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REPORT OF THE ICES-IOC-SCOR WORKING GROUP ON GEOHAB IMPLEMENTATION IN THE BALTIC (WGGIB)

7-9 MAY 2007

HELSINKI, FINLAND

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International Council for the Exploration of the Sea
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Contents

Executive summary

The ICES-IOC-SCOR Working Group on GEOHAB Implementation in the Baltic (WGGIB) met in Helsinki, Finland, 7–9 May to:

a) Report and discuss new findings on HABs and HAB modelling in the Baltic;
b) Update the checklist of the harmful species of the Baltic Sea;
c) Agree on actions needed for implementing the Proposal for a Cooperative HAB study in the Baltic.

New findings

New findings pertaining HABs in the Baltic were presented and discussed, and potential co-operative projects on the basis of these findings were discussed.

Some of the new findings included, e.g., expansion of *Alexandrium ostenfeldii* and occurrence of DSP toxins in the Baltic Sea, bulk estimates of nodularin in the seawater and seston during blooms of *Nodularia spumigena*, allelopathic interactions between diatoms and dinoflagellates, the effect of pulsed nutrient supply on community phosphorus dynamics during cyanobacteria blooms, and application of phycobilin fluorescence in quantification of cyanobacteria. Also, high-resolution modelling of hydrodynamic features favouring HAB blooms was presented.

List of the potentially harmful algal species of the Baltic Sea

The HAB species checklist was updated by WGGIB taxonomical experts. It was decided that the information in the Baltic list will be offered to the IOC IPHAB Task Team on Algal Taxonomy to be amended into the Global HAB species list. As the global list has no search category for specific sea areas, this was decided to be suggested to the keepers of the IOC list. Meanwhile, the WGGIB will keep on updating the Baltic HAB list.

GEOHAB Implementation in the Baltic

The revised “Proposal for a cooperative HAB Study in the Baltic Sea” was reviewed. The proposal was renamed as “BALTIC GEOHAB – Cooperative Research Plan”, which will be submitted for GEOHAB for endorsement It was decided that the plan is formulated as a GEOHAB associated “science plan”, which can be used as a platform for more specific projects.

It was decided that, after the Cooperative Plan is ready, the main emphasis of the WGGIB will be in actual implementing of the BALTIC GEOHAB, i.e., setting up GEOHAB-endorsed research projects within the Baltic region. It was also decided that the issues dealing with new findings in Baltic HAB dynamics and national HAB results will in the future be reported through the Working Group of Harmful Algae Dynamics [WGHABD].

At least one further WGGIB meeting is held necessary in order to enhance the networking between the new projects. The necessity of any further meetings was left to be decided in the next meeting, which will be held in 2008 in Gothenburg, Sweden.

1 Opening of the meeting

The ICES-IOC-SCOR Working Group on GEOHAB Implementation in the Baltic (WGGIB) met in 7–9 May 2007 in Helsinki, Finland. The meeting was hosted by the Finnish Institute of Marine Research.

Altogether 19 scientists from Finland, Estonia, Sweden and Poland participated. The list of participants is presented in Annex 1 and the meeting agenda in Annex 2.

The meeting was opened by the Chair, and the participants introduced themselves.

2 Adoption of the agenda

The agenda was approved, and Emil Vahtera, Finland, kindly agreed to act as a rapporteur.

3 Terms of reference for 2007

At the 93rd Statutory Meeting (2006), Maastricht, The Netherlands, the Council approved the proposed Terms of Reference (C. Res. 2006/BCC:05).

The ICES-IOC-SCOR Working Group on GEOHAB Implementation in the Baltic [WGGIB] (Chair: M. Viitasalo, Finnish Institute of Marine Research, Finland) will meet in Riga, Latvia, 5–7 April 2007 (later changed to Helsinki, Finland, 7–9 May 2007):

a) Report and discuss new findings on HABs and HAB modelling in the Baltic;

b) Update the checklist of the harmful species of the Baltic Sea;

c) Agree on actions needed for implementing the Proposal for a Cooperative HAB study in the Baltic.

4 New Findings

New findings pertaining HABs in the Baltic were presented and discussed, and potential co-operative projects on the basis of these findings were discussed.

Observations of the massive blooms in the southern Baltic in summer 2006 in the Polish and Swedish waters were presented. The high interannual and areal variation was highlighted by satellite imagery. Other important new findings included occurrence of DSP toxins along the Gulf of Finland. DSP toxins were found from the Archipelago Sea and western Gulf of Finland. Furthermore, it was shown that *Alexandrium ostenfeldii*, a toxic dinoflagellate, is presently expanding in the Baltic Sea. Significant amounts of PSP toxins were measured in clonal cultures established from these blooms. *A. ostenfeldii* blooms may be a serious new HAB phenomenon in the Baltic that may have harmful effects on co-occurring biota.

Also, an attempt was made to estimate bulk quantities of nodularin in the water column during cyanobacteria blooms. The results suggest that nodularin probably is the most abundantly existing harmful compound in the Baltic Sea environment. The need and possibility for monitoring the algal toxins (both cyanobacteria and dinoflagellates) was emphasized by the group.

Studies where cold-water dinoflagellates (*Peridiniella catenata*, *Scrippsiella hangoei* and *Woloszynskia halophila*) were subjected to diatom filtrates had showed that the growth of *P. catenata* and *W. halophila* was reduced in by diatom filtrates, but that certain other species combinations produced an opposite effect. The results indicate that diatom exudates do affect the growth of the studied dinoflagellates and this effect is species specific. Another presentation reviewed the current knowledge on whether zooplankton is able to induce and maintain blooms as a result of selective feeding. It has been shown that some cyanobacteria strains increase their toxin production in the presence of grazing copepods or chemical cues originating from grazers. It was concluded that future HAB studies should include biotic interactions, especially allelopathy and the ability of meso- and microzooplankton to initiate and/or prolong HAB blooms by their selective foraging.

Studies on the effect of pulsed nutrient supply on community phosphorus dynamics showed that, although the Baltic Proper and Gulf of Finland are held nitrogen limited during summer, at the peak of cyanobacteria blooms the communities are however P deficient and pulses of P favour directly diazotrophic cyanobacteria, especially the non-toxic *Aphanizomenon flos-aquae*. Further, as phosphate is released from the anoxic sediments, the hydrodynamic processes determining the possibilities of nutrients pulsing to the surface may determine if a bloom is formed or not. As a technical finding, the application of phycocyanin (PC) fluorometer in the monitoring of filamentous cyanobacterial blooms in the Baltic Sea was presented. During single transects, or for the whole summer, the variability in Chl*a* concentrations was better explained by PC fluorescence than by Chl*a* fluorescence. It was also shown that a high resolution hydrodynamic model is able to produce realistic hydrodynamic features (e.g. jets and gyres). These models are a useful tool for explaining, e.g. peculiar blooms observed by ships-of-opportunity or remote sensing.

The MarCoast GMES (Global Monitoring for Environment and Security) project was presented and held a useful platform onto which different mor4e specific studies could be adhered. Also, B-NEAT, a new web site and database containing information, images and video of plankton from the Baltic, the Skagerrak and the Kattegat was presented. A proposal for deeper collaboration with researchers and institutes in the Baltic was put forward and further collaboration with the EU-project Plankton*net was discussed.

5 List of the potentially harmful algal species of the Baltic Sea

To understand HAB dynamics, reliable species identification is of primary importance. This need is stressed by the rapidly developing genetical methods, diminishing of the number of people with classical taxonomical skills, and recurrent changes in nomenclature. Therefore WGGIB has been keeping up a full list of Baltic phytoplankton species that may be forming harmful blooms.

Updating of the Baltic HAB species list had been done by the WGGIB experts before the meeting. In Helsinki the checklist and its developments were introduced by S. Hällfors, Finland. The taxonomic status of *Aphanizomenon* sp. and *Chattonella* sp. are currently under debate. New publications are being produced, but, since they have not been published yet, no changes in the species list were made.

It was recognized that the IOC has a similar type of global HAB species list, *IOC Taxonomic Reference List of Toxic Plankton Algae,* which is continuously updated on the Internet. It was decided that the information in the Baltic list will be offered to the IOC IPHAB Task Team on Algal Taxonomy to be amended into the Global list. As the *IOC Taxonomic Reference List of Toxic Plankton Algae* has no search category for specific sea areas, this was decided to be suggested to the keepers of the IOC list Meanwhile, the WGGIB will keep on updating the Baltic HAB list.

The full species list can be seen in Annex 6.

6 GEOHAB Implementation in the Baltic

BALTIC GEOHAB – Cooperative research Plan

The "Proposal for a cooperative HAB Study in the Baltic Sea" had been updated by a subgroup. The revised proposal was reviewed. The proposal was renamed as "BALTIC GEOHAB – Cooperative Research Plan", which will be submitted for GEOHAB for endorsement. The usability of the plan as a true research proposal that can be sent to financing parties was discussed. It was decided that, rather than writing a (more focused) research proposal, the plan should be formulated as a GEOHAB associated "science plan", which reviews the current status of Baltic HAB research and highlights the open research questions, and which can be used as a platform plan for more specific projects. These projects will be formed upon practicalities, such as existence of research infrastructure, research consortia that are already functioning, and true possibilities for funding. After this decision, different subtasks of the Plan were further discussed and elaborated in subgroups.

It was held essential that the key activities of the future projects will help in building up and improving the existing ecosystem models that describe HAB dynamics in the Baltic Sea. Also, although the GEOHAB focus is in studies of bloom dynamics, studies of biotic interactions were held necessary in order to better understand the bloom formation. Also, purely physical processes, such as advection, dispersion and small-scale turbulence, need to be better understood to be able to describe HAB dynamics in the Baltic Sea. Therefore especially the following items were discussed: gaps in knowledge regarding model parameterisation, the importance of biotic interactions in initiation and termination of the blooms, development of methods for automatic observation and operational monitoring of HABs.

GEOHAB recommends that regional comparisons of HAB dynamics should made to fully understand the ecosystem-level regulation of bloom formation and decay. It was maintained that the Baltic Sea forms a special case where comparisons can be made between basins and, e.g., between the open sea and the archipelago areas. Comparative approach can also be adopted by comparing the HAB dynamics of different taxa, such as Cyanobacteria, dinoflagellates, and haptophytes.

Data mining would be needed for not to repeat what has already been done. It was held important that a metadata bank of existing HAB studies should be incorporated in order to facilitate data sharing and better use of data in modelling.

The BALTIC GEOHAB – Cooperative Research Plan is in Annex 7.

7 Other Business

It was decided that, after the Cooperative Plan is ready, the main emphasis of the WGGIB will be in actual implementing of the BALTIC GEOHAB, i.e., setting up GEOHAB-endorsed research projects within the Baltic region, and facilitating of Baltic nations to prepare joint proposals on implementing GEOHAB objectives.

It was also decided that since WGGIB will meet only to review the practical needs of the BALTIC GEOHAB projects, the issues dealing with new findings in Baltic HAB dynamics and national HAB results will in the future be reported through the Working Group of Harmful Algae Dynamics [WGHABD], as kindly suggested by the WGHABD chair.

It was noted that while WGGIB has had a continuous support from both ICES and IOC, it has no true affiliation to SCOR. Therefore it was decided to suggest that the group will be renamed ICES-IOC Working Group on GEOHAB implementation in the Baltic [WGGIB].

At least one further WGGIB meeting was held necessary because of the review of the progress of the new projects, and due to the need of developing a functional network between the different projects. The necessity of any further meetings was left to be decided in the next meeting. Bengt Karlson, Sweden, invited the WGGIB to meet in 2008 in Gothenburg, Sweden, which was cordially accepted. The proposed terms of Reference for 2008 are in Annex 3.

Annex 1: List of participants

* = present only during the joint day with WGHABD.

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Annex 2: Agenda

ICES-IOC-SCOR Working Group on GEOHAB Implementation in the Baltic [WGGIB]

7-9 May 2007, Finnish Institute of Marine Research, Helsinki, Finland

Meeting Room: Terra, Floor 1.

Monday, 7 May 2007

12:00 Welcome & Introduction; adoption of the WGGIB agenda (M. Viitasalo, FIMR)

12:30 Cyanobacterial blooms in the southern Baltic: reasons for the atypical bloom development in the Polish waters in 2006 (Hanna Mazur-Marzek, Univ. Gdansk, Poland)

13:00 DSP toxins along the Gulf of Finland in 2006 (Pirjo Kuuppo, SYKE, Finland)

13:30 A case study on vertical distribution of nodularin in Baltic Sea water column at high resolution (Harri Kankaanpää, FIMR)

14:00 Afternoon break

14:30 Alexandrium ostenfeldii - a new toxigenic dinoflagellate expanding in the Baltic Sea? (Anke Kremp, Univ. Helsinki, Finland)

15:00 Potential allelopathic interactions between diatoms and dinoflagellates during spring bloom in the Baltic Sea (Kristian Spilling, SYKE, Finland)

15:30 HABs, turbidity and behaviour of plankton (Jonna Engström-Öst, FIMR)

16:00 Effect of pulsed nutrient supply on physiological and systemic nutrient limitation and community phosphorus dynamics during cyanobacteria blooms (Emil Vahtera, FIMR)

16:30 Discussion

~17:00 Adjourn for the day; Get together in the FIMR premises

Tuesday, 8 May 2007

09:30 Results from HAB-observations and -modelling by SMHI in the Baltic Sea (Bengt Karlson, SMHI, Sweden)

10:00 Ship-of-opportunity based phycocyanin fluorescence monitoring of the filamentous cyanobacteria bloom dynamics in the Baltic Sea (Jukka Seppälä, FIMR)

10:20 Modelling of upwelling events in the Baltic (Oleg Andrejev, FIMR)

10:40 In situ and satellite data assimilation in algal bloom modelling and forecast for the Baltic Sea: MarCoast project (Seppo Kaitala, FIMR)

11:00 Operational ecosystem and HAB modelling in the Baltic (Tapani Stipa, FIMR)

11:20 Discussion on development of operational monitoring and modelling of HABs in the Baltic

12:00 Lunch

13:00 B-NEAT (Baltic and North East Atlantic Taxa) - a new database and web site for information on marine organisms - a proposal for collaboration (Bengt Karlson, SMHI)

13:30 Update the checklist of the harmful species of the Baltic Sea. Updating has been done by the WGGIB experts before the meeting. In Helsinki brief presentation of the checklist (Seija Hällfors, FIMR), discussion, and possible editions.

