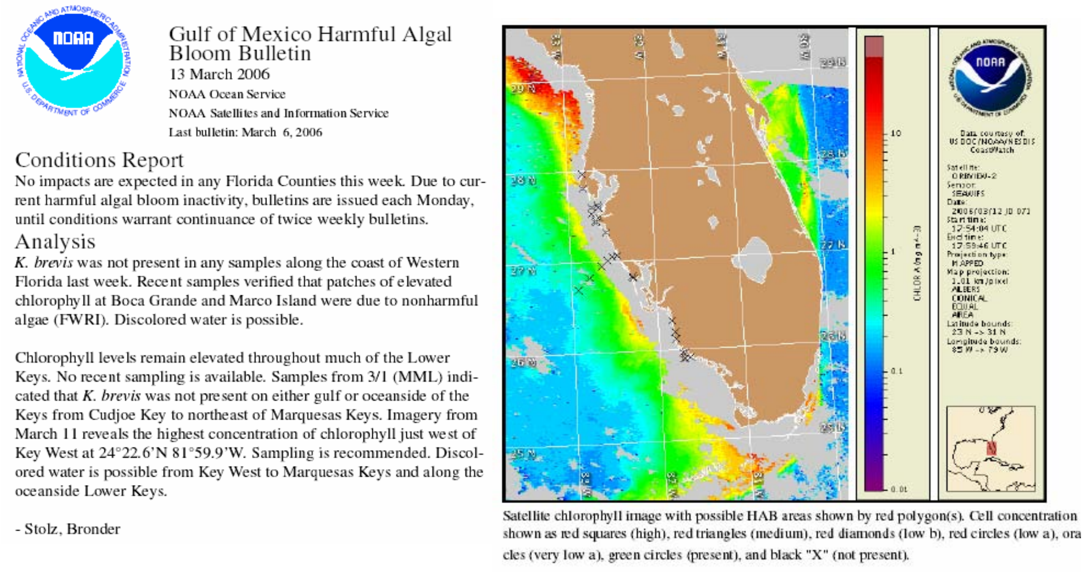
The advantages of Satellite sensing of HABs were described to include the fact that they offer a unique synoptic view of large areas of the oceans and provide regular monitoring (during cloud free conditions) repeat cycle about 0.5–6 days. They also show position of favourable blooming areas, ocean fronts upwelling, advection of water masses. (SST) and can improve model predictions. Other information such as inter-annual variability on extent, duration and occurrence can be mapped. When a HAB event has been confirmed with in situ measurement it is possible to monitor movements and development. In effect, remote sensing of HABs in combination with in situ monitoring and models result can be used as an efficient monitoring and prediction system.

However, certain disadvantages were also pointed out including HAB events must always be confirmed by in situ measurement, it is difficult to distinguish between species and also between other properties of the water; yellow substance, particles, etc. HABs usually occur in coastal waters where the rfesolution form satellites is poor, and

HABs are often present in too small amount to be detected but enough amounts to cause problems. Satellites rely on HABs being present in the surface layer, and also rely on cloud free conditions

A selection of applications using satellite derived data were presented:

Some notable applications included the Gulf of Mexico Harmful Algal Bloom Bulletin (Figure 4.1.1). In the Gulf area, harmful red tides (*Karenia brevis*) frequently occur and these can cause death to fish, birds and marine mammals. In addition eating shellfish from contaminated waters can cause NSP. Since 1999, Harmful Algal Bloom Bulletins have been issued by NOAA´s National Centers for Coastal Ocean Science (NCCOS) to help coastal environmental managers Information and conclusions are based on satellite data (SeaWiFS), in situ measurements, models, wind observations Bulletins are issued frequently (once or twice a week)In South Africa a joint effort between the University of Cape Town, Marine and Coastal Management and the Benguela Current Large Marine Ecosystem (BCLME) programme provides near real time HABs information on a website (http://www.hab.org.za). The Benguela system is characterised by upwelling circulation along the entire west coast of southern Africa HABs are common, one or another dinoflagellate species and are associated with either high biomass or the toxicity of some species. Impact on both commercial and recreational interests, causing fish kills, contaminating seafood with toxins resulting in serious public health problems, or altering ecosystems.



Gulf of Mexico Harmful Algal Bloom Bulletin
13 March 2006
NOAA Ocean Service
NOAA Satellites and Information Service
Last bulletin: March 6, 2006

Conditions Report

No impacts are expected in any Florida Counties this week. Due to current harmful algal bloom inactivity, bulletins are issued each Monday, until conditions warrant continuance of twice weekly bulletins.

