Baltic Committee **ICES CM 2003/H:04**

Report of the

ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic

by Correspondence

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 BACKGROUND

The ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic, Chaired by Markku Viitasalo, Finland, has met by correspondence, and by two informal meetings, on 17–20 March in Aberdeen, Scotland, and on 26 August in Helsinki, Finland.

A list of people who have taken part in the discussions and resolutions reported in this report is listed in the Annex 1.

2 TERMS OF REFERENCE

At the Annual Science Conference, Copenhagen, Denmark the Council resolved that (C. Res. 2002/2H04):

The **ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic** [SGGIB] (Chair: M. Viitasalo, Finland) will meet to:

a) continue the planning of GEOHAB implementation in the Baltic;

b) plan a SG meeting combined with an open workshop for the spring 2003 to discuss and finally develop the Baltic project, including the co-ordination of field experiments to be implemented 2002-06;

c) prepare application to the GEOHAB SSC for endorsement of the Baltic project and the planned workshop.

SGGIB will report for the attention of the Baltic Committee.

3 SUMMARY AND CONCLUSIONS

Term of Reference 1: Continue the planning of GEOHAB implementation in the Baltic;

The SGGIB Chair, M. Viitasalo attended the WGHABD meeting in Aberdeen, 17–20 March 2003, to present the situation to WGHABD. Some of the WGHABD participants had also participated in one or both of the previous SGGIB meetings, so this was an opportunity to discuss SGGIB problematic issues as well.

During this meeting, M. Viitasalo presented the history of the group, and presented some recent research results concerning the effects of cyanobacteria on various aquatic animals in the Baltic. Highlights of the results include: (*i*) a large part of the cyanobacteria blooms do not sediment but decay in the water column, thus fueling the microbial loop; (*ii*) certain copepods reproduce efficiently within the decaying bloom, despite the large amount of toxins in water, (*iii*) cyanobacteria filaments interfere with the predation of crustacean predators; (*iv*) nodularin is transferred from cyanobacteria to fish through zooplankton; (*v*) fish larvae grow slower when feeding on zooplankton exposed to cyanobacteria toxins.

Viitasalo further presented a possibility for implementation of the multiship experiment, which is planned in the SGGIB proposal. In 2003, for the first time in the Baltic Sea, multiship surveys will be made to reveal the distribution of zooplankton and fish in relation to hydrographical patterns and biological parameters. The cruises that will be made during 2004-2005 will focus on determing the distributions and production rates of phytoplankton, zooplankton and fish (mainly herring, sprat and three-spined sticklebacks) during cyanobacteria blooms in the northern Baltic.

Further, Maija Balode, Latvia, presented research with *Mycrocystis aeruginosa* and *Nodularia spumigena* in the Baltic where egg production and survival of copepods decreased with increased toxicity in the food source. In herring, the early stages of development appeared to be impacted.

The WGHABD noted the many links between the two groups and encouraged continuing the SGGIB work. The support was especially given to developing the ecosystem approach and to extending the scope of the planned proposal from investigations of cyanobacteria bloom dynamics to their food web consequences. The following recommendations were given by the WGHABD:

(*i*) Development of Harmful Algal Studies in the Baltic Sea would provide a unique opportunity in studying HABs at the scale of one ecosystem;

(*ii*) Implementation of scientific activities related to Baltic HABs in coherence with the GEOHAB Science Plan is essential;

(*iii*) WGHABD recommends that, despite its present difficulties, SGGIB be continued under the new chairmanship of M. Viitasalo.

Term of Reference 2: Plan a Study Group meeting combined with an open Workshop for spring 2003 to discuss and finally develop the Baltic project, including the co-ordination of field experiments to be implemented 2002–2006;

After the appointment as the SGGIB Chair, Viitasalo contacted the three remaining members of the SGGIB that were appointed by ICES. Two of them were unable to participate in any meetings arranged in 2003. Consequently, after consulting ICES it was decided that SGGIB will continue meeting by correspondence. It was also decided that the SGGIB Chair would participate in the WGHABD meeting in Aberdeen (cf. ToR 1).

The SGGIB meeting and open workshop was later decided to take place in Tallinn on 23 September 2003, prior to the ICES Annual Science Conference. To revive the activity, invitations were distributed to 35 HAB-interested people as well as the official SGGIB members.

An ad hoc SGGIB meeting was arranged in Helsinki, 26 August 2003, during the Baltic Sea Science Congress. In addition to Viitasalo, Maija Balode (Latvia) and seven other researchers from Finland and Sweden participated. The meeting further confirmed the need to continue planning the multiship experiment with the existing resources: current financing from the Academy of Finland allows performing two-ship surveys in the northern Baltic Sea in 2003-05. It was decided that invitations should be sent to all SGGIB partners to join these cruises in 2004–2005.