14:00 Afternoon break

14:30 Presentation of the revised Proposal for the Baltic Co-operative study (Emil Vahtera, FIMR)

15:30 Discussions on the structure and contents of the Proposal. Deciding on the sub-groups and the schedule for work in Wednesday

~17:00 Adjourn for the day

Wednesday, 9 May 2007

09:30 Proposal/implementation discussions continue. Review on other HAB projects/activities in the Baltic region. Gaps in knowledge. Discussions on implementing of the GEOHAB goals in the Baltic.

12:00 Lunch

13:00 Proposal/implementation discussions continue.

15:00 WGGIB in 2008-09: Terms of reference for 2007; deciding on future actions; meeting place for 2007. Organising the report writing.

~16:00 Meeting adjournment

Annex 3: WGGIB proposed Terms of Reference 2007

The ICES-IOC **Working Group on GEOHAB Implementation in the Baltic** [WGGIB] (Chair: M. Viitasalo, Finland) will meet in Gothenburg, Sweden, in 27–29 February 2008 to:

a) Review progress in implementation of the GEOHAB-BALTIC cooperative research plan, with:
   reports from the projects in progress,
   reports from projects at planning stage;

b) define processes and plan experiments that are needed for better parameterisation of dynamical HAB models;

c) review the progress of incorporating the Baltic HAB list into the *IOC Taxonomic Reference List of Toxic Plankton Algae*;

d) discuss the need of a Baltic HAB researcher network.

WGGIB will report by 30 April 2008 for the attention of the Baltic Committee.

Supporting Information

Priority:	The current activities of this Group will lead ICES into issues related to the effects of HABs on Baltic Ecosystem, as well as fisheries. Consequently these activities are considered to have a high priority.
Scientific Justification and relation to Action Plan:	Action Plan No: 1. Term of Reference a) There is currently an intense research activity on HABs in the Baltic. It is in the interest of ICES, IOC and GEOHAB to foster international cooperative HAB research in the Baltic Sea. In 2007, the BALTIC GEOHAB – Cooperative Research Plan was prepared. This Cooperative Plan was intended to serve as a platform for more specific research projects to which funding will be applied during 2007 and 2008. For the implementation of the Cooperative Plan it is necessary to review the progress of the newly formed projects. Term of Reference b) The ultimate goal of the BALTIC GEOHAB is to develop means for better observation and prediction of HAB blooms in the Baltic Sea. To achieve this, ecosystem models are a primary tool. However, there are still gaps in knowledge in key parameters necessary for reliable modelling of HABs. These processes need to be identified and explicit experiments need to be designed to fulfil the existing gaps and to parametrisize the models. Term of Reference c) A list of potentially toxic and bloom forming species has been prepared during the former SGGIB and WGGIB meetings. In 2007 it was decided that this information should be incorporated into the *IOC Taxonomic Reference List of Toxic Plankton Algae* .. Until this is completed the Baltic list will be updated if necessary. Term of Reference d) One of the GEOHAB objectives is to promote the cooperation and networking of HAB scientists. This Term of Reference intends to investigate if there is a need for a formal organisation of Baltic HAB scientists.
Resource Requirements:	Part of the research that provides input to this group is already underway in the participating countries, and resources are already committed. Additional resources will be sought for from various sources to build up research projects

	to implement different subtasks of the Cooperative Plan.
Participants:	In 2005 the Group was attended by xx participants
Secretariat Facilities:	None.
Financial:	No financial implications.
Linkages To Advisory Committees:	There are no obvious direct linkages with the advisory committees.
Linkages To other Committees or Groups:	There is a close working relationship with several working groups in the Oceanography Committee (Harmful Algae Bloom dynamics, Working Group on Modelling of Physical/Biological Interactions, Phytoplankton Ecology and Phytoplankton and Protist Taxonomy). The scientific content of the planned projects will be reported through WGHABD.
Linkages to other Organisations:	The Group is fulfilling the requirements of IOC and GEOHAB to foster international cooperative HAB research in the Baltic Sea.
Secretariat Marginal Cost Share:	

Annex 4: Recommendations

RECOMMENDATION	ACTION
1. The WGGIB members will from 2008 onwards report the scientific contents of their research in the WGHABD meetings. WGGIB recommends maintaining the Baltic HAB issues on the WGHABD agenda.	To the attention of Oceanography Committee, Baltic Committee and WGGIB and WGHABD members

Annex 5: Abstracts of the presentations

Cyanobacterial blooms in the southern Baltic: reasons for the atypical bloom development in the Polish waters in 2006

Hanna Mazur-Marzek (University of Gdansk, Poland)

Phytoplankton composition, and concentrations of chlorophyll *a* (chl*a*) and cyanobacterial toxins were determined in samples collected in the Polish coastal waters of the Baltic from the beginning of June till the end of August 2006. In most of the samples two cyanobacterial species, *Nodularia spumigena* and *Aphanizomenon flos-aquae* dominated. Increased number of *N. spumigena* filaments occurred 19–22 June when water temperature reached over 17ºC. During those days chl*a* and nodularin concentrations reached up to 302.4 µg l^{-1} and 159.7 µg l^{-1}, respectively. Then the cyanobacterial abundance declined, probably due to a decrease in water temperate caused by an upwelling event. In the central part of the Polish coast, a mass occurrence of *N. spumigena* was observed in late July (chl a > 150 µg l^{-1}, nodularin > 100 µg l^{-1}, salinity 7.2–7.3 psu; temperature 13–18 ºC) and resulted in beach closures lasting several days. Microscopic observation revealed the presence of decaying *N. spumigena* filaments with attached diatoms of the genus *Nitzschia* as well as numerous bacteria. At this part of the Polish coast, this is the highest biomass of cyanobacteria recorded this far. Soon after the bloom, a high number of *Mesodinium rubrum* occurred in the same area.

In the second week of August increased concentrations of chla and nodularin were recorded in the whole Gulf of Gdańsk. On 9 August they reached the maximum values of 111.9 µg l^{-1} and 50.7 µg l^{-1}, respectively. Additionally, HPLC/DAD analyses revealed a presence of microcystin-LR (9.9 µg l^{-1}). The bloom was characterized by unusual abundance of cyanobacteria of the genera *Anabaena*. In samples collected on 9 August *Anabaena flos-aquae* constituted up to 50 % of the phytoplankton community; *A. lemmermannii, A. spiroides* and *A. circinalis* were the other species; *N. spumigena* (30 %) and *Aphanizomenon* flos-aquae (10 %) were less abundant. In summer 2006, the average water temperature in the Gulf of Gdańsk was about 2 ºC higher than in the past few years.

In the presentation the applicability of nodularin HPLC measurements in the studies of *N. spumigena* bloom dynamics is discussed.

DSP toxins along the Gulf of Finland in 2006

Pirjo Kuuppo (Finnish Environment Institute), Pauliina Uronen (University of Helsinki, Finland), Katrin Erler (Friedrich-Schiller-Universität Jena, Germany)

We surveyed variation of *Dinophysis* spp. and DSP toxins along the Gulf of Finland in relation to environmental variables (temperature, salinity and nutrients). The survey was done on a cruise on July 31–August 11, 2006. DSP toxins were analysed from 50 net stations (integrated <20µm net sample was taken from thermocline to surface) and 10 vertical stations. The spectrum of DSP toxins was analysed using HPLC/MS and *Dinophysis* cells were counted with the Utermöhl method. Temperature, salinity and nutrients were measured onboard using CTD and standard methods.

The abundance of *Dinophysis* varied between 0 and 1.3 10^5 (mean 1.5 10^3) cells l^{-1}. The maximum abundance was found at 22 m depth in an area where bottom sediment was dredged due to harbour construction. *D. acuminata* was the dominating species with on average 88 % of the community. *D. norvegica* (mean contribution 3 %) was more common in the west, while *D. rotundata* (4%) was present throughout the cruise track. The abundance of

Dinophysis did not correlate significantly with ambient nutrient concentrations, temperature or salinity.

DSP toxins were found from the Archipelago Sea and western Gulf of Finland: yessotoxin, DTX-2, PTX-1, PTX-2-SA and PTX-2, the last-mentioned in measurable concentrations. PTX-2 varied from 0 to 4.2 µg PTX-2 l^{-1} (mean 1.1) in the net samples, having a significant positive correlation with surface salinity (Pearson 0.656 $P < 0.001$) and a negative one with temperature (Pearson −0.772 $P < 0.001$). In the vertical samples mean PTX-2 concentration was 449 ng l^{-1}, and maxima (>1.6 µg l^{-1}) occurred at 20 m depth at two stations. Cellular PTX-2 content in *Dinophysis* was 0-11.3 pg $cell^{-1}$ (mean 2.7), correlating significantly with salinity (Pearson 0.625 $P < 0.001$).

A case study on vertical distribution of nodularin in Baltic Sea water column

Harri kankaanpää (Finnish Institute of Marine Research)

Information pertaining to the total quantities of the major algal toxin in the Baltic Sea, nodularin, in cyanobacterial blooms is still limited. Also, attempts to quantify bloom patchiness have been few.

Finnish Institute of Marine research has during the past few years quantified cyanobacteria and their toxins in different horizons of the water column. Sampling techniques include large-volume water sampling and vertical sampling at high resolution. During a cruise in August 2006, the cyanobacteria blooms were not very intense in the central and northern Baltic Sea. The strongest surface accumulation occurred in the southern part of the Archipelago Sea, Finland.

Nodularin was horizontally and vertically very patchily distributed. Microstratification of nodularin was also observed. Dynamic range of nodularin concentrations was approx. 10-fold within 0.2–3.0 m vertical range, and correlated positively with chlorophyll *a* concentration. Typical concentrations were in the range of 0.35–500 mg nodularin kg^{-1} dw (ELISA) in solids. However, taking into account the concentration of total particulate material in the water mass, the larger share of nodularin was extracellular (water-bound). This translates into ca. 0.07–11 mg nodularin m^{-3}.

Overall the results suggest that nodularin probably is the most abundantly existing harmful compound in the Baltic Sea environment. Since there are no HELCOM or ICES monitoring programmes related to nodularin, it is recommended that the need and possibility for such an activity should be assessed.

Alexandrium ostenfeldii, a new toxigenic dinoflagellate expanding in the Baltic Sea?

Anke Kremp (University of Helsinki, Finland) & T. Lindholm, G. Gerdts, T. Helbig

This presentation indroduces *Alexandrium ostenfeldii*, a toxic dinoflagellate that presently expands in the Baltic Sea. We report the occurrence of exceptionally dense blooms of this species (1.8 10^5 and 2.3 10^6 cells l^{-1} respectively) in the summers of 2003 and 2004 in the Åland archipelago, Northern Baltic Sea, where it has not been observed earlier in bloom quantities. Significant amounts of PSP toxins (STX, GTX2 and GTX3 with GTX 3 being the major toxin) were measured in clonal cultures established from these blooms, confirming that the Åland population has a potential for toxicity. Salinity tolerance experiments revealed that the Northern Baltic *A. ostenfeldii* strains are well adapted to the low saline brackish water environment as they grew well at salinities as low as 5 psu, but did not tolerate full saline water. All clones formed large amounts of dormant resting cysts when grown at nutrient deplete conditions. This indicates an efficient seasonal survival strategy which potentially contributes to the establishment and retention of the species in northern Baltic Sea. The preliminary results presented here emphasize that *A. ostenfeldii* blooms are a serious new HAB phenomenon in the Baltic that may have harmful effects on co-occurring biota and which deserve and demand the attention of the scientific community.

Potential allelopathic interactions between diatoms and dinoflagellates during spring bloom in the Baltic Sea

Kristian Spilling (Finnish Environment Institute)

In this study, the growth rate of cold-water dinoflagellates from the Baltic Sea, *Peridiniella catenata*, *Scrippsiella hangoei* and *Woloszynskia halophila* were determined in filtrates (0.2 µm and 2.0 µm) of co-occurring diatoms, established in monocultures (*Melosira arctica*, *Chaetoceros wighamii*, *Diatoma tenuis*, *Thalassiosira baltica*, *Skeletonema costatum*). Aged, autoclaved seawater was used as control. The growth of *P. catenata* and *W. halophila* was reduced in filtrates of diatom cultures compared with the control; the growth of *S. hangoei*, on the other hand, generally increased in diatom filtrates. The filtrate of *S. costatum* was the only treatment producing lower growth rate of *S. hangoei* compared with the control, but produced the highest growth rate of *P. catenata* of the diatom filtrates. Generally the 2.0 µm filtrate produced a greater effect when compared with the 0.2 µm filtrate, and the effect on growth rate was stable over the duration of the experiment (2 weeks). This suggests that the effect is caused by compounds that are not easily degradable. The results indicate that diatom exudates do affect the growth of the studied dinoflagellates and this effect is species specific.