Analysis

K. brevis was not present in any samples along the coast of Western Florida last week. Recent samples verified that patches of elevated chlorophyll at Boca Grande and Marco Island were due to nonharmful algae (FWRI). Discolored water is possible.

Chlorophyll levels remain elevated throughout much of the Lower Keys. No recent sampling is available. Samples from 3/1 (MML) indicated that *K. brevis* was not present on either gulf or oceanside of the Keys from Cudjoe Key to northeast of Marquesas Keys. Imagery from March 11 reveals the highest concentration of chlorophyll just west of Key West at 24°22.6'N 81°59.9'W. Sampling is recommended. Discolored water is possible from Key West to Marquesas Keys and along the oceanside Lower Keys.

- Stolz, Bronder

Satellite chlorophyll image with possible HAB areas shown by red polygon(s). Cell concentration shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), ora cles (very low a), green circles (present), and black "X" (not present).

Figure 4.1.1: Gulf of Mexico Harmful Algal Bloom Bulletin.

The Baltic Algal Watch System (BAWS) has been operational since 2002. This system produces daily map of extent of surface accumulation during bloom season. It is based on satellite data (NOAA-AVHRR and MODIS). An integrated web presentation for environmental managers and a public web site are available (www.smhi.se). The website provides information on bloom coverage, near real-time information, weather forecasts, model results, seatrack-web (Forecasts and dispersion of oil and chemicals, including surface accumulations of cyanobacteria) and incoming solar radiation.

4.2 Detection of harmful algal blooms and their toxins by *in situ* and remote techniques

Allen Cembella gave a useful overview of developments in the field of *in situ* and remote sensing of HABS

A wide array of emerging technologies have been developed within the last decade to specifically address the problem of detection and quantification of harmful algae and their toxins. Classical methods for cell enumeration and species identification are hampered by the requirements for a high level of taxonomic expertise, the time constraints imposed by tedious (and thus perhaps erroneous) manual counting and the difficulties of interpreting the results of point-source discrete sampling in long-term monitoring programmes. For example, discrimination of the various members of the genus *Alexandrium* by morphological criteria with microscopic methods generally involves careful study of diagnostic features (presence/absence and shape of the ventral pore; morphology of the apical pore complex) of individual cells, often with the aid of fluorochrome staining. Similarly, the diagnostic features of many species of the diatom genus *Pseudo-nitzschia* (e.g., arrangement and number of poroids on the valves) are at the limits of resolution of the light microscope and therefore misidentification at the species level is undoubtedly common.

From the perspective of phycotoxin assays and analysis, there are also urgent requirements for supplanting conventional whole-animal bioassays such as the AOAC mouse bioassay with more precise and refined methods for individual toxins or groups of toxins with a common mode of action. In both cases, it is desirable to move towards implementation of methods that offer real-time and continuous data on harmful taxa and their respective toxins for field deployment in monitoring programmes.

Deployable systems for bloom and toxin monitoring should be developed to fulfil three basic niches: surveillance, operational aspects and investigative requirements. Surveillance implies the ability to survey the target sites and regions of interest with the objective of providing information on early warning of impeding blooms, as well as on the subsequent stages of the bloom development cycle – including both qualitative and quantitative data. The operational elements refer to the function and integration of the technology into workable systems for field deployment, involving data acquisition and retrieval, use of the appropriate algorithms and calibration procedures, networking and reliability (e.g., with respect to biofouling), sensitivity, precision and accuracy of the measurements. As investigative tools, the systems should be amenable to incorporation into field-based research programmes on bloom dynamics and mechanisms of toxin propagation in marine food webs.