Term of Reference 3: Prepare application to the GEOHAB SSC for endorsement of the Baltic project and the planned workshop;

Previously, a "proposal for a Cooperative HAB study in the Baltic Sea" has been prepared by the SGGIB (Annex 2). Updating of this proposal will continue in Tallinn, 23 September 2003.

4 SUGGESTED TERMS OF REFERENCE FOR 2004

Term of reference	Justification
ToR 1: continue the planning of GEOHAB implementation in the Baltic;	The Baltic project will be a contribution to GEOHAB implementation. Development of HAB studies in the Baltic Sea would provide a unique opportunity in studying HABs at the scale of one ecosystem.
ToR 2: update the checklist of harmful species in the Baltic Sea;	The existing checklist that has been prepared by the Group in 2001 needs revising.
ToR 3: report and discuss new findings on species and ecosystem effects of Baltic HABs;	There is currently an intense research activity on HABs in the Baltic.
ToR 4: review ecosystem and other models that are relevant with Baltic HAB studies;	Model development is an essential tool in HAB prediction. Parametrisizing the models requires field and experimental data that partly exists and partly does not. Reviewing the existing knowledge will help in defining the gaps.
ToR 5: plan a SG meeting combined with an open workshop for the spring 2005 to discuss and finally develop the Baltic project, including the co-ordination of field experiments to be implemented 2004-06;	Presently there is wide interest in HAB studies in the Baltic, with several strong groups working independently. The interest towards the SGGIB has however been rather meager. It will be essential to revive the study group by organising an open workshop and by updating the current plan.
ToR 6: prepare application to the GEOHAB SSC for endorsement of the Baltic project and the planned workshop;	Updating the information on financing sources and preparing a finacing plan will be essential for the success of the Baltic project.

ANNEX 1: LIST OF PARTICIPANTS WORKING BY CORRESPONDNCE

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ANNEX 2: PROPOSAL FOR A COOPERATIVE HAB STUDY IN THE BALTIC SEA

ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic Sea

PROPOSAL FOR A COOPERATIVE HAB STUDY IN THE BALTIC SEA

Dynamics of Harmful Algal Blooms in the Baltic Sea

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1 BACKGROUND

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 massive algal and cyanobacterial blooms has become the most serious environmental issue in the area.

The plankton dynamics of the Baltic Sea is 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 create 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 bloom biomass settles down to the bottom. 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 the profound salinity gradients, the Baltic Sea is a hydrodynamically complex system, where different hydrodynamical events (wind-induced mixing, currents, eddies, fronts, upwelling) show considerable spatial and temporal variation. Small spatial and temporal scales characterize the Baltic Sea hydrodynamics. The most important hydrodynamical 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 hours
Inertial oscillations	14 hours
Time scale of weather patterns (wind forcing)	≈ 3 – 5 days

The phytoplankton ***species diversity*** in the Baltic Sea**,** like in other brackish waters, is low in comparison to fresh or marine waters. The current species checklist lists altogether over 2000 phytoplankton taxa in the Baltic Sea, of which more than 20 are known to be potentially toxic (Table 2).

1.2 HABs in the Baltic Sea

Two types of HABs are common in the Baltic Sea: cyanobacterial and dinoflagellate blooms, the dynamics of which are quite different. The two HABs occur at the same time of the year, the highest cell numbers being found at the end of July- first half of August. The dinoflagellates (*Dinophysis norvegica* and *D. acuminata*) are usually found in high concentrations in a one-meter thick layer close to the halocline. The cyanobacteria (*Nodularia spumigena* and *Aphanizomenom* spp.) are either found distributed throughout the upper water layer or if the temperature is above 18^{o}C and if no strong turbulence occurs, accumulates in half meter thick layers at the surface waters. When the cyanobacterial cells accumulate in surface waters, they are dying, forming large aggregates where bacteria and other heterotrophic organisms thrive.

In addition to the above mentioned cyanobacteria and dinoflagellates, several other toxic planktonic species are regular components of the plankton flora of the Baltic Sea (Table 2) and may form highly unpredictable harmful blooms.

Table 2. Harmful species of the Baltic Sea.