HABs, turbidity and behaviour of plankton

Jonna Engström-Öst (Finnish Institute of Marine Research)

Secchi depth and turbidity have decreased in all basins in the Baltic Sea. It has been shown that eutrophication and algae-induced phytoplankton growth are important factors affecting the water transparency negatively in the whole area. Filamentous cyanobacteria belong to one of the taxa that have increased most in the Baltic Sea. Previous studies have shown that feeding and reproduction of copepod zooplankton are fairly low within the bloom, whereas copepod survival is high. On the other hand, recent studies report that blooms and turbid water may provide shelter and refuge for feeding zooplankton, because fish larvae and mysid shrimps are unable to catch as many prey in bloom-containing water as in clear water. Hence, I hypothesise that the survival benefits of associating with dense albeit toxic blooms may override the relatively minor impact of toxicity on copepod fecundity. Further, it has been debated in the literature whether zooplankton is able to induce and maintain blooms as a result of selective food intake. It has been shown that some cyanobacteria strains increase their toxin production in the presence of grazing copepods or chemical cues originating from grazers. Future studies should focus on the ability of meso- and microzooplankton to initiate and persist blooms by their selective foraging.

Effect of pulsed nutrient supply on physiological nutrient limitation and community phosphorus dynamics during blooms of nitrogen-fixing cyanobacteria in the Baltic Sea

Emil Vahtera, Riitta Autio, Hermanni Kaartokallio (Finnish Institute of Marine Research), and Maria Laamanen (Ministry of Environment, Finland)

We examined the effect of altered nutrient supply stoichiometry through single pulsed nutrient additions (ammonia or phosphate additions) on biomass, productivity and phosphorus dynamics of diazotrophic cyanobacteria bloom communities. Our aim was to elucidate bloom-time phosphorus (P) limitation characteristics and to study effects of pulsed nutrient supply on P uptake and transfer in a size fractionated community. Bloom formation of diazotrophic cyanobacteria in the Baltic is based mainly on P acquired from cellular stores, nutrient pulses mediated by hydrodynamic processes or through regenerative pathways. The bloom communities studied showed clear signs of P limitation in the Baltic Proper where cellular storage and regenerative pathways dominate P supply. Areas affected by hydrodynamic activity showed P deficiency but not limitation, indicated by lower specific hydrolytic enzyme activities and specific phosphate affinities. The two main bloom forming species *A. flos-aquae* (non-toxic) and *N. spumigena* (hepatotoxic), showed differing responses to pulsed P supply. *A. flos-aquae* directly benefited from P pulses during P deficient conditions indicated by decreased hydrolytic enzyme activity, increased particulate P concentrations and a relative increase of accumulation of P in the cyanobacteria fraction of the community. The Baltic Proper and Gulf of Finland are generally regarded nitrogen limited during summer. At the peak of cyanobacteria blooms the communities are however P deficient or limited, and pulses of P favour directly diazotrophic cyanobacteria, especially the non-toxic *Aphanizomenon flos-aquae.*

Results from HAB observations and modelling by SMHI in the Baltic

Bengt Karlson (Swedish Meteorological and Hydrological Institute)

Long term data on the oxygen and nutrient concentrations in the deep parts of the central Baltic indicate that phosphate is released from the sediments during oxygen free conditions. The oxygen concentrations are coupled both to eutrophication and to the inflow of high saline water from the Kattegat and the resulting increased stratification. Results from the RCO-SCOBI- model (Rossby Centre Ice-Ocean Circulation model and the Swedish Coastal and Ocean Biogeochemical Model) was presented. Model results and validation data on oxygen is well correlated for the period 1902–1998. The model also includes three groups of phytoplankton: cyanobacteria, diatoms and flagellates. The cyanobacteria component is relevant for HAB-studies.

One major problem when trying to describe HAB- dynamics is how to sample at relevant temporal and spatial scales. Problems include

- Horisontal patchiness;
- Vertical patchiness – thin layers;
- Large species diversity;
- Low cell numbers is often relevant for HAB-species;
- Behaviour: Swimming, Sinking, Floating and Grazing etc.

A combination of techniques is needed to address the problem. The oceanographic buoy *Måseskär West*, partly funded by the EU-project Forum Skagerrak II, was presented. Measurements are made every 3 hours with a vertical resolution of ca 30 cm. The system includes a multi parameter profiling device and near real time data transmission to SMHI. Some data from measurements in the Baltic current was presented.

Results from SMHI's monitoring of HAB in the Baltic in 2006 are presented. The cyanobacteria bloom was most intense in mid July in the southern part but a *Nodularia* bloom was observed in August in the Bothnian bay. Satellite data from SMHI's Baltic Algae Watch System (BAWS) show that the bloom was one of the largest for the period 1997–2006. Remnants of the bloom were observed in the Kattegat and the Skagerrak. The range of *Nodularin* concentrations were 0–6.6 µg L^{-1} in the samples from the southern Baltic.

The background to the bloom and non-bloom years in the 2000's was discussed in connection with phosphate concentrations in surface water. The difference between the southern Baltic proper and the Central Baltic proper is striking.

Ship-of-opportunity based phycocyanin fluorescence monitoring of the filamentous cyanobacteria bloom dynamics in the Baltic Sea

Jukka Seppälä, Pasi Ylöstalo, Seppo Kaitala, Seija Hällfors, Mika Raateoja, Petri Maunula (Finnish Institute of Marine Research)

Distribution of cyanobacteria cannot be evaluated using chlorophyll *a* (Chl*a*) *in vivo* fluorescence, as most of their Chl*a* is located in non-fluorescing photosystem I. Phycobilin fluorescence, in turn, is a useful tool in the detection of cyanobacterial blooms. We applied phycocyanin (PC) fluorometer in the monitoring of filamentous cyanobacterial blooms in the Baltic Sea. For the filamentous cyanobacteria *Aphanizomenon flos-aquae* and *Nodularia spumigena*, PC fluorescence maximum was identified using the excitation-emission fluorescence matrix. The optical setup of our instrument was noted appropriate for the detection of PC, and with minor or no interference from Chl*a* and phycoerythrin fluorescence, respectively.

During summer 2005, the instrument was installed on a ferryboat commuting between Helsinki (Finland) and Travemünde (Germany), and data was collected during 32 transects providing altogether 200 000 fluorescence records. PC *in vivo* fluorescence was compared with Chl*a in vivo* fluorescence and turbidity measured simultaneously, and with Chl*a* concentration and biomass of the bloom forming filamentous cyanobacteria determined from discrete water samples.

PC fluorescence showed a linear relation to the biomass of the bloom forming filamentous cyanobacteria. The other sources of PC fluorescence are considered minor in the open Baltic Sea. Estimated by the PC fluorescence, cyanobacterial bloom initiated in late June at the Northern Baltic Proper, rapidly extended to the central Baltic Proper and the Gulf of Finland, and peaked in the mid-July with values up to 10 mg l^{-1} (fresh weight). In late July, the bloom vanished in most areas. During single transects, or for the whole summer, the variability in Chl*a* concentrations was better explained by PC fluorescence than by Chl*a* fluorescence. Thus, filamentous cyanobacteria dominated the overall variability in phytoplankton biomass. We show that during the cyanobacterial blooms, the estimation of Chl*a* concentration using only Chl*a in vivo* fluorescence is not applicable, but PC *in vivo* fluorescence is required as a predictor as well.

Modelling of upwelling events in the Baltic

Oleg Andrejev (Finnish Institute of Marine Research)

Two coastal upwellings that took place in August 1996 near the Hel Peninsula, southern Baltic, were simulated with OAAS 3D hydrodynamic model, which used realistic wind conditions during that period as a forcing factor. The first one was caused by easterly wind that dominated in the area during the first half of August. A total wind impulse applied to the sea surface during this period was as large as 36 000 kg m^{-1} s^{-1}. This upwelling made the thermocline to disappear completely near the coast, and seawater temperature declined to 6°C (temperature of the ambient water was about 19°C).

In the next 10 days wind changed direction and become very weak, water in the upwelling area warmed up, but when the depth of the newly formed thermocline reached a few metres, the wind strength and direction again started to favour upwelling. When wind impulse increased to 1700 kg m^{-1} s^{-1}, upwelling near the Hel Peninsula started again. This second upwelling was also verified by R/V Baltica (owner: Sea Fisheries Institute in Gdynia, Poland) on August 29, 1996. A difference between seawater temperature in the upwelling zone and temperature of the ambient water was up to 9 degrees. This shows that even a weak wind forcing can induce upwelling and cause a significant decrease of the sea water temperature in areas influenced by recent upwellings.

Furthermore, the model produced a realistic simulation of developing of filaments in the upwelling area and generation of vorticities in the vicinity of the upwelling front.

In situ and satellite data assimilation in algal bloom modelling and forecast for the Baltic Sea: MarCoast project

Seppo kaitala, tapani Stipa (Finnish Institute of Marine Research) & Jouni Pulliainen (Finnish Meteorolgical Institute)

MarCoast (Marine & Coastal Environmental Information Services) is a three year (2005–2008) GMES (Global Monitoring for Environment and Security) Service Element funded by the European Space Agency (ESA) focused in marine and coastal information services.

The baseline Baltic Sea water quality service as real-time and assessment are extended to the analysis of continuous temporal and spatial coverage and to forecasts of its evolution. The resulting time series will be used for assessment purposes. Principles of data assimilation (satellite and in situ observations) in ecosystem model forecast are demonstrated.

B-NEAT (Baltic and North East Atlantic Taxa) - a new database and web site for information on marine organisms - a proposal for collaboration

Bengt Karlson (Swedish Meteorological and Hydrological Institute)

B-NEAT (Baltic and North East Atlantic Taxa) is a new web site and database containing information, images and video of plankton from the Baltic, the Skagerrak and the Kattegat. It will likely grow to include the North Sea, The Norwegian Sea, the Barent Sea and the Greenland Sea. The web address for the prototype is www.test.b-neat.org and the operational site will be www.b-neat.org. The content of B-NEAT is based on *Checklist of phytoplankton in the Skagerrak-Kattegat* http://www.smhi.se/oceanografi/oce_info_data/plankton_checklist/ssshome.htm and on the *Checklist of Baltic Sea Phytoplankton Species* (Hällfors 2004) plus information on plankton species in Norwegian Seas from the Institute of Marine Research in Norway and the University of Oslo. Also zooplankton is being added. The site includes links to other sources of information, e.g. the IOC list on toxic algae, Integrated Taxonomic Information System (ITIS) and the European Register of Marine Species. At present there are seven B-NEAT partners. A proposal for deeper collaboration with researchers and institutes in the Baltic is put forward and further collaboration with the EU-project Plankton*net is discussed.

Annex 6: Potentially harmful phytoplankton species of the Baltic Sea

Potentially harmful phytoplankton species of the Baltic Sea

REGULAR BLOOMS

Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Nodularia spumigena	CYAN	Nost	HT	water	O, C	whole Baltic Sea except Bothnian Bay (occasional blooms in Gulf of Riga)	B
Aphanizomenon flos-aquae	CYAN	Nost	NT,PSP	water	O, C	whole Baltic Sea except Bothnian Bay (occasional blooms in Gulf of Riga)	B, F

OCCASIONAL BLOOMS

Species	***Division***	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Microcystis aeruginosa	CYAN	Nost	HT	water	C	in estuaries and low saline coastal areas	F, B
Microcystis flos-aquae	CYAN	Nost	HT	water	C	in estuaries and low saline coastal areas	F
Anabaena circinalis	CYAN	Nost	HT, NT; PSP	water	C	in estuaries and low saline coastal areas	F
Anabaena cylindrica	CYAN	Nost	HT, NT; PSP?	water	O, C	whole Baltic Sea except Archipelago Sea and Bothnian Bay	F, B
Anabaena flos-aquae	CYAN	Nost	HT, NT; PSP	water	C	whole Baltic Sea	F
Anabaena lemmermannii	CYAN	Nost	HT, NT; PSP?	water	O, C	northern Baltic Proper and Gulf of Finland	B, F
Anabaena spiroides	CYAN	Nost	HT, NT; PSP?	water	O, C	whole Baltic Sea, except northern Baltic Sea, Archipelago Sea and Bothnian Sea	F
Planktothrix agardhii	CYAN	Nost	HT	water	C	in estuaries, in highly eutrophied coastal areas with low salinity and in Bothnian Bay	B

OCCASIONAL BLOOMS (CONTINUED)							
Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Prorocentrum minimum (different strains)	DINO	Dino	depends on the strain	Oyster larvae	O, C	Kattegat, southern, central and northern Baltic Sea, Gulf of Finland	M, B
Dinophysis acuminata	DINO	Dino	DSP	mussels	O, C	whole Baltic Sea	M, B
Dinophysis norvegica	DINO	Dino	DSP	mussels	O, C	whole Baltic Sea	M, B
Heterocapsa triquetra	DINO	Dino	could be harmful in small inlets causing oxygen depletion	?	O, C	whole Baltic Sea except Bothnian Bay, (in low numbers in Gulf of Riga)	M, B
Alexandrium ostenfeldii	DINO	Dino	PSP, NSP	mussels	O, C	southern, central and northern Baltic Sea, Gulf of Gdansk, Archipelago Sea (in low numbers in Kattegat and Belt Sea,)	M
Ceratium fusus	DINO	Dino	anoxia, and harmful to invertebrate larvae	?	O	Kattegat, southern Baltic Sea	M
Dictyocha speculum, (flagellate form)	CHRY	Dict	IC	fish	C	western and southern Baltic Sea	M, B
Chrysochromulina spp. (at least about 40 species, e.g. C. polylepis, C. leadbeateri, C. brevifilum, C. kappa, C. strobilus)	HAPT	Prym	IC	fish	O, C	western Baltic Sea (sometimes in high numbers also in the northern Baltic proper)	M, B, (F)
Prymnesium parvum	HAPT	Prym	IC	water	C	coastal inlets with very low salinity	B, F
Chaetoceros borealis	CHRY	Diat	mechanical	fish	O	Kattegat and Belt Sea	M
Chaetoceros danicus	CHRY	Diat	mechanical	fish	O, C	whole Baltic Sea	M, B
Chaetoceros decipiens	CHRY	Diat	mechanical	fish	O	western and southern Baltic Sea	M