Field systems based upon general biooptical principles (fluorescence, spectral absorption, optical back-scatter, etc.) are best suited for detection and monitoring of high biomass HAB blooms, especially where the taxon of interest has a unique optical signature and where the bloom approaches monospecificity. By comparison, taxon- and toxin-specific methods will also work for low biomass blooms and complex assemblages where the target species may be dispersed and in low abundance. Among the taxon-specific probe methods, techniques based upon molecular targets at the cell surface (e.g. lectins, antibodies), in cell membranes, and moieties of intracellular proteins, nucleic acids and nuclear genes have proven to be most useful. As detection systems, many platforms, such as ELISA plate assays, epifluorescence microscopy, flow cytometry, and molecular approaches involving sandwich hybridization assays of extracted RNA and PCR-based methods have been successfully applied in the laboratory but most of these techniques have not been adapted for field deployment. Among the laboratory methods, fluorescence *in situ* hybridization (FISH) coupled with epifluorescence microscopy, flow cytometry or solid-phase support cytometry (Chemscan) are among the most advance and widely employed for species discrimination. Operational field-deployable systems are at present limited to the Environmental Sample Processor (ESP) developed at Monterrey Bay Aquarium, which employs a custom-printed oligonucleotide probe array to detect taxon- specific rRNA molecules by the principles of sandwich hybridization. An image of the resulting array is recorded using the CCD camera. An alternative system, developed from a prototype of a hand-held electrochemical detector (Inventus BioTech, Germany) is based upon detection of specific 18 rRNA sequences attached to a reporter probe and digoxigenin to generate an electrochemical signal. This system has been further developed to incorporate a multiprobe chip for simultaneous detection of 14 taxa in flow-through mode (Palm Sense, Germany); the intention is to incorporate this into a field system for cell-based detection (e.g. CytoBuoy, Netherlands).

In situ and portable ship board systems are particularly useful in monitoring and bloom dynamic studies in small-scale coastal embayments where the horizontal and vertical patchiness of the blooms renders satellite-based surveillance largely ineffective. Even the most advanced satellite-based optical sensors (SeaWifs, MODIS, etc.) have a minimal patch size of several hundred square metres and cannot provide data from below the surface, on cloudy days, or continuously. Aircraft-transported spectral sensors, such as CASI – compact airborne spectrographic imager – have been used successfully to map chlorophyll distribution and concentration with a spatial resolution of several metres with several meters of vertical penetration even in coastal waters, but again they cannot be used continuously or in poor weather. Such systems provide only limited taxonomic information based on spectral signature.

Developments in biooptical buoys, including for example the tethered attenuation coefficient chain sensor (TACCS) from Satlantic, offer the opportunity to continuously monitor the diffuse attention coefficient by spectroradiometric measurements – essentially a measure of ocean colour and the underwater light field. New hyperspectral sensors now provide more information on the discrimination of phytoplankton pigment signatures as distinct from seston and CDOM but cannot resolve the profiles of individual species or in most cases even taxonomic groups (e.g. diatoms versus dinoflagellates) in complex assemblages without a dominating taxon. This technology is ideally used in conjunction with more cell-specific detection systems as a coordinated package.

It is now possible to conduct surveys of toxin profiles in the water column with on board liquid chromatography mass-spectrometry (LC-MS) systems. Underwater mass spectrometers do exist but thus far the marine toxins of interest cannot be detected with this technology. Nevertheless, such developments can be anticipated in the next few years.

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4.3 Regulation of alongshore *Alexandrium* transport in the Gulf of Maine USA

Don Anderson reported on developments in the use of AVHRR imagery rather than ocean colour imagery to detect conditions conducive to bloom development and transport in a Gulf of Maine *Alexandrium* event in 2005.

Many applications of remote sensing technology to HAB detection and tracking rely on ocean colour. There are locations, however, where HAB species do not make up a significant proportion of the plankton, and thus where pigment signatures cannot be used for detection. *Alexandrium fundyense* blooms in the Gulf of Maine are an example of this situation. Nevertheless, remote sensing technologies can be useful in management of paralytic shellfish poisoning (PSP) events – in this instance through a focus on sea surface temperature. In a recent paper by Luerssen et al (2005), relationships between satellite-derived sea-surface temperature (SST) patterns and the occurrence of PSP toxicity events caused by *A. fundyense* in the western Gulf of Maine were examined. Comparison between surface cell distribution patterns and SST images indicates that highest cell concentrations are associated with colder waters of the eastern segment of the Gulf of Maine coastal current (EMCC) and that frontal zones at the edges of the EMCC often act as boundaries to surface distributions. Surface thermal patterns can reveal enhanced connectivity between the EMCC and the western Gulf of Maine, suggesting transport linking *A. fundyense* cells in the EMCC to inshore areas of the western Gulf of Maine. Surface drifter data support such transport. Thirteen years (1990–2002) of toxicity data from eight monitoring sites along the coast of Maine and concurrent SST data show that in years of either large or very-reduced toxicity, a consistent relationship exists between the timing and strength of fronts, calculated from the SST data and taken as an indicator of alongshore connectivity, and the occurrence and strength of toxic events. Years with weak fronts and/or fronts that become established relatively late in the summer growing season are years of the strongest toxicity events in western Gulf of Maine. Years of early and strong fronts are years with few and/or weak toxicity events. These results point to the utility of SST and other coastal observing system data for the monitoring and prediction of conditions linked to toxic events in coastal waters.