Species	Division	Class	Toxicity and/or other harmful effect	Toxins in or harmful effect through….	Open/ coastal	Distribution in the Baltic	Marine/ brackish/ fresh water
Regular blooms							
Nodularia spumigena	CYA	Nost	HT	water	O, C	whole Baltic Sea except the Bothnian Bay (occasional blooms in the Gulf of Riga)	B
Aphanizomenon sp.	CYA	Nost	NT (not proved in the Baltic)	water	O, C	whole Baltic Sea except the Bothnian Bay (occasional blooms in the Gulf of Riga)	B, F
Occasional blooms							
Microcystis spp.	CYA	Nost	HT	water	C	in estuaries and low saline coastal areas	F, B
Anabaena lemmermannii	CYA	Nost	HT	water	O, C	northern Baltic (in low numbers in the Gulf of Riga)	B
Planktothrix agardhii	CYA	Nost	HT	water	C	in estuaries, in highly eutrofied coastal areas with low salinity and in the Bothnian Bay	B
Heterocapsa triquetra	DINO	Dino	could be harmful in small inlets causing oxygen depletion	?	O, C	Whole Baltic Sea Except the Bothnian Bay, (in low numbers in the Gulf of Riga)	M, B
Prymnesium parvum	HAPT	Prim	not harmful IC	water	C	Coastal inlets with very low salinity	B, F
Prorocentrum minimum	DINO	Dino	?	mussels ?	O, C	Central Baltic, western Gulf of Finland (in low numbers in the Gulf of Riga)	B, M
Dictyocha speculum, (flagellate form)	CHRY	Dic	IC	Fish	C	Western and southern Baltic	M, B
Chrysochromulina spp.	HAPT	Prim	IC	Fish	O, C	Western Baltic (sometimes in high numbers also in northern Baltic proper)	M, B, (F)
Chaetoceros spp. (C. wighamii, C. danicus)	CHRY	Diat	mechanical	fish	O, C	South-eastern Baltic	M, B
Regularly in plankton but not in bloom amounts							
Anabaena lemmermannii	CYA	Nost	HT	water	O, C	Whole Baltic Sea, Except western proper, Kattegat and the Belt Sea	B
Anabaena spp.	CYA	Nost	HT, NT	water	O, C	Whole Baltic Sea	F, B
Dinophysis spp.	DINO	Dino	DSP	mussels	O, C	Whole Baltic Sea	M, B
Prorocentrum spp.	DINO	Dino	DSP?	mussels ?	O, C	whole Baltic Sea except the Bothnian Bay	M, B
Chrysochromulina spp.	HAPT	Prim	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							
Alexandrium spp.	DINO	Dino	PSP?	mussels	C	southern and western Baltic Sea	M, B
Gyrodinium aureolum	DINO	Dino	IC	water	O	southern Baltic Sea	M

Species	Division	Class	Toxicity and/or other harmful effect	Toxins in or harmful effect through….	Open/ coastal	Distribution in the Baltic	Marine/ brackish/ fresh water
Dictyocha speculum	CHRY	Dic	IC?	water	O, C	southern and western Baltic, Arkona, Kattegat, Skagerrak	M
Only cyst form observed							
Alexandrium excavata	DINO	Dino	PSP	mussels	C	Skagerrak, Kiel bight	M

From Kononen K., Elbrachter M., Balode M., Hallfors S., Hallfors G., Goebel J., Hajdu S., Olenina I., Konoshina I., Jaanus A., Ledaine I., Dahl E.

DIVISIONS:

Cyanophyta (cyanobacteria) – CYA
Dinophyta (pyrrophyta) –DINO
Haptophyta- HAPT
Chrysophyta (heterokontophyta) – CHRY

CLASSES

Nostocophyceae (Cyanophyceae) - Nost
Dinophyceae - Dino
Prymnesiophyceae (Haptophyceae) - Prym
Dictyochophyceae – Dic
Diatomophyceae (Bacillariophyceae) - Diat

1.3 Baltic-GEOHAB

The Baltic Sea offers good opportunities for research of HAB dynamics to be carried out in several spatial and temporal scales simultaneously. There exist already systems 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 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. Baltic-GEOHAB Implementation Plan will focus on integrated experiments carried out with several research approaches, i.e., real-time, high-resolution observation systems, laboratory and mesocosm experiments combined with parallel field experimentation. Relative simplicity of the system, already existing observational capabilities, experience in multiscale research strategies and decades long experience in multinational co-operation within ICES and HELCOM create a good basis for Baltic Sea to be as a test laboratory for the GEOHAB approach.

2 GOAL AND OBJECTIVE

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

3 OUTPUTS

- Better understanding of the role of human impact in relation to natural variability of HABs in the Baltic Sea.
- Improved monitoring and surveillance capability of HABs.
- Better prediction capabilities of HABs in the Baltic Sea.
- Sound scientific basis for advice concerning environmental management strategies in the Baltic Sea.