Chaetoceros impressus	CHRY	Diat	mechanical	fish	O, C	south-eastern Baltic Sea	M, B
Pseudo-nitzschia spp. (P. calliantha, P. delicatissima, P. multiseries, P. pseudodelicatissima, P. pungens, P. seriata)	CHRY	Diat	ASP	mussels	O, C	Kattegat and Belt Sea, southern Baltic Sea	M
cf. Chattonella sp.	CHRY	Dict	clogging of fish gills by mucus excretion, gill damage by haemolytic substances; NT?	fish	O, C	Kattegat and Belt Sea	M

REGULARLY IN PLANKTON BUT NOT IN BLOOM AMOUNTS							
Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Anabaena cylindrica	CYAN	Nost	HT, NT; PSP?	water	O, C	whole Baltic Sea except Archipelago Sea and Bothnian Bay	F, B
Anabaena lemmermannii	CYAN	Nost	HT, NT; PSP?	water	O, C	Gulf of Bothnia, Gulf of Riga, Central Baltic Sea, Southern Baltic proper	B, F
Dinophysis acuta	DINO	Dino	DSP	mussels?	O, C	whole Baltic Sea except Gulf of Bothnia	M, B
Dinophysis rotundata	DINO	Dino	DSP	mussels	O, C	whole Baltic Sea	M, B
Protoceratium reticulatum	DINO	Dino	DSP	mussels?	O	whole Baltic Sea	M
Chrysochromulina spp.	HAPT	Prym	IC	fish	O, C	whole Baltic Sea	M, B, (F)
Chaetoceros spp.	CHRY	Diat	mechanical	fish	O, C	whole Baltic Sea	M, B

OCCASIONALLY IN PLANKTON IN LOW NUMBERS							
Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Coelosphaerium kuetzingianum	CYAN	Nost	NT, HT	water	C	whole Baltic Sea, except Archipelago Sea and Bothnian Sea	F
Microcystis ichtyoblabe	CYAN	Nost	HT?	water	C	in estuaries, in highly eutrophied coastal areas with low salinity in Kattegat and Belt Sea, Arkona Basin, southern Baltic Sea	F
Microcystis viridis	CYAN	Nost	HT	water	C	in estuaries, in highly eutrophied coastal areas with low salinity in Arkona Basin, southern Baltic Sea	F
Microcystis wesenbergii	CYAN	Nost	HT	water	C	in estuaries, in highly eutrophied coastal areas with low salinity in Arkona Basin, southern Baltic Sea, Gulf of Riga, Gulf of Finland	F

Occasionally in plankton in low numbers (continued)							
Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Snowella lacustris	CYAN	Nost	HT	water	C	whole Baltic Sea in estuaries, in highly eutrophied coastal areas with low salinity	F
Woronichinia naegeliana	CYAN	Nost	NT, HT	water	C	whole Baltic Sea, in estuaries, in highly eutrophied coastal areas with low salinity	F
Anabaena spp. (A. macrospora, A. planctonica)	CYAN	Nost	NT	water	O, C	southern Baltic Sea, Bothnian Bay	F, B
Aphanizomenon gracile	CYAN	Nost	PSP	water	O	whole Baltic Sea except Kattegat and Belt Sea	F, B
Aphanizomenon issatschenkoi	CYAN	Nost	NT	water	C	southern Baltic Sea, Gulf of Finland	F
Trichormus variabilis	CYAN	Nost	NT	water	O	southern Baltic Sea, Gulf of Finland	F
Prorocentrum lima	DINO	Dino	DSP	?	C	benthic, occasionally in littoral plankton, Kattegat and Belt Sea	M
Dinophysis sacculus	DINO	Dino	DSP	mussels	C	Kattegat and Belt Sea	M
Amphidinium carterae	DINO	Dino	Haemolytic compounds	?	O	Kattegat and Belt Sea	M
Amphidinium operculatum	DINO	Dino	Haemolytic compounds	?	O	Kattegat and Belt Sea	M
Akashiwo sanguinea	DINO	Dino	Anoxia	fish	O	whole Baltic Sea	M
Karenia mikimotoi	DINO	Dino	IC	fish	O	Kattegat and Belt Sea	M
Karlodinium veneficum	DINO	Dino	IC	fish	O	Kattegat and Belt Sea	M
Noctiluca scintillans	DINO	Dino	NH_3-producer	fish	O	Kattegat, Belt Sea and Arkona Basin	M

Peridiniopsis polonicum	DINO	Dino	?	fish	C	southern Baltic Sea, Gulf of Riga, Gulf of Finland	F
Protoperidinium crassipes	DINO	Dino	DSP		O	Kattegat and Belt Sea	M
Protoperidinium curtipes	DINO	Dino	DSP	?	O	Kattegat and Belt Sea	M
Scrippsiella trochoidea	DINO	Dino	IC?	?	O	whole Baltic Sea	M
Alexandrium tamarense	DINO	Dino	PSP	fish	O	Kattegat and Belt Sea	M

OCCASIONALLY IN PLANKTON IN LOW NUMBERS (CONTINUED)							
Species	*Division*	*Class*	*Toxicity and/or other harmful effect*	*Toxins in or harmful effect through…*	*Open sea/ coastal*	*Distribution in the Baltic Sea*	*Marine/ brackish/ fresh water*
Alexandrium spp.	DINO	Dino	PSP, NT	mussels	C	southern and western Baltic Sea	M, B
Ceratium tripos	DINO	Dino	Anoxia, hypoxia	?	O	Kattegat and the Belt Sea, southern Baltic Sea	M
Gonyaulax spinifera	DINO	Dino	DSP	mussels	O, C	whole Baltic Sea except Gulf of Bothnia , Archipelago Sea and Gulf of Riga	M
Lingulodinium polyedrum	DINO	Dino	DSP	mussels	O, C	Arkona Basin, Kattegat, Skagerrak,	M
Phaeocystis globosa	HAPT	Prym	Anoxia, hypoxia	?	C	Kattegat and Belt Sea, southern Baltic Sea	M
Dictyocha speculum	CHRY	Dict	IC?	water	O, C	southern and western Baltic Sea, Arkona Basin, Kattegat, Skagerrak	M

DIVISIONS:

Cyanophyta (Cyanobacteria) - CYAN

Dinophyta (Pyrrhophyta) - DINO

Haptophyta - HAPT

Chrysophyta (Heterokontophyta) - CHRY

CLASSES:

Nostocophyceae (Cyanophyceae) - Nost

Dinophyceae - Dino

Prymnesiophyceae (Haptophyceae) - Prym

Dictyochophyceae - Dict

Diatomophyceae (Bacillariophyceae) - Diat

Raphidiophyceae (Chloromonadophyceae) – Raph

ABBREVIATIONS OF TOXIN SYNDROMES:

ASP = Amnesic Shellfish Poisoning

DSP = Diarrhetic Shellfish Poisoning

HT = Hepatotoxic

IC = Ichtyotoxic

NT = Neurotoxic

NSP=Neurotoxic Shellfish Poisoning

PSP = Paralytic Shellfish Poisoning

Acknowledgements and references

This checklist of potentially harmful species of the Baltic Sea is an update of Table 2 (compiled by K. Kononen, M. Elbrächter, M. Balode, S. Hällfors, G. Hällfors, J. Göbel, S. Hajdu, I. Olenina, I. Konoshina, A. Jaanus, I. Ledaine & E. Dahl) in Report of ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic ICES CM 2002/H:02 Ref. ACME, Annex 3: Proposal for Cooperative HAB Study in the Baltic Sea.

Updates

Updated in April 2004 by Seija Hällfors and Guy Hällfors, according to:

Hällfors, G. 2004: Checklist of Baltic Sea Phytoplankton Species including some heterotrophic protistan groups. - Baltic Sea Environment Proceedings Series No 95. 208 pp.

Wasmund, N. 2002. Harmful Algal Blooms in Coastal Waters of the South-Eastern Baltic Sea. - Pp. 93–116 in Schernerwski, G. & Schiewer, U. (eds.): Baltic Coastal Ecosystems Structure, Function, and Coastal Zone Management. Springer Verlag, Berlin.

Hallegraeff, G. M., Anderson, D. M., and Cembella, A. D. 2003. Manual on Harmful Marine Microalgae.-Monographs on Oceanographic Methology 11, UNESCO.

Moestrup, Ø. *et al.* 2004. IOC Taxonomic Reference List of Toxic Plankton Algae. Intergovernmental Oceanographic Commission of UNESCO. http://www.bi.ku.dk/ioc/.

Updated by Seija Hällfors in May 2005 according to comments by Malte Elbrächter, Bengt Karlson and Norbert Wasmund.

Updated by Seija Hällfors in May 2006 according to:

Bowers, H., Tomas, C., Kempton, J., Diaz-Mendez, F., Goto, S., Lewitus, A., and Oldach, D. 2004. Raphidophyte systematics and rapid identification: sequence analyses and real time PCR assays. – P. 74 in 11th International Conference on Harmful Algal Blooms, Cape Town, South Africa, 14–19 November 2004. Programme and abstracts. 337 pp.

Edvardsen, B., Eikrem, W., Naustvoll, L., Riisberg, I., Shalchian-Tabrizi, K., and Throndsen, J. 2004. Phylogeny of a new icthyotoxic Dictyochophyte forming blooms in the Skagerrak. – P. 103 in 11th International Conference on Harmful Algal Blooms, Cape Town, South Africa, 14–19 November 2004. Programme and abstracts. 337 pp.

ICES. 2005. Report of the ICES-IOC Working Group of Harmful Algal Bloom Dynamics (WGHABD), 4-7 April 2005, Flødevigen, Norway. C:03 Re. ACME, ACE. 42 pp.

Luckas, B., Dahlmann, J., Erler, K., Gerdts, G., Wasmund, N., Hummert, C. and Hansen, P. D. 2005: Overview of key phytoplankton toxins and their recent occurrence in the North and Baltic Seas. Environmental Toxicology, 20: 1–17.

Rhodes, L., McNabb, P., de Salas, M., Briggs, L., Beuzenberg, V., and Gladstone, M. 2006. Yessotoxin production by Gonyaulax spinifera. –Harmful Algae, 5: 48–155.

and comments and unpublished information by Malte Elbrächter, Susanna Hajdu, Heidi Hällfors, Anke Kremp, Tore Lindholm and Allan Cembella.

Updated by Seija Hällfors in May 2007 according to:

Wood, S., Rasmussen, P., Holland, P., Campbell, R., and Crowe, A. 2007. First report of the cyanotoxin anatoxin-a from Aphanizomenon issatschenkoi (Cyanobacteria). – Journal of Phycology, 43(2): 356–365.

The description of cf. *Chattonella* sp. (Dictyochophyceae) has not yet been published, so no valid species name is available for update at the present time.

A nomenclatural change will concern also Baltic strains of Aphanizomenon flos-aquae that will be separated and described as a new species according unpublished information from Prof. J. Komárek.

Annex 7: BALTIC GEOHAB – Cooperative Research Plan

ICES-IOC working Group of GEOHAB Implementation in the Baltic Sea

PROPOSAL FOR A COOPERATIVE HAB STUDY IN THE BALTIC SEA

BALTIC GEOHAB

June 20, 2007

BALTIC GEOHAB – Proposal for a cooperative HAB study in the Baltic Sea

1 BACKGROUND

The BALTIC GEOHAB research plan is intended to function as an open platform facilitating international cooperative research on harmful algal bloom (HAB) dynamics in the Baltic Sea region. The research plan assembles the most urgent research needs in accordance with the GEOHAB programme elements:

1. Biodiversity and biogeography
2. Nutrients and eutrophication
3. Adaptive strategies
4. Comparative ecosystems
5. Observation, modeling and prediction

The purpose of the plan is to concentrate research efforts and coordinate international cooperation in order to fulfil the present gaps in knowledge regarding HAB dynamics in the Baltic Sea.

1.1 The Baltic Sea

The Baltic Sea is a semi-enclosed, non-tidal, brackish sea characterized by a pronounced density stratification due to large river inflow from the surrounding drainage area and occasional inflowing salt water from the North Sea. Ca. 85 million people inhabit the drainage area. During recent decades, eutrophication, resulting in increased phytoplankton biomass, decreased water transparency and massive cyanobacteria blooms have become the most serious environmental issue in the area.

The plankton dynamics of the Baltic Sea are dominated by seasonality. Two seasonal blooms occur. The diatom-dinoflagellate spring bloom develops in March–May as soon as solar irradiation in relation to density stratification creates a suitable light environment for algae to grow. This bloom contributes about half of the annual primary production. As soon as nutrients become exhausted from the surface layer and begin to limit algal growth, most of the diatom bloom biomass settles down to the bottom; a larger proportion of the dinoflagellate bloom is decomposed in the water column. The other seasonal bloom is caused by cyanobacteria that accumulate at the surface. The growth of cyanobacteria is based on surplus phosphorus in the surface layer and on nitrogen fixation from the atmosphere. This bloom is decomposed in the surface layer.

Owing to the shallow and variable bottom topography and also profound salinity gradients, the Baltic Sea is, regarding hydrodynamics, a complex system. Different hydrodynamic events (wind-induced mixing, currents, eddies, fronts, upwelling) show considerable spatial and temporal variation in the Baltic Sea. Generally, they are characterized by small spatial and temporal scales. The most important hydrodynamic processes that induce external, auxiliary energy to the system are those occurring over a time scale of hours or at most a few days. The spatial and temporal scales characteristic to the Baltic Sea hydrodynamics are presented in Table 1.