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4.4 HAB forecast for *Karenia brevis* in the Gulf of Mexico

Pat Tester described the utilisation of chlorophyll anomaly in the Gulf of Mexico to identify HABs of *Karenia Brevis.*

The HAB forecast for *Karenia brevis* in the Gulf of Mexico is based on ocean colour satellite imagery and is possible, in part, due to the lower backscatter of *K. brevis* compared to blooms of diatoms or *Trichodesmium* spp. (Carder and Steward 1985). Stumpf *et al.* (2003) suggested a simple chlorophyll anomaly might be useful to detect and monitor *K. brevis*. They developed a forecast model based on a 60-day running mean of chlorophyll when diatom and *Trichodesmium* spp. were not indicated. An anomaly is the difference in chlorophyll value per pixel between the image of interest and the 60-day running mean for the same pixel mean (lagged by 14 days to avoid the influence of a new bloom on the chlorophyll mean) (Figure 4.1.1). This was the first step in an early warning system to forecast *K. brevis* blooms in the eastern Gulf of Mexico and was available as an experimental product form 2001 to 2003 when the HAB forecast became operational on a regular basis with the frequency depending on the intensity of *Karenia brevis* blooms (http://coastwatch.noaa.gov/hab/bulletins). The bulletin also includes wind speeds and directions so potential surface movement of the blooms under the influence of the wind field can be judged. This forecast was evaluated (Tomlinson *et al.* 2004) and found to be accurate >83% of the time. There are plans to expand this forecast into the northern Gulf of Mexico in late 2006.

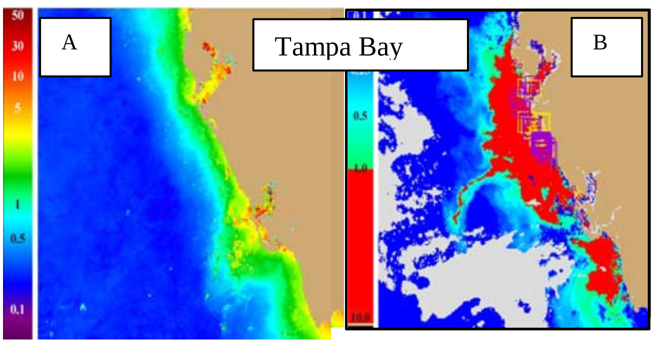

Figure 4.4.1: Harmful algal bloom forecast for *Karenia brevis* in the Gulf of Mexico is based on chlorophyll anomaly. A. 3 August–3 September 2001 Sixty-day running mean for each pixel in image. B) An anomaly is the difference in chlorophyll value per pixel between the image of interest and the 60-day running mean lagged by 14 for the same pixel in the image of interest. Anomalous chlorophyll values of 1 ug/L. are flagged in red. See Stumpf *et al.* 2003.

References

Carder, K.L., and Steward, G.R. 1985. Remote-sensing reflectance model of a red-tide dinoflagellate off west Florida. Limnology and Oceanography, 2: 286–298.

Stumpf *et al.* 2003. Monitoring *Karenia brevis* blooms in the Gulf of Mexico using satellite ocean color imagery and other data. Harmful Algae, 2: 147–160.

Tomlinson *et al.* 2004. Evaluation of the use of SeaWiFS imagery for detecting *Karenia brevis* harmful algal blooms in the Gulf of Mexico. Remote Sensing of the Environment, 91: 293–303.

4.5 *Alexandrium* measurements using remote sensing in Grand Manan Island in Bay of Fundy

Jennifer Martin showed an example where ocean colour imagery should be treated with caution. In 2003 highest cell counts of *Alexandrium* were not reflected in ocean colour (Modus or SEAWiFS) 888,000 cells/L in the next year with up to 4M cell/L still not able to tease out signal from ocean colour imagery

The presentation demonstrated with series of ocean colour images – areas of high chlorophyll that did not match where the high cell counts were recorded. It was noted that the variability between sea surface chlorophyll and high cell counts may not coincide due to mixing of the upper levels of the water column.