4 ACTIVITIES/TASKS

4.1 High resolution monitoring of HABs

Objective

The objective is to further develop effective early warning systems of HABs covering the spatial and temporal scales of blooms in the Baltic Sea. This is achieved by implementing the state of the art technologies for real-time *in situ* observations. The resulting high quality data will also be used to develop and verify models for forecasting of blooms.

Justification

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, dynamics of the development of blooms cannot be studied without the integration of a variety of observation approaches.

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. The plankton composition and abundance is analysed weekly in these samples as well as nutrient and chlorophyll *a* concentrations. This system gives a good spatial and temporal coverage of blooms but does not reveal true vertical variation. Another approach is remote sensing using satellites or aeroplanes as instrument platforms. Satellite images can be very valuable in clear weather but are often useless because of clouds. Results from air-borne sensors are mostly non-quantitative. Both methods record information from the upper part of the sea only.

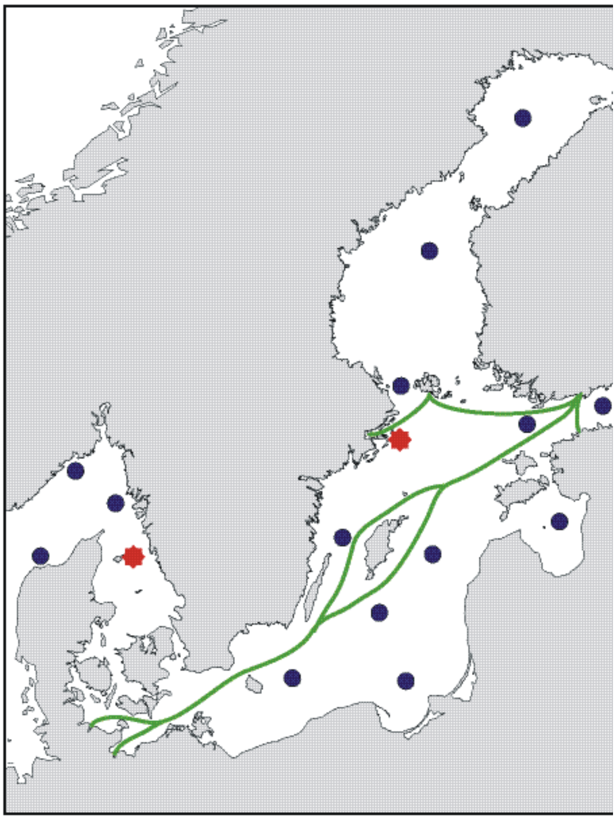

Figure 1. Map of the Baltic and adjacent seas showing approximate positions of proposed buoys for real-time *in situ* data acquisition. Red dots indicate buoys to be deployed in 2001. These are initially equipped with sensors for chlorophyll *a* fluorescence at one depth only. The red lines indicate the present SOOP lines. Preferred extensions are marked with dotted lines.

Techniques for real-time monitoring of HABs using automatic detection have developed rapidly during the last few years. Equipment has become smaller and less expensive and instruments measuring new parameters relevant for the formation of HABs have been developed. Also automatic-profiling devices has become available meaning that single set of sensors can cover the whole photic zone. Transmission of data using mobile phones and satellites makes it possible to publish data from offshore localities on the Internet in near real-time. These systems are still under development but their reliable operational use can be estimated to start in few years.

Specific activities:

A. Further development of ship of opportunity (SOOP) recordings and sampling:

- The present ferry route network should be extended especially in the southern –and southwestern Baltic Sea.
- New types of sensors should be added to existing ones, e.g., phycoerythrin fluorescence.
- Sampling techniques should be developed for better sampling of cyanobacterial assemblages.
- Undulating towed instrumentation should be taken in operation when available for unattended use.
- To establish routines for near real-time presentation of data on the Internet and for archiving and quality control of data.

B. Real-time monitoring using buoys as instrument platforms:

- To organise a workshop on the state of the art of the sensor and buoy technology and to select suitable systems and choosing positions for buoys in the Baltic taking into account present knowledge of HABs and physical oceanography, the SOOP routes as well as other practical circumstances.
- The instrumentation should cover not only the sensors necessary for HAB studies but also basic oceanographic and meteorological sensors for multi-user purposes.
- To deploy 10–15 buoys (two to start with) using satellite data transmission and e.g., the following sensors:

    1) Chlorophyll *a* fluorescence (profiling)
    2) Phycoerythrin fluorescence (profiling)
    3) Turbulence (profiling)
    4) Temperature (profiling)
    5) Salinity (profiling)
    6) Nutrients (profiling NH_4, NO_3, PO_4, Si)
    7) Current speed and direction (profiling ADCP)
    8) In air – light (PAR)
    9) Wind speed and direction
    10) Wave height and direction

- To establish routines for near real-time presentation of data on the Internet and for archiving and quality control of data.