Table 1. Characteristic physical scales in the Baltic Sea.

SPATIAL SCALES	CHARACTERISTIC RANGE
Microscales	
- The Kolmogorov scale	0.1 cm
- The Ozmidov scale	0.1–3.0 m
Scale of light penetration	1–10 m
Mixed layer depth	
- Summer (thermocline)	10–20 m
- Winter (halocline)	60–70 m
Topographical scales	
- Sill depths	20–60 m
MESOSCALES	
- The internal Rossby radius	5–10 km
- The external Rossby radius	150–300 km
TEMPORAL SCALES	
Internal/inertial wave band	10 min–14 h
Inertial oscillations	ca. 14 h
Time scale of weather patterns (wind forcing)	3–5 d

The phytoplankton species diversity in the Baltic Sea is low in comparison to fresh or true marine waters. The current species checklist reports altogether over 2000 phytoplankton taxa in the Baltic Sea (Hällfors, 2004), of which more than 40 are known to be potentially toxic (see Annex 6 of the Report of the ICES-IOC-SCOR Working group on GEOHAB implementation in the Baltic Sea, WGGIB, 6–7 April 2006 [http://www.ices.dk/reports/BCC/2006/WGGIB06.pdf]).

1.2 HABs in the Baltic Sea

The most common and conspicuous HABs in the Baltic Sea are formed by cyanobacteria. Occasional blooms of potentially toxic dinophytes, diatoms, haptophytes and chrysophytes are also observed. The dynamics of these blooms are quite different. The two main cyanobacteria HAB species, *Nodularia spumigena* and *Aphanizomenon flos-aquae*, occur at the same time of the year, the highest cell numbers being found at the end of July first half of August. The cyanobacteria (*Nodularia spumigena* and *Aphanizomenon flos-aquae*) are either found distributed throughout the upper water layer or if the temperature is above 18 ºC and if no strong turbulence occurs, accumulates in approximately a half meter thick layer at the surface. When the cyanobacterial cells accumulate in surface waters a part of the bloom is senescent. The filaments form large aggregates where bacteria and other heterotrophic organisms thrive facilitating efficient nutrient regeneration.

The blooms of dinophytes and haptophytes in the Baltic are sporadic and unpredictable, which increases their harmfulness. Some of the dinophytes, e.g. *Dinophysis norvegica* and the haptophyte *Chrysochromulina* sp. can be found in high concentrations in few meter thick layers close to pycnoclines. Accumulation of organisms in the pycnoclines is driven by biological and physicochemical interactions. Several other toxic planktonic species are regular components of the plankton flora of the Baltic Sea and may form highly unpredictable harmful blooms (see Annex 6 of the Report of the ICES-IOC-SCOR Working group on GEOHAB implementation in the Baltic Sea, WGGIB, 6–7 April 2006 [http://www.ices.dk/reports/BCC/2006/ WGGIB06.pdf]).

1.3 BALTIC GEOHAB

The Baltic Sea offers good opportunities for research of HAB dynamics to be carried out on several spatial and temporal scales simultaneously. Systems already exist to obtain high-resolution oceanographic and remote sensing data from the surface layer over the whole sea. Because of the relatively small spatio-temporal scales of the hydrodynamics, studies of physical-biological couplings and ecological interactions and their influence on HABs are possible with reasonable allocation of ship-time. Processes on small scales are best carried out in mesocosms and laboratory conditions, for which there are several suitable field stations available around the entire Baltic. The BALTIC GEOHAB research plan will focus on integrated experiments carried out with several research approaches, i.e., laboratory and mesocosm experiments combined with parallel field experimentation and real-time, high-resolution observation systems. The relative simplicity of the system, the existing observational capabilities, experience in multiscale research strategies and decades long experience in multinational co-operation within ICES, HELCOM and EU-funded research projects create a solid basis for the Baltic Sea to function as a GEOHAB Core Research area or Targeted Research area (cf. GEOHAB Implementation Plan).

1.4 Current status of knowledge on HABs in the Baltic Sea

Cyanobacteria

The most common HAB species in the Baltic are the filamentous cyanobacteria (*Nodularia spumigena*, *Aphanizomenon flos-aquae*), of which *N. spumigena* is toxic in the Baltic. Extensive research and reviews regarding these species have been made on topics ranging from general environmental factors and food web interactions promoting occurrence to investigations of cellular ultra-structure (e.g. Kivi *et al*., 1993; Janson *et al*., 1994; Wasmund 1997; Kangro *et al*., 2007; Karjalainen *et al*., 2007; Tamminen and Andersen, 2007). Recent advances in cyanobacteria bloom formation research include e.g. detailed investigations of community nutrient dynamics and the nutrient limitation characteristics along Baltic Sea gradients of salinity and eutrophication. These studies elucidate reasons behind dominance patterns in the phytoplankton community (Tamminen and Andersen, 2007; Vahtera *et al*., 2007b).

Recognition of a suite of variables governing bloom formation and sustenance has emerged during decades of research, spanning from large-scale physical processes to physiological limitation of growth and nitrogen fixation. Large-scale physical phenomena determining mainly phosphorus availability for the extensive pelagic blooms have a reasonable predictive ability, and knowledge on physiological characteristics of bloom forming species and susceptibility to meso- and small scale physical phenomena can be used to explain dominance patterns between the toxic *N. spumigena* and non-toxic *A. flos-aquae*.

It has been suggested that the eutrophied status of the Baltic Sea persists because of intense internal loading of phosphorus caused by anoxic sediments, which further favors extensive diazotrophic cyanobacteria blooms (Tamminen and Andersen 2007; Vahtera *et al*., 2007a). It has been noted that more pristine areas (e.g. Gulf of Bothnia) show predominantly systemic P limitation or deficiency whereas more eutrophied areas (e.g. Gulf of Finland and Baltic Proper) show systemic N limitation (Tamminen and Andersen, 2007). In the N limited areas extensive cyanobacteria blooms might induce temporal systemic P limitation during a period of a few weeks during bloom peaks (Nausch *et al*., 2004; Tamminen and Andersen, 2007). This shows the temporally dynamic nutrient deficiency/limitation pattern of phytoplankton communities.

Empirical studies have shown that *A. flos-aquae* is promoted in areas where frontal upwelling occurs, inducing pulsed nutrient input. *N. spumigena* has been noted to be favored by inert and strongly stratified areas (Kononen *et al.*, 1996). *N. spumigena* has been observed to have a lower half saturation constant for P than *A. flos-aquae* indicating that *N. spumigena* would rely on regenerative pathways for P acquisition (e.g. Larsson *et al.*, 2001).

Mesocosm studies have shown that post spring bloom growth of algae in coastal communities dominated by *A. flos-aquae* is supported by internal nutrient stores and regenerative pathways (Lignell *et al*., 2003). In accordance, *A. flos-aquae* bloom formation in the pelagic Baltic Proper has been shown to predominantly form on intracellular P stores (Larsson *et al*., 2001). However, also *N. spumigena* has exceptional cellular P storage capacities (Vahtera *et al*., 2007b) and blooms dominated by *N. spumigena*, hypothesized to have been formed on intracellular stores, have been observed (Nausch *et al*., 2004). Also, a relationship between surplus P and *N. spumigena* seasonal peak biomasses during warm summers has been observed in the Gulf of Finland (Laanemets *et al*., 2006). The observed slow growth rates of filamentous cyanobacteria and the predominance of use of intracellular stores and regenerative pathways as nutrient sources and the generally low grazability of cyanobacteria (e.g. Sellner *et al*., 1994; Engström-Öst *et al*., 2002) supports the idea that the filamentous cyanobacteria are “dead end” organisms in the foodweb and that their prevalence is governed by large scale processes on systemic scales (Vahtera *et al*., 2007a).

Dinoflagellates

Despite the regular occurrence of dinoflagellates in the Baltic Sea it is generally believed that they play only a minor role as HAB organisms. So far, their occurrence has not been connected to harmful ecosystem effects or human intoxication. Blooms of *Alexandrium ostenfeldii* have been observed during the recent decade on Baltic coasts (HELCOM PHYTO Group, Kremp and Lindholm unpubl. data). Furthermore, circumstantial evidence exists that mass mortalities of seabirds in the eastern Gulf of Finland in spring 1992, 2000 and 2006 may have been caused by toxic algae, with symptoms resembling saxitoxin poisoning. Earlier measurements have revealed DSP toxins (okadaic acid) in blue mussels and common flounder in the Gulf of Finland (Pimiä *et al*., 1997; Sipiä *et al*., 2000).

Increasing knowledge on the occurrence of potentially toxic dinoflagellates and potential blooms formed by these organisms warrant further study on dinoflagellate HABs in the Baltic Sea. The biodiversity and biogeography of dinoflagellates in the Baltic is of dynamic nature. *Prorocentrum minimum*, a widely distributed marine species, has arrived into the Baltic Sea presumably by cargo ballast waters or drifting along currents through the Danish straits (Pertola, 2006). P. minimum was first found in 1978 in Danish waters, and already in 1993 it was observed in the Gulf of Finland (Hajdu *et al*., 2000; Pertola, 2006). Blooms of *P. minimum* have not yet been reported in the Baltic Sea. *P. minimum* has been connected to PSP occurrences elsewhere, but it is not known whether the Baltic strains are toxic.

Heterocapsa triquetra, a non-toxic dinoflagellate, is known to form dense sub-surface maxima and also alter nutriclines depths through their nutrient uptake (Kononen *et al*., 2003). Blooms of *H. triquetra* have been observed in coastal inlets as well (Lindholm and Nummelin, 1999). The blooms may affect the pelagic nutrient dynamics and cause temporal hypoxic or anoxic conditions in smaller inlets due to their large biomass production.

Dinophysis acuminata, *D.norvegica* and *D. rotundata* are common in summer and autumn plankton communities, which are known to form subsurface or deep maxima in the central and northern Baltic Proper (e.g. Hajdu *et al*., 2007). While the occurrences of *Dinophysis* in coastal areas of the oceans are connected to diarrhetic shellfish poisoning (DSP) syndrome in humans, they have only recently been measured in the Baltic Sea plankton (Kuuppo *et al*., 2006, Kuuppo and Uronen unpublished). Abundance of *Dinophysis* and DSP toxins is correlated with salinity, but the role of nutrients and physical factors in their occurrence, dynamics and cellular toxicity is unclear.

Observations of *Alexandrium ostenfeldii* have increased significantly in the Baltic since 1990's. Dense blooms of have been observed in Swedish coastal waters, in the Bay of Gdansk in the southern Baltic and in the Åland archipelago. It produces PSP toxins and neurotoxic spirolides (e.g. Cembella *et al.*, 2001). The strain isolated from the Åland islands in the Baltic Sea has been found to produce saxitoxins (Kremp *et al.*, unpubl. data). The reasons for the sudden expansion or growth dynamics of *A. ostenfeldii* in the Baltic Sea are not known.

Estuaries and coastal marine waters are areas of greatest diversity and abundance of dinoflagellates and occurrence is most often related to high nutrient supplies from land or through e.g. upwelling (Graham and Wilcox 2000). Many species of dinoflagellates are capable of rapid growth. For example, the maximum growth rates of *Prorocentrum minimum* have been observed at 3.54 day^{-1} (Smayda, 1997). As a survival mechanism, many species also form cysts in response to e.g. adverse environmental conditions; therefore elucidation of life cycles of harmful dinoflagellates occurring in the Baltic Sea is of importance. In addition, many HAB dinoflagellates are mixotrophs, being able to utilize organic molecules, bacteria and small algae (Stoecker, 1999), hence facilitating their competition among the phytoplankton community.

Prymnesiophytes

Prymensiophytes are common members of Baltic phytoplankton community, especially during summer (Edler 1979). Within the genus *Chrysochromulina*, two species - *C. leadbeateri* and *C. polylepis* are known to be toxic. Both of these appear on the Baltic Sea phytoplankton, and they have also been observed in the northern Baltic Sea (PELAG, 1990). An extensive bloom of *C. polylepis* was observed in Skagerrak and Kattegat in 1987, causing mass mortality of fish and other marine organisms (e.g. Maestrini and Granéli, 1991).

Prymnesium parvum blooms in coastal or brackish waters (Edvardsen and Paasche, 1998). Reports of *P. parvum* blooms in the Baltic Sea include the cases in Stockholm Archipelago, on Finnish coast, at the island of Rügen and Danish coastal waters. Both *P. parvum* and *C. polylepis* are widely distributed globally, euryhaline and eurythermal and adapted to variable conditions, although *P. parvum* has wider tolerance limits (Edvardsen and Paasche, 1998). Both species exhibit intermediate maximal growth rates (1.5 day^{-1}). Species of *Chrysochromulina* and *Prymnesium* have shown requirements for vitamins B_1 and B_{12} and selenium, in addition they are capable of uptake of dissolved organic matter and display mixotrophy (Jones *et al*., 1994). Furthermore, both species exhibit strong allelopathic effects enabling them to compete for resources in the phytoplankton community (Legrand *et al*., 2003; Schmidt and Hansen, 2003).

Climate change

HABs have been advocated to increase due to anthropogenic influences (e.g. Hallegraef, 1993) and climate variability (e.g. Sellner *et al*., 2003). Understanding the effects of increased mean temperature and runoff that increases availability of inorganic nutrients and organic particulate and dissolved material is thus of importance when considering management and forecasting of HABs. E.g. dissolved organic matter addition has been noted to increase *N. spumigena* abundance in laboratory mesocosms (Stolte *et al*., 2006). Mixotrophic, DOM-utilizing dinoflagellates can also benefit from increased organic matter loading from rivers. Increases in mean surface water temperatures will enhance stratification during summer and shorten the ice-covered period in the Baltic, possibly shifting the spring bloom peak. Increased stratification can favour motile and buoyancy controlling species, such as dinoflagellates and cyanobacteria.