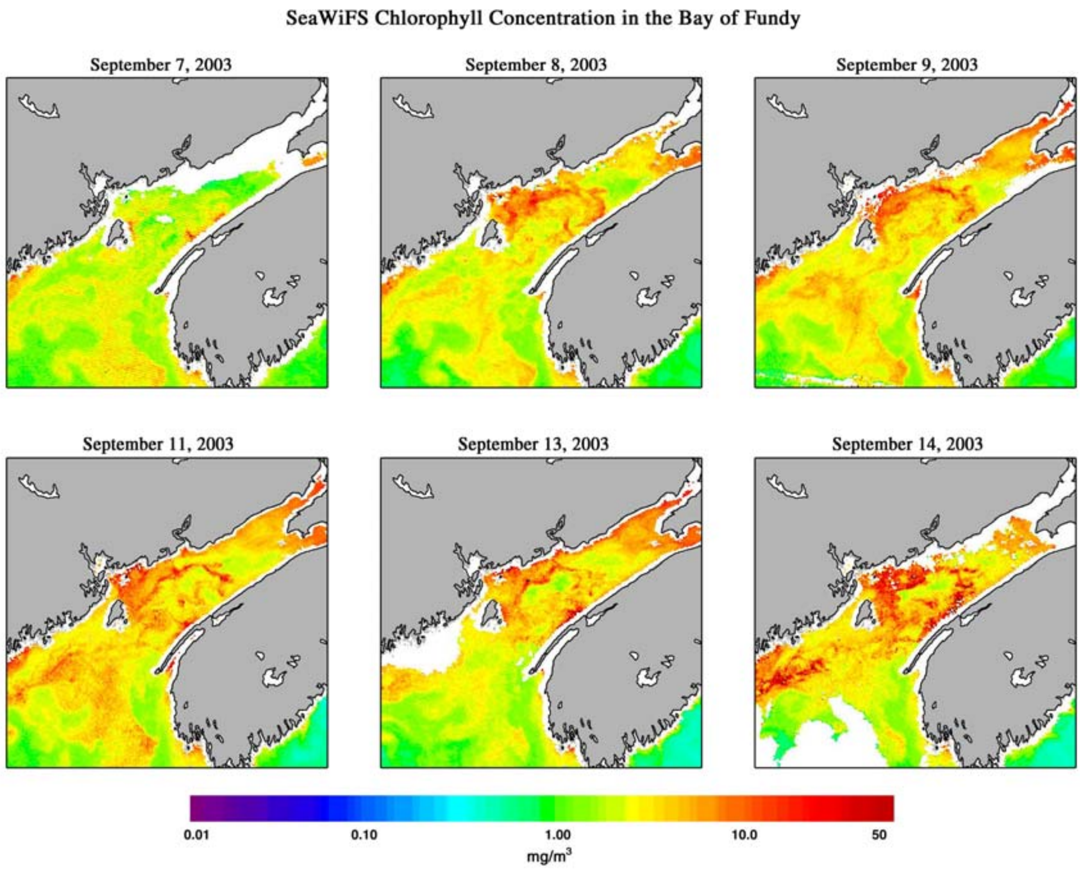

Figure 4.5.1: Chlorophyll concentrations in the Bay of Fundy 2003.

5 Term of Reference b)

5.1 Phytoplankton Monitoring in the Report of the Joint FAO/IOC/WHO Ad Hoc Expert Consultation for Codex Alimentarius on Biotoxins in Bivalve Mollusks (Oslo 26 September 2004).

Per Anderson gave a presentation on the section of the Report. This expert working group was made up of the following scientists who convened to draft guidelines for FAO/WHO/ IOC.

Expert Panel:

Dr Per Andersen, Bio/Consult, Denmark
Prof Tore Aune, Norwegian School of Veterinary Science, Norway
Dr Daniel G. Baden, University of North Carolina Wilmington, United States of America
Mrs Catherine Belin Ifremer Centre de Nantes, France
Prof Luis Botana, Univ. Santiago de Compostela, Spain
Mr Phil Busby, New Zealand Food Safety Authority, New Zealand
Dr Bob Dickey, US Food and Drug Administration, United States of America
Dr Valerie Fessard, French Food Safety Agency (AFSSA), France
Prof Lora E. Fleming, University of Miami, United States of America
Mr John Foorde, Marine and Coastal Management, South Africa
Dr Jean-Marc Fremy, French Food Safety Agency (AFSSA), France
Dr Sherwood Hall, US Food and Drug Administration, United States of America
Dr Philipp Hess, Marine Institute, Ireland
Dr Patrick Holland, Cawthron Institute, New Zealand
Dr Emiko Ito, Chiba University, Japan
Dr Tine Kuiper-Goodman, Health Canada, Canada
Dr Jim Lawrence, Health Canada, Canada
Mr David Lyons, Food Safety Authority of Ireland, Ireland
Dr Rex Munday, AgResearch, New Zealand
Prof Yasukatsu Oshima, Tohoku University, Japan
Dr Olga Pulido, Health Canada, Canada
Dr Michael Quilliam, National Research Council, Canada
Prof Gian Paolo Rossini, Universita di Modena e Reggio Emilia, Italy
Prof Michael Ryan, University College Dublin, Ireland
Dr Covadonga Salgado, Centro do Control do Medio Marino, Spain
Mr Joe Silke, Marine Institute, Ireland
Dr Gerrit I.A. Speijers, National Institute of Public Health and the Environment, the Netherlands
Dr Benjamin Suarez-Isla, Universidad de Chile, Chile
Dr Toshiyuki Suzuki, Tohoku National Fisheries Research Institute, Japan
Dr Andy Tasker, University of Prince Edward Island, Canada
Dr Hans P.van Egmond, National Institute of Public Health and the Environment, The Netherlands
Dr Phillippe J.P. Verger, Institut National Agronomique Paris-Grignon, France
Prof Takeshi Yasumoto, Japan Food Research Laboratories, Japan

Working group 3: was a sub-group tasked to draft guidelines on growing area management and monitoring

Working Group 3 Members

Per Andersen , Catherine Belin, Phil Busby (Chair), Henrik Enevoldsen, John Foord, David Lyons, Yolanda Pazos, Joe Silke, Covadonga Salgado

Task: Provide Guidance on Growing Area Management and Monitoring

1) Provide guidance on sampling methods for shellfish, including sampling depths, sample size, representative sampling, frequency of sampling

2) Provide guidance on the use of phytoplankton monitoring (strengths and weaknesses) as part of a shellfish marine biotoxin program
3) Provide guidance on indicator organisms for the different toxin groups
4) Provide information on the existence of biotoxin forming marine algae in various geographical regions of the world
5) Provide guidance on phytoplankton laboratories, accreditation, training of analysts, counting methods etc
6) Provide guidance on marine biotoxin management plans, including micro management
7) Provide guidance on environmental/hydrographic/oceanographic influences in growing areas
8) Provide guidance on sampling, including location of sample stations, sample size, use of indicator organisms, training of samplers, frequency of sampling, sample collection methods, transport of samples
9) Provide guidance on reporting, release and exchange of data

The Role of Micro-Algal Monitoring in Marine Biotoxin Management

Micro-algae (including planktonic and benthic organisms) are the primary source of biotoxins in bivalve molluscs. A marine biotoxin management programme should be described in a **marine biotoxin management plan (MBMP)**. The MBMP should include marine biotoxin action plans (MBAPs) for growing areas containing, for example, sampling strategy and requirements (frequency, sample size and composition), analyses to be carried out, and management action to be based on monitoring results and expert judgment.

Toxicity monitoring cannot be replaced solely by micro-algae monitoring. Information from micro-algal monitoring, especially if it is carried out regularly (for example weekly during harvesting), as part of a bivalve mollusc biotoxin management program, has particular strengths, including:

- Generally, observable concentrations of toxic micro-algae precede critical levels of toxins in bivalve molluscs and, therefore, allows management options to be considered, such as:
  - Precautionary closures;
  - Intensified monitoring or depth-specific sampling.
- Micro-algal monitoring can also help <u>focus</u> shellfish testing, for example on likely toxins, at the right location, at the appropriate time and when new toxin-producing species of micro-algae are found in an area.
- Micro-algal monitoring as part of an integrated biotoxin management program, is cost effective and operationally efficient.
- It may be used to investigate unknown, unusual or atypical toxic events.
- It may be used to provide information to set or use switching factors. These may activate associated management options.
- It may provide information not only on the onset of a toxic event but on the duration of any intensified management action.