Increased runoff from land with increased precipitation, together with an earlier depletion of water column nitrogen reserves, leads to complex feedback mechanisms regulating nutrient supply and removal from the Baltic Sea. Warmer waters also increase the window of occurrence for many warm water HAB species. Climate warming might have caused increases in occurrence and magnitude of HABs through shifts of community composition towards flagellate dominated systems due to milder winters and higher sea surface temperatures (Wasmund *et al*., 1998). Also, purely physical changes in stratification and inflow dynamics of saline water from the North Sea, with possibly increasing storm activity, affect the Baltic Sea on a systemic scale.

To conclude, climate change will probably alter meteorological phenomena, increase sea surface temperatures and increase precipitation. These factors will affect stratification, nutrient supply, saline water inflow dynamics and biogeochemical cycles of key nutrients. The effects are a complex array of factors working on several temporal and spatial scales warranting further study.

1.5 Past and present key projects and research programs

Past and present key projects and research programs need to be identified in order not to repeat unnecessary work. Below is an open list of the main projects and programs relating to Baltic Sea GEOHAB activity through their research foci:

- BANSAI (The Baltic and North Sea Marine Environmental Modeling Assessment Initiative, Nordic Council of Ministers' Sea and Air Group, 2005).
- MARCOAST (Marine & Coastal Environment Information Services, ESA, 2005–2008).
- MARE (Marine Research on Eutrophication, MISTRA, 1999–2006).
- BIREME (The Baltic Sea Research Programme, Academy of Finland, Ministry of Environment, Ministry of Agriculture and Forestry, Ministry of Transport and Communications, Maj and Nessling Foundation and The Russian Foundation for Basic Research, 2003–2006).
- DANLIM (Detection and Analysis of Nutrient Limitation: Impacts of Loading on Coastal Plankton Communities across a Hierarchy of Temporal and Physiological-Systemic Scales, EU FP5, 2002–2004).
- HABES (Harmful Algal Blooms Expert System, EU FP5, 2001–2004).
- HABILE (Harmful Algae Bloom Initiation in Large European Marine Ecosystems, EU FP5, 2002–2004).
- FATE ('Transfer and Fate of Harmful Algal Bloom (HAB) Toxins in European Marine Waters, EU FP5, 2001–2003)
- SEED (Life Cycle Transformations among HAB Species, and the Environmental and Physiological Factors that Regulate them, EU FP6, 2005–2008).
- DOMTOX (Importance of dissolved organic matter from terrestrial sources for the production, community structure and toxicity of phytoplankton of the European Atlantic and Baltic coastal waters; role of micropredators for transmission of toxins to commercial shellfish and fish larvae, EU MAST III, 1998–2001).
- NUTOX (Effect of Nutrient Ratios of Harmful Phytoplankton and their Toxin Production, EU MAST III, 1998–2001).
- FERRYBOX (EU FP5).
- BASYS (Baltic Sea System Study, EU, 1996–1999)

1.6 Potential key cooperative partners

An open list of potential cooperative partners (in alphabetical order) is given below to identify the institutions in the Baltic Sea region that are currently working on HAB related issues and to facilitate a broad a spectrum as possible of potential actors within the BALTIC GEOHAB.

- Estonian Marine Institute, University of Tartu, Estonia
- Finnish Environment Institute, Finland
- Finnish Institute of Marine Research, Finland
- Göteborg Marine Research Center, Sweden
- Institut für Ostseeforshung Warnemünde, Germany
- Kalmar University, Sweden
- Marine Systems Institute, Tallinn University of Technology, Estonia
- National Environmental Research Institute, Denmark
- Stockholm Marine Research Center, Sweden
- Swedish Meteorological and Hydrological Institute, Sweden
- Umeå Marine Research Center, Sweden
- University of Copenhagen, Denmark
- University of Gdansk, Institute of Oceanography, Poland
- University of Helsinki, Finland
- University of Latvia, Latvia
- Åbo Akademi University, Finland

1.7 Future prospects

Cyanobacteria bloom dynamics

Quantification of the in situ response of HAB species to environmental factors and determining factors that regulate proliferation of *A. flos-aquae* and *N. spumigena* need to be refined. Further work on differences in nutrient uptake characteristics and growth efficiencies at varying cellular C:P ratios in varying environmental conditions (light and temperature) of *A. flos-aquae* and *N. spumigena* need also to be performed. Frames of variation for different P sources (internal P storage, uptake of new and regenerated P during bloom formation and blooms and the role of P scavenging (in P uptake) for the two species under variable environmental conditions need to be constructed in order to obtain more accurate parameterizations for these species in ecosystem models. Implementation of monitoring strategies applying novel bio-optical methods, such as phycocyanin fluorescence for reliable detection of cyanobacteria is crucial.

Dinoflagellate bloom dynamics

The frequency and magnitude of potentially toxic dinoflagellate, diatom and prymnesiophyte blooms occurring in the Baltic Sea need to be clarified and their relevance in the system dynamics needs to be elucidated. As dinoflagellate blooms are more sporadic the dynamics of dinoflagellate blooms differ from the dynamics of cyanobacteria blooms basic information on the occurrence and the bloom incidents is insufficient or lacking. Cellular level (N and P affinities growth rates, salinity tolerances, alternative nutrition), community level (competition, allelopathy, grazing), ecosystem level (hydrodynamic processes, cascading food web interactions factors influencing bloom formation along with toxicity of Baltic Sea dinoflagellate strains need to be studied

Biotic interactions

To identify and quantify the community interactions influencing HAB dynamics the role of top-down control, through e.g. selective grazing, on HAB formation needs more study along with elucidation of the consequences of allelopathic effects of HAB toxins or other compounds in bloom formation.

2 Primary goals

The goal of the BALTIC GEOHAB is to improve observation and prediction of HABs by determining the ecological and oceanographic mechanisms underlying the population dynamics of harmful algae. This is achieved by integrating biological, chemical and physical studies supported by enhanced observation and modelling systems. The objective of the BALTIC GEOHAB is to identify mechanisms underlying HAB species population and community dynamics in the Baltic Sea and compare them to those identified in other regional studies under GEOHAB. Further, the goal of the BALTIC GEOHAB is to produce easily accessible and applicable support for decision making on abatement measures of HABs in the Baltic Sea.

3 Activities, tasks and objectives

3.1 High resolution observations systems of HABs

Objective

The objective is to observe HABs in the Baltic at the relevant temporal and spatial scales. This is achieved by establishing observation systems of HABs implementing the state of the art technologies for real-time *in situ* observations on ships of opportunity (SOOPs), buoys and fixed platforms in combination with remote sensing systems. The resulting high-resolution data will also be used to develop and verify models for forecasting of blooms.

Justification

To understand the dynamics of HABs in the Baltic it is essential to observe them at the relevant temporal and spatial scales. Sampling from research vessels gives high quality data but it is not possible to study basin scale events due to cost restraints. Thus, automatic techniques are needed. Development of HABs is the result of interactions between physiological and ecological characteristics of the species as well as the physical and chemical processes in its environment. Therefore, to quantify the response of HAB species to environmental factors in natural ecosystems and identify and quantify the effects of physical processes on accumulation and transport of harmful algae an integration of a variety of observation approaches is warranted.

Most planktonic algae have ways of influencing their vertical position in the sea, e.g., by swimming or control of buoyancy. Populations often develop at depth. Algal blooms often last days to weeks while monitoring from research vessels in the open Baltic is made monthly at best. Only at very few stations the sampling is carried out more frequently. Thus the development of blooms is seldom reliably recorded.

To solve this problem, several complementary observation systems are required. Ferries are being used for automatic recording of e.g., chlorophyll *a* concentrations and also for sampling at predefined positions. This system gives a good spatial and temporal coverage of blooms but does not reveal vertical variation. Another approach is remote sensing using satellites or airplanes as instrument platforms. Satellite images of surface accumulations of blooms can be very valuable but are often not available because of clouds. Results from air-borne sensors are mostly non-quantitative, although recently more and more reliable algorithms for e.g. chlorophyll a in the Baltic Sea have been developed. Nevertheless, both methods record information from the upper part of the sea only.

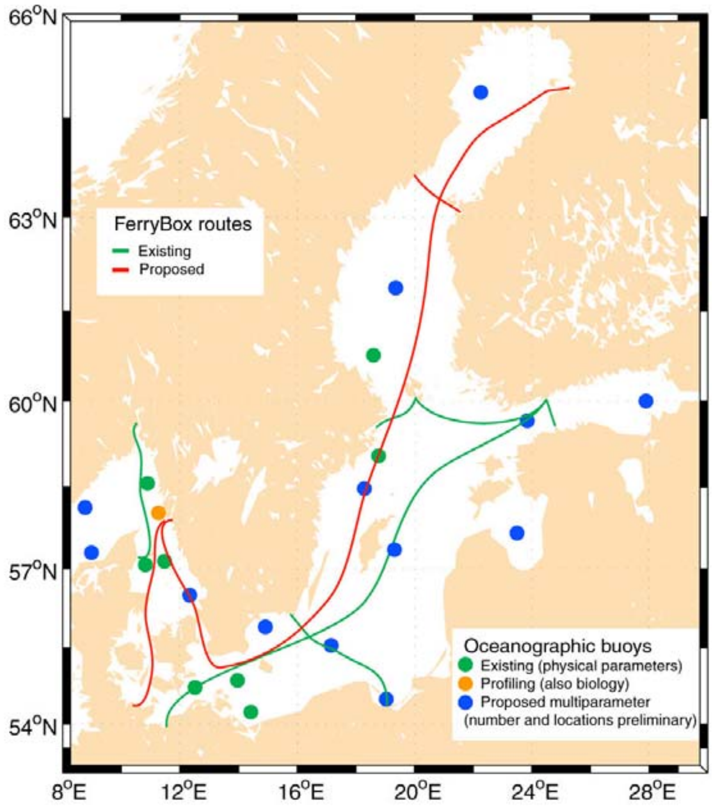

Figure 1. Map of the Baltic and adjacent seas showing ship of opportunity (SOOP) FerryBox routes and approximate positions of proposed buoys for real-time *in situ* data acquisition.

Techniques for real-time monitoring of HABs using automatic detection have developed rapidly during the past few years. Equipment has become smaller and less expensive and instruments measuring parameters relevant for the formation of HABs have been developed. Also automatic-profiling devices have become available, meaning that a single set of sensors can cover the whole photic zone with high vertical resolution. Transmission of data using mobile phones and satellites makes it possible to obtain and publish data from offshore localities on the Internet in near real-time.

Research questions

1. The specificity of optical sensors for detections of Baltic Sea HABs should be tested in situ and verified using cultures of HAB-species.
2. Combinations of different optical techniques to identify HAB-species should be explored. The techniques include hyper spectral absorptions, fluorescence as well as scattering and reflectance measurements. Advanced computational techniques to use the data are required.
3. Above-water radiometry for detection of HABs from SOOPs and fixed platforms should be explored.

4. Reliable algorithms for retrieval of chlorophyll a from remote sensing should be developed and verified using sea truth data. Verification for the separate sub-basins of the Baltic Sea is necessary due to different optical properties.
5. The applicability of molecular biological techniques for HAB-species identification in automated systems should be explored. Promising techniques include RNA -probes.
6. Automated particle analyzers such as flow cytometers, e.g. the FlowCam, the CytoBuoy, should be verified for identification and abundance estimates of Baltic Sea HAB-species.
7. Unattended undulating towed instruments should be tested and validated.

Specific activities

A. Further development of SOOP systems
   a. The present ferry route network should be extended especially with routes crossing the Baltic including the Bothnian bay (north-south), Gulf of Riga and eastern Gulf of Finland.
   b. New types of sensors should be added to existing ones, e.g. phycoerythrin / phycocyanin fluorescence, nutrient analyzers.

B. Real-time monitoring using buoys as instrument platforms
   a. To deploy a number of buoys in positions relevant for HAB-dynamic studies in the Baltic. The basic requirements regarding sensors are
      i. Chlorophyll a fluorescence (profiling)
      ii. Phycoerythrin/phycocyanin fluorescence (profiling)
      iii. Turbidity (profiling)
      iv. Temperature (profiling)
      v. Salinity (profiling)
      vi. Nutrients (profiling NH_4, NO_3, PO_4, Si)
      vii. Current speed and direction (profiling ADCP)
      viii. In air – light (PAR)
      ix. Wind speed and direction
      x. Wave height and direction

C. Fixed platforms
   a. Radiometry towers located in the open sea
      i. Multispectral water leaving irradiance
      ii. Downwelling irradiance
   b. Land based systems
      i. Chlorophyll *a* fluorescence
      ii. Phycocyanin/phycoerythrin fluorescence
      iii. Temperature
      iv. Salinity

3.2 Understanding the short-term and seasonal dynamics of HAB species

Objective

The goal is to understand the dynamics of HAB initiation, development, maintenance and termination. The high quality real-time monitoring data obtained from Section 3.1 makes it possible to use ship and other resources efficiently by the implementation of adaptive sampling strategies. To Identify and quantify the community interactions influencing HAB dynamics biological interactions should also be considered as they might facilitate shifts in species dominance patterns and the formation of HABs.

Justification

Physical factors influencing formation of HABs in the Baltic basically operate on the time scales of seasons and the passage of low and high-pressure meteorological systems, i.e., days to weeks. In general, cyanobacteria blooms occur in late summer in the Baltic Sea, but blooms have also been observed late in the autumn or in spring. There is a large inter-annual variation in the intensity of the blooms and blooms of dinoflagellates and prymnesiophytes are highly irregular. It is unknown to which extent this variability might be influenced by the intensity of the blooms of the previous year, winter conditions, pre-bloom conditions or biological interactions such as allelopathy, selective grazing or mixotrophy. For cyanobacteria it is not known in detail how and where the blooms start, what determines their termination, and where and how the cells over-winter. The role of biological factors in termination of blooms, such as (1) physiological nutrient deficiency, (2) the effect of competition with other phytoplankton and bacteria, and (3) viral lysis need to be further studied.

Monitoring programs, aimed at detecting long-term changes, investigate the phytoplankton at a low temporal resolution and depth distribution is not necessarily investigated. Description of the plankton community has been restricted to the larger phytoplankton in most monitoring programs. Using high temporal and depth resolution with the addition of molecular biology techniques coupled with flow cytometry and fluorescence microscopy makes it possible to describe and understand the dynamics of the plankton community in much more detail. Analyses of HAB-toxins can be performed onboard research vessels. The information obtained on short-term bloom dynamics would be very useful for the implementation of cost-efficient sampling strategies.

Specific activities:

- Close to some of the buoys (c.f. Section 3.1) sampling of phytoplankton and other relevant parameters, including toxicity, should be performed with high frequency (lower during winter), using modern techniques and high depth resolution. It is probably necessary to use resources from different nations to perform the sampling and analyses concomitantly.
- Effective use of SOOP sampling should be implemented.
- For some of the parameters an adaptive sampling strategy should be used. This means e.g., that toxins should be analyzed with higher frequency of samples during blooms.
- Towed undulating vehicles with multisensor- and sampling-systems should be effectively used on research vessels.
- Onboard experiments should be encouraged in addition to the sampling.
- Acquired data should be used to calibrate sensors on buoys.
- Acquired high quality data should be used for the development and verification of models for bloom forecasting.

3.3 Hydrodynamic control of HAB development

Objective

To understand the mechanisms by which hydrodynamic processes regulate nutrient limitation, species selection and HAB development.

Justification

The question which nutrient is limiting algal growth and how ratios of nutrients affect species selection is critical in evaluating the linkage between HABs and eutrophication. It is also one of the key issues of GEOHAB. Physical processes play a major role in nutrient entrainment and transport as well as plankton species selection, dispersal and accumulation.

Plankton ecosystems are not horizontally bounded, and therefore laboratory or mesocosms experiments with no horizontal dispersal of the patch have only a limited capability to simulate the effects nutrient pulsing caused by meso- and small-scale physical processes. Synoptic studies in situ, carried out simultaneously in different scales are required for revealing the mechanisms of physical-biological couplings. This cannot be done with one research vessel only, but coordinated multi-ship field campaigns are required.

A novel approach to solve the problem of nutrient regulation was applied in the equatorial Pacific and Southern ocean iron fertilization experiments, where bloom patch dynamics was followed in situ after addition of a limiting nutrient. In 1986, ICES organized the Baltic Sea Patchiness Experiment, which studied the patch dynamics without addition of nutrients. In 2002, Cycling of Phosphorus in the Mediterranean, the first phosphorus fertilization experiment in the world was conducted. A coordinated multiship experiment, where nutrients are added directly to the system and the development of the bloom patch is followed, species selection, development of toxicity and various other aspects of HABs are studied (complemented with SOOP-systems, moored oceanographic instrumentation and remote sensing) could allow a true integration of biology and physics. The large-scale studies performed in other marine ecosystems have vastly improved the holistic understanding of plankton dynamics in the open ocean, which should also be the next step in the Baltic Sea.

Research questions:

- How do hydrodynamic processes modify nutrient limitation of HAB species?
- How do physical processes affect patch formation and species selection?
- What is the species' physiological response to nutrient pulsing?
- How rapidly does a bloom patch develop and disperse?
- How does the species selection operate and which species become dominating?
- Is the patch development *in situ* comparable to the development observed in a mesocosm?

Specific activities:

- Planning and organization of coordinated multiship *in situ* nutrient addition experiments during 2008.
- Integration of information obtained from 3.1, 3.2 and 3.4 for the interpretation of bloom development *in situ*.
- Using the information obtained from in situ nutrient addition experiments for the development and verification of species-of-interest models to be developed under Section 3.6.
- Studying the effect of small scale turbulence on HAB species.

3.4 Studying biology of HAB species

Objectives

To obtain information about key biological characteristics of the HAB species, which are necessary for the interpretation of the findings obtained during oceanographic expeditions in the Baltic Sea, using parallel land-based experiments (micro and mesocosms) with natural phytoplankton communities and unialgal (and axenic when possible) cultures of relevant HAB-species.

Justification

Field surveys are powerful tools that can be used to understand the physical processes involved in HABs initiation and accumulation at different depths of the water column, fronts, eddies, etc. However, there are not, at the moment, methods and techniques that enable us to understand how HAB species interact with their chemical and biological environments in the field. These interactions depend on intrinsic characteristics of HAB species such as their life cycle, morphology, toxicity, mixotrophic behavior, production of info-chemicals, growth rates, etc. Some of these characteristics will enable HABs to outcompete other species and/or eliminate their grazers. On the other hand, HAB intrinsic characteristics might change if the cells are growing under nutrient sufficient or deficient conditions, low or high light and/or temperature conditions. The combination of both factors (chemical and physical factors affecting HAB-cell-intrinsic characteristics) will be of importance for the success of the HAB species, and this is best studied by examining the influence of these factors on the growth of HAB species and their losses (grazing, sensitivity to infection by virus, bacteria, parasites) and apoptotic behaviour.

Thus, in order to understand why HAB populations are found at specific layers/fronts etc. complementary laboratory and mesocosms studies will be carried out using natural plankton communities and unialgal cultures of the regional HAB species.

Research questions:

- What are the most important factors contributing to the accumulation of the cyanobacteria in surface layers during warm periods in late summer? What is the role of nutrient deficiency (and in particular P-starvation) in this buoyancy process?
- How are life cycle strategies involved in the initiation of blooms and survival of species during adverse conditions?
- How do nutrients, algal morphology, and other biological or behavioural factors interact to diminish losses from grazing?
- What factors control nitrogen fixation in Baltic waters, and what determines the species succession among species with this N-acquisition strategy?
- How plastic is the C:N:P ratio of HAB cyanobacteria and how does the C:N:P ratio vary with environmental factors and how does this plasticity affect growth?

Specific activities

The following experiments need to be performed: How nutrient quality (e.g. dissolved organic forms) concentrations and ratios (N, P and Fe) light environment and temperature affect:

a) Production of toxins
b) Production of info-chemicals
c) Sensitivity to parasites
d) Apoptosis
e) Accumulation or flotation
f) Growth rates
g) Life cycle
h) Mixotrophic behavior
i) Species succession
j) Nutrient uptake

3.5 Modelling

Objective

To develop species-of-interest and ecosystem models that allows reliable prediction of HAB development in their natural physico-chemical environment.

Justification

Models are important and often necessary tools to increase the understanding of processes, to improve interpretation of measurements and design of experiments, and to develop capabilities to make predictions.

Ecological modelling has a long tradition in the Baltic area and a set of models ranging from box, 1-d water column to fully coupled 3-d circulation and biological models are in operation. Using the state-of-the-art modelling is an integral part of the planning of a co-operative HAB study in the Baltic Sea.

The combination of high resolution, coastal, physical modelling with biological and biogeochemical models has made progress during the last years. However, many improvements are required. For example, for some species the importance of physical-biological processes at scales ranging from millimetres to meters; behaviour, thin layers, predator-prey interaction, and turbulence have been demonstrated. At least some of these factors need to be taken into account in species-of-interest models. Details of interactions of individual organisms with the environment may also use modelling based on the organisms' physiology, behaviour, life cycles etc.

Biogeochemically biased ecosystem models often overlook sporadic HAB events, especially in spatially restricted problem areas. Thus, integrated use of specific species-of-interest models with more general ecosystem models should be encouraged.

Specific activities:

As with any modelling, the ecosystem modelling involves simplifications and approximations. For models designed to be useful in practical applications the introduction of errors have to be accurately analyzed and ranked for each source of error. The modelling community needs to develop methodologies for estimating errors associated with forcing and initialization data as well as due to approximations in physical/biological models.

Validation, both in the laboratory and in the field, is an essential part of establishing model skill assessment. Comparative studies are also an important component of validation. A cooperative HAB study in the Baltic can serve as an excellent experimental basis for the validation of model components.

Many components of modelling physical/biological interaction still remain to be developed. Examples of required components or needs for improvements are:

- Methodologies for dealing with multiscale problems, such as interactions in thin layers.
- Systematic methods for aggregating species into functional groups. Functional groups are here defined to include those species that share a common biological primitive equation but have different values for the parameters in the equations.
- Modelling of turbulence at scales appropriate to the physical/biological interaction of interest.
- Determination of rates required for biological primitive equations.

A cooperative HAB study in the Baltic is recommended to include projects where several of the model requirements for physical/biological interaction can be approached.

3.6 Update of the phytoplankton HAB species checklist

Objective

To improve the knowledge of the taxonomy, toxicity and distribution of the HAB species in the Baltic Sea area.

Justification

The phytoplankton species diversity in the Baltic Sea area is low in comparison to fresh or marine waters. From the current species checklist (Hällfors, 2004) more than 40 are known to be potentially toxic or can cause other harmful effects. In addition to several cyanobacteria species, many species of Chromophytes (representatives of following classes: Dinophyceae, Bacillariophyceae, Prymnesiophyceae, Dictiophyceae), are known to form harmful blooms in the Baltic Sea area.

Specific activities

The checklist for Baltic Sea phytoplankton has been completed (Hällfors 2004). It should be available and further developed in a specific database with Internet access. ICES should complete the leaflets of HAB species in the Baltic Sea area and they should be included in the above-mentioned database. The diversity of different strains of HAB species occurring in the Baltic should be examined and the biogeographical and temporal distribution of species and strains further studied. E.g., elucidation of genetic similarity of Aphanizomenon sp. winter and summer populations should be studied.

4 The geohab approach to a cooperative baltic sea study

The mechanisms of HAB development are unique for each HAB species, and depend both on the ecophysiological properties of the organism, and on characteristics of the system where they occur such as geographical location, climatological and meteorological factors, bathymetry, hydrodynamic peculiarities, freshwater influence, specifics of the drainage area etc. The mitigation of each specific HAB requires science-based, site-specific management strategies, which can benefit from comparison of experience gained in other regions and with other species.

The BALTIC GEOHAB will implement the GEOHAB mission by fostering international co-operative research on HABs within the Baltic Sea. Key species will be studied, and the oceanographic and biotic processes that influence their population dynamics will be explored with an experimental, observational, and modelling approach, using current and innovative technologies.

As a result, observation and prediction of HABs will be enhanced, and management and mitigation measures can be based on sound scientific knowledge on the ecological and oceanographic mechanisms underlying the HABs.

THE GEOHAB Programme Elements are:

1. Biodiversity and biogeography
2. Nutrients and eutrophication
3. Adaptive strategies
4. Comparative ecosystems
5. Observation, modelling and prediction

The BALTIC GEOHAB will explore all these elements through international cooperative research. The **biodiversity and biogeography**, including community species composition and horizontal and vertical distribution, of HAB species will be revealed by regular studies conducted on research vessels and through enhanced SOOP networks. **Seasonal and interannual variations** of HABs and HAB species will be revealed by an extensive network of SOOPs. The **abiotic and biotic mechanisms underlying temporal and spatial variations of HABs, and responses of HABs to environmental change**, are studied by several workpackages through empirical and experimental laboratory and fieldwork. The **genetic variability of HAB species** and their strains will be studied by modern molecular ecological methods.

A major part of the programme is devoted to studying the effects of **eutrophication**, i.e. determining to what extent the increased nutrient loading and associated environmental changes influence HABs and their harmful effects. One of the main HAB groups in the Baltic, Cyanobacteria, are diatzotrophic, i.e. capable of fixing dissolved atmorpheric nitrogen gas, and a special emphasis will be put on investigating the influence of **variations in the C:N:P-ratio** for these species. Investigations of **nutrient cycling processes** and **physiological responses** to environmental variability form a key element in these studies. Also, the influence of the above processes on the **harmful properties**, especially toxin production, will be explored by experimental research.

Adaptive strategies of HAB species that determine when and where they occur and produce harmful effects will be investigated by both empirical and experimental research made on various scales, from **cellular level** experiments **to meso-scale** field studies. Despite decades of research, especially the factors affecting in situ **growth potential** of the key species have not been reliably quantified. Also, **biotic factors affecting bloom initiation** are largely unknown. Since sound estimates of the growth potential of the HAB species are necessary for model parameterisation, this will be one of the main goals of this research. Also**, interactions with other species**, competing species as well as grazers, will be investigated in order to reveal the factors influencing the **initiation and termination of the blooms**.

One of the objectives of the GEOHAB programme is to identify mechanisms underlying HAB population and community dynamics across ecosystem types through comparative studies. The Comparative Approach will be adopted by analyzing HAB dynamics within different Baltic areas, which differ in salinity level and nutrient conditions. Also, dynamics will be explored in (i) the open sea, (ii) coastal areas subjected to upwelling and (iii) within archipelagoes.

The ultimate goal of the BALTIC GEOHAB is to improve the detection and quantification of HABs in the Baltic Sea, and to develop hydrodynamic and ecosystem models that can reliably predict the occurrence, intensity and drifting of mass occurrences of HABs.