Therefore, for early warning purposes and direct risk management activities it is recommended to have a program to monitor growing areas for species of toxin-producing micro-algae. The program should also include evaluation of other environmental conditions, for example wind, water temperature and salinity, which may suggest upwelling, stratification or mixing. These conditions may indicate that favourable conditions for a toxic event are developing.

However the weaknesses of such a system may include:

- Micro-algal observations may not accurately reflect the actual level of toxins in shellfish. In part this may be due to significant inter- and intra-species variability in toxin profile and toxin content for many micro-algal species even from the same area and over a short period.
- While micro-algae are the primary source of toxicity in shellfish, the toxins may remain in shellfish long after the toxic micro-algae are gone. Thus, the absence of toxic micro-algae cannot be taken as an indication that the shellfish are safe.
- Micro-algae are not always distributed uniformly in either time or space. “Patchy” distribution of micro-algae may make representative sampling difficult.
- The logistics of sampling offshore or remote areas, where scallops or clams for example are fished, may make micro-algal monitoring less cost effective.
- Special monitoring arrangements may be necessary to address the problems posed by benthic species of toxic micro-algae, for example *Prorocentrum lima.*

In conclusion, decisions made on the safety of shellfish can only be based on the direct measurement of toxins in shellfish flesh. However, an integrated shellfish and micro-algal monitoring programme is highly recommended to provide expanded management capability and enhanced consumer protection.

Furthermore, recent developments indicate that micro-algal monitoring coupled with operational oceanographic, meteorological, and remote sensing data, including modelling and other measurements may be used to base advice on the imminent onset of harmful events.

6 Term of Reference c)

6.1 A summary of the intercalibration workshop on cell counts held in Kristinaberg

Presented by Bengt Karlson, Caroline Cusack and Eileen Bresnan.

This workshop was held to compare traditional and novel methods for counting cells under controlled conditions, in order to attempt to identify the state of the art with regards to cell enumeration. The following objectives were set to be addressed by the workshop:

- Used *Alexandrium ostenfeldii* and *A. fundyense*;
- Examine traditional microscope methods for cell abundance to determine if traditional and molecular or new methods would provide comparable results;
- Is there one method that can be recommended?
- Used nine traditional methods, eight molecular methods and FlowCam, 100 ml used for all:
    - Utermohl’s, settling bottle, counting chambers;
    - Molecular techniques used different versions and different personnel.

Bengt summarized findings

Generally the counting chambers with the small volumes were less reliable at low cell concenrations. At 500 cell/L results somewhat more consistent. Samples were fixed and sent to Canada to J. Martin’s lab for FloCam analyses. In experiment 4 the numbers were in good agreement.

Problems observed:

- Time constraints;
- Limited sample volume;
- Aberrant cells from cultures observed;

- Some labs not perfect for molecular biological work;
- Not correct temp in incubation ovens;
- Some methods were not properly calibrated for the material used.

Did not test:

- Total phyto community;
- Biomass;
- Other species that target.

Results:

- Short report distributed on ICES website;
- Scientific article to Harmful algae;
- IOC Manuals and Guides – A practical guide to quantitative phytoplankton analyses.

Conclusions: Successful:

- 24 participants from three continents;
- 18 methods for quantitative phytoplankton analysis were compared;
- Approx 1000 samples were made up and analyzed;
- Inter comparison focused on only one species *A. f.*

Financial support was acknowledged from IOC, BIM Ireland, and Marine Institute Ireland. SMHI Kristineberg Marine Research Station supported lodging.

Comments:

- A discussion of the workshop followed It was felt that the expectation was that traditional methods would not be good at identification of cells but would be better at enumeration. As it turned out this was not really the case, however, some the traditional methods were not as good at cell ID as expected. Some of the molecular methods were better at enumerating cells than expected;
- It was pointed out that one did not really have a big challenge in cell identification – and that this was the best case scenario and any natural samples would have greater error;
- Overall the working group said that the exercise was successful. Some of the tests were under some constraints. – Molecular techniques were difficult to set up – needed more lead time than microscope;
- The organizers were commended for their fine work in setting up and conducting a successful workshop.

7 Term of Reference d)

7.1 Update on the ASC theme session entitled "Harmful Algae Bloom Dynamics: Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge"

The Annual Science Conference will host a theme session jointly convened by Patrick Gentien (France) and Tapani Stipa (Finland). Dr Gentien provided information on this session for the working group.

In spite of large gaps of basic process knowledge around HAB dynamics, several 3-D modelling initiatives are ongoing with respect to studying and predicting HABs. Therefore it