4.1 Objectives with reference to GEOHAB Science Plan and Implementation Plan objectives

The overall objectives of the BALTIC GEOHAB are (1) to identify mechanisms underlying HAB population and community dynamics in the Baltic Sea, (2) to compare them to those identified in other regional studies under GEOHAB and (3) to produce accurate and appropriate models describing and forecasting the development and occurrence of HABs in the Baltic Sea. The relationships of different BALTIC GEOHAB activities to the overall and specific objectives of GEOHAB are summarized in Table 2.

Table 2. The relationships of different BALTIC GEOHAB activities to the overall and specific objectives of GEOHAB.

BALTIC GEOHAB ACTIVITY	BALTIC GEOHAB OBJECTIVE	REFERENCE TO THE GEOHAB-SCIENCE PLAN OBJECTIVES
High resolution monitoring of HABs.	To further develop effective early warning systems of HABs covering the spatial and temporal scales of blooms in the Baltic Sea.	#5.1. Develop capabilities to observe HAB organisms in situ, their properties, and the processes that influence them #5.5. Develop capabilities in real-time observation and prediction of HABs
Understanding the short-term and seasonal dynamics of the HAB species.	To understand the dynamics of HAB initiation, development, maintenance and termination.	#2.4. Determine the role of nutrient cycling processes in HAB development #3.1. Define the characteristics of HAB species that determine their intrinsic potential for growth and persistence
Hydrodynamic control of HAB development	To understand the mechanisms how hydrodynamic processes regulate nutrient limitation, species selection and HAB development	#2.1. Determine the composition and relative importance to HABs of different nutrient inputs associated with human activities and natural processes #2.4. Determine the role of nutrient cycling processes in HAB development #4.2. Identify and quantify the effects of physical processes on accumulation and transport of harmful algae. #5.4. Develop capabilities for describing and predicting HABs with empirical models.
Studying biology of HAB species	To obtain information about key biological characteristics of the HAB species, which are necessary for the interpretation of the findings obtained during oceanographic expeditions in the Baltic Sea, using parallel land-based experiments (micro and mesocosms) with natural phytoplankton communities and unialgal cultures of relevant HAB-species.	#2.2. Determine the physiological responses of HAB and non-HAB species to specific nutrient inputs #2.3. Determine the effects of varying nutrient inputs on the harmful properties of HABs #3.1. Define the characteristics of HAB species that determine their intrinsic potential for growth and persistence #3.2. Define and quantify biological-physical interactions at the scale of individual cells #3.3. Describe and quantify chemical and biological processes affecting species interactions.
Update of the phytoplankton HAB species checklist	To improve the knowledge of the taxonomy, toxicity and distribution of the HAB species in the Baltic Sea area.	#1.1. Assess the genetic variability of HAB species in relation to their toxicity, population dynamics and biogeography #1.2. Determine the changes in the biogeographical range of HAB species caused by natural mechanisms or human activities. #1.3. Determine changes in microalgal species composition and diversity in response to environmental change
Modelling	To develop species-of-interest models that allows reliable prediction of HAB development in their natural physico-chemical environment.	#5.2. Develop models to describe and quantify the biological, chemical and physical processes related to HABs

4.2 Outputs of BALTIC GEOHAB

1. Better understanding of the role of human impact in relation to natural variability of HABs in the Baltic Sea;
2. Improved monitoring and surveillance capability of HABs;
3. Improved understanding of the biology and ecology of HAB species;
4. Better prediction capabilities of HABs in the Baltic Sea;
5. Sound scientific and improved basis for advice concerning environmental management strategies in the Baltic Sea.

5 Data issues

An agreement upon data management should be made before data actually is collected, and existing systems for data sharing should be used. Free data sharing is recommended.

Methods described in the "Manual for Marine Monitoring in the COMBINE Programme of HELCOM" http://www.helcom.fi should be the first choice. If methods described there do not cover relevant parameters documents should be produced describing methods in detail. These documents should be made available to partners within BALTIC GEOHAB to make intercalibration possible.

In addition to methods, also quality assurance and validation of data should also be done according to the COMBINE Programme of HELCOM.

ICES will perform long-term data and metadata banking. Also cruise summary report forms ("ROSCOP forms") should be submitted to ICES.

Most data produced within BALTIC GEOHAB will have the same requirements as EU-projects. Data produced by individual scientists with his/her own funding will be accessed by others through negotiations, payment or co-authorship. Data availability is defined for each data set according to the following categories:

1. Data produced will be "foreground information" as defined in general conditions of EU-contract, i.e., they should be made available to other participants of the project within six months after sampling.
2. Data will remain "foreground information" until 6 months after the formal end of project when they will become public information.
3. Data will be available from the producer through co-authorship of out coming publications.
4. Data will be available through bi- or multilateral negotiations between producers.

Data from real time measurements should be made available to other participants in near real time using the Internet.

6 References

Cembella, A.D., Bauder, A. G., Lewis, N. I., Quilliam, M. A. 2001. Association of the gonyaulacoid dinoflagellate *Alexandrium ostenfeldii* with spirolide toxins in size-fractionated plankton. Journal of Plankton Research, 23: 1413–1419.

Edler, L. 1979. Recomendations on methods for marine biological studies in the Baltic Sea. The Baltic Marine Biologists Publication, 5: 1–38.

Edvardsen, B., Paasche, E. 1998. Bloom dynamics and physiology of Prymnesium and Chrysochromulina. Ed. by D. M. Anderson, A. D. Cembella, G. M. Hallegraef. *In* Physiological ecology of harmful algal blooms. Springer, Berlin Heidelberg New York.

Engström-Öst, J., Koski, M., Schmidt, K., Viitasalo, M., Jónasdóttir, S. H., Kokkonen, M., Repka, S., and Sivonen, K. 2002. Effects of toxic cyanobacteria on a plankton assemblage: community development during decay of *Nodularia spumigena*. Marine ecology progress series, 232: 1–14.

Graham, L. E., Wilcox, L. W. 2000. Algae, Vol. Prentice Hall, Upper Saddle River, NJ.

Hajdu, S., Edler, L., Olenina, I., and Witek, B. 2000. Spreading and establishment of the potentially toxic dinoflagellate *Prorocentrum minimum* in the Baltic Sea. International Review of Hydrobiology, 85: 561–575.

Hajdu, S., Hoglander, H., and Larsson, U. 2007. Phytoplankton vertical distributions and composition in Baltic Sea cyanobacterial blooms. Harmful Algae, 6: 189–205.

Hallegraef, G. M. 1993. A review of harmful algal blooms and their apparent global increase. Phycologia, 32: 79–99.

Hällfors, G. 2004. Checklist of Baltic Sea phytoplankton species (including some heterotrophic protists). Baltic Sea Environment Proceedings, 95: 1–208.

Janson, S., Carpenter, E. J., and Bergman, B. 1994. Fine structure and immonulocalisation of proteins in *Aphanizomenon* sp. from the Baltic Sea. European Journal of Phycology, 29: 203–211.

Jones, H. L. J., Leadbeater, B. S. C., and Green, J. C. 1994. Mixotrophy in haptophytes. Ed. by J. C. Green and B. S. C. Leadbeater. *In* The haptophyte algae. Clarendon press, Oxford: 247–263.

Kangro, K., Olli, K., Tamminen, T., and Lignell, R. 2007. Species-specific responses of a cyanobacteria-dominated phytoplankton community to artificial nutrient limitation: a Baltic Sea coastal mesocosm study. Marine Ecology Progress Series, 336: 15–27.

Karjalainen, M., Engström-Öst, J., Korpinen, S., Peltonen, H., Pääkkönen, J. –P., Rönkkönen, S., Suikkanen, S., and Viitasalo, M. 2007. Ecosystem consequences of Cyanobacteria in the northern Baltic Sea. Ambio, 36: 195–202.

Kivi, K., Kaitala, S., Kuosa, H., Kuparinen, J., Leskinen, E., Lignell, R., Marcussen, B., and Tamminen, T. 1993. Nutrient limitation and grazing control of the Baltic plankton community during annual succession. Limnology and Oceanography, 38: 893–905.

Kononen, K., Huttunen, M., Hällfors, S., Gentien, P., Lunven, M., Huttula, T., Laanemets, J., Lilover, M., Pavelson, J., and Stips, A. 2003. Development of a deep chlorophyll maximum of *Heterocapsa triquetra* Ehrenb. at the entrance to the Gulf of Finland. Limnology and Oceanography, 48: 594–607.

Kononen, K., Kuparinen, J., Mäkelä, K., Laanemets, J., Pavelson, J., and Nõmmann, S. 1996. Initiation of cyanobacterial blooms in a frontal region at the entrance to the Gulf of Finland, Baltic Sea. Limnology and Oceanography, 41: 98–112.

Kuuppo, P., Uronen, P., Petermann, A., Tamminen, T., and Granéli, E. 2006. Pectenotoxin-2 and dinophysistoxin-1 in suspended and sedimenting organic matter in the Baltic Sea. Limnology and Oceanography, 51: 2300–2307.

Laanemets, J., Lilover, M-J., Raudsepp, U., Autio, R., Vahtera, E., Lips, I., and Lips, U. 2006. A fuzzy logic model to describe the cyanobacteria *Nodularia spumigena* blooms in the Gulf of Finland, Baltic Sea. Hydrobiologia, 554: 31–45.

Larsson, U., Hajdu, S., Walve, J., and Elmgren, R. 2001. Baltic Sea nitrogen fixation estimated from the summer increase in upper mixed layer total nitrogen. Limnology and Oceanography, 46: 811–820.

Legrand, C., Rengefors, K., Fistarol, G. O., and Graneli, E. 2003. Allelopathy in phytoplankton - biochemical, ecological and evolutionary aspects. Phycologia, 42: 406–419.

Lignell, R., Seppälä, J., Kuuppo, P., Tamminen, T., Andersen, T., and Gismervik, I. 2003. Beyond bulk properties: Responses of coastal summer plankton communities to nutrient enrichment in the northern Baltic Sea. Limnology and Oceanography, 48: 189–209,

Lindholm T, and Nummelin, C. 1999. Red tide of the dinoflagellate *Heterocapsa triquetra* (Dinophyta) in a ferry-mixed coastal inlet. Hydrobiologia, 393: 245–251.

Maestrini, S.Y., and Granéli, E. 1991. Environmental conditions and ecophyiological mechanisms which led to the 1988 *Chrysochromulina polylepis* bloom: a hypothesis. Oceanol Acta, 14: 397–413.

Nausch, M., Nausch, G., and Wasmund, N. 2004. Phosphorus dynamics during the transition from nitrogen to phosphate limitation in the central Baltic Sea. Marine Ecology Progress Series, 266: 15–25.

Pertola, S. 2006. Diffusive and ship-mediated spread of dinoflagellates in the Baltic Sea with *Prorocentrum minimum* as a special case. Doctoral thesis, University of Helsinki.

Pimiä, V., Kankaanpää, H., and Kononen, K. 1997. The first observation of okadaic acid in *Mytilus edulis* from the Gulf of Finland. Boreal Environment Research, 2: 381–385.

Schmidt, L. E., Hansen, P. J. 2003. Allelopathy in the prymnesiophyte *Chrysochromulina polylepis*: Effect of cell concentration, growth phase and pH. Marine Ecology Progress Series, 216: 67–81.

Sellner, K. G., Doucette, G. J., Kirkpatrick, G. J. 2003. Harmful algal blooms: causes, impacts and detection. Journal of Industrial Microbiology and Biotechnology, 30: 383–406.

Sellner, K. G., Olson, M. M., and Kononen, K. 1994. Copepod grazing in a summer cyanobacteria bloom in the Gulf of Finland. Hydrobiologia, 292/293: 249–254.

Sipiä, V., Kankaanpää, H., and Meriluoto, J. 2000. The first observation of okadaic acid in flounder in the Baltic Sea. Sarsia, 85: 471–475.

Smayda, T. J. 1997. Harmful Algal Blooms: Their Ecophysiology and General Relevance to Phytoplankton Blooms in the Sea. Limnology and Oceanography, 42: 1137–1153.

Stoecker, D. K. 1999. Mixotrophy among dinoflagellates. Journal of Eukaryotic Microbiology, 46: 397–401.

Stolte, W., Balode, M., Carlsson, P., Grzebyk, D., Janson, S., Lips, I., Panosso, R., Ward, C. J., and Granéli, E. 2006. Stimulation of nitrogen-fixing cyanobacteria in a Baltic Sea plankton community by land-derived organic matter or iron addition. Marine Ecology Progress Series, 327: 71–82.

Tamminen, T., and Andersen, T. 2007. Seasonal phytoplankton nutrient limitation patterns as revealed by bioassays over Baltic Sea gradients of salinity and eutrophication. Marine Ecology Progress Series, 340: 121–138.

Vahtera, E., Conley. D. J., Gustafsson, B. G., Kuosa, H., Pitkänen, H., Savchuk, O. P., Tamminen, T., Viitasalo, M., Voss, M., Wasmund, N., and Wulff, F. 2007a. Internal ecosystem feedbacks enhance nitrogen-fixing cyanobacteria blooms and complicate management in the Baltic Sea. Ambio, 36: 186–194.

Vahtera, E., Laamanen, M., Rintala, J-M. 2007b. Use of different phosphorus sources by the bloom-forming cyanobacteria *Aphanizomenon flos-aquae* and *Nodularia spumigena*. Aquatic Microbial Ecology, 46: 225–237.

Wasmund, N. 1997. Occurrence of cyanobacterial blooms in the Baltic Sea in relation to environmental conditions. Int Revue ges Hydrobiol., 82: 169–184.

Wasmund, N., Nausch, G., and Matthäus, W. 1998. Phytoplankton spring blooms in the southern Baltic Sea - spatio-temporal development and long-term trends. Journal of Plankton Research, 20: 1099–1117.