4.2 Understanding the short-term and seasonal dynamics of the 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 5.1 makes it possible to use ship and other resources efficiently by the implementation of adaptive sampling strategies.

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, cyanobacterial blooms occur in late summer in the Baltic Sea, but blooms have also been observed late in autumn or in spring. There is a large interannual variation in the intensity of the blooms. It is unknown if this variability is due to the intensity of the blooms of the previous year, winter conditions, or to pre-bloom conditions. It is not known how and where the blooms start, what determines its termination, and where and how the cells overwinter.

Monitoring programs, aimed at long-term changes, investigate the phytoplankton at a low temporal resolution and depth distribution is not investigated at all since only mixed samples from 0–10 m are analysed. Description of the plankton community has been restricted to the larger phytoplankton in most monitoring programmes. 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 are possible to do onboard research vessels today. The information obtained would be very useful for the implementation of adaptive sampling strategies.

Specific activities:

- This part should be implemented as a four-year project.
- Near a few of the buoys described in Section 5.1, 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.
- 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 analysed with higher frequency of samples during blooms and their development.
- Towed undulating vehicles with multisensor and sampling systems should be effectively used on research vessels.
- On ship experiments should be encouraged in addition to the sampling.
- Data on the basic, but advanced, parameters should be presented on the Internet within 3 days after sampling.
- Acquired data should be used to calibrate *in situ* sensors on buoys.
- Acquired high quality data should be used for the development and verification of models for bloom forecasting.
- Standardisation of techniques and intercalibration should be co-ordinated by the ICES.
- ICES should organise meetings of ship managing institutes.

4.3 Hydrodynamical control of HAB development

Objective

To understand the mechanisms how hydrodynamical 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. In addition, atmospheric deposition of nutrients, operating in large scales, creates an additional source of nutrients in the open sea. 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 Baltic Sea Patchiness Experiment, which studied the patch dynamics without addition of nutrients. A coordinated multiship experiment where nutrients are added directly to the system, the development of the bloom patch is followed, the species selection, development of toxicity and various other aspects of HABs are studied, complemented with measuring transects by 'ships-of-opportunity', a set of moored oceanographic instrumentation and remote sensing, could serve as a platform for biological studies, will allow a real integration of biology and physics.

Questions to be solved:

- how do the hydrodynamical processes modify nutrient limitation of the bloom species
- how do physical processes affect the 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, which species becomes 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 2002–2006
- integration of information obtained from 5.1. and 5.4. 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 5.6.
- studying the effect of small scale turbulence on HAB species

4.4 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 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 behaviour, production of infochemicals, growth rates, etc. Some of these characteristics will enable HABs to out compete 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 these factors will have on their growth and their losses (grazing, sensitivity to infection by virus, bacteria, parasites) and apoptotic behaviour.

Thus, in order to get a complete picture on the *how* and *why* the targeted HAB populations are found at specific layers/fronts, etc. during the oceanographic surveys, complementary laboratory and mesocosms studies will be carried out using natural plankton communities and unialgal cultures of the regional HAB species.

Questions to be solved:

What are the most important factors contributing to the accumulation of the cyanobacteria in surface layers during warm periods in late summer? Is temperature affecting the expansion of gas vacuoles or are physical processes the only reason for such accumulations? 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.

Specific activities:

The following experiments need to be performed:

1. How nutrient concentrations and ratios affect:
   a) Production of toxins
   b) Production of infochemicals
   c) Sensitivity to parasites
   d) Apoptosis
   e) Accumulation or flotation
   f) Growth rates
   g) Life cycle
   h) Mixotrophic behaviour
   i) Species succession

4.5 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 more than 20 are known to be potentially toxic or can cause other harmful effects. In addition to several cyanobacterial species, many species of Chromophytes division (representatives of following classes: *Dinophyceae*, *Bacillariophyceae*, *Prymnesiophyceae*, *Dictiophyceae*), are known to form harmful blooms in the Baltic Sea area.

Specific activities:

Right now the update of the overall phytoplankton checklist of the Baltic Sea is under the work co-ordinated by the HELCOM. It should be completed in the near future. The checklist 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.

4.6 Modelling

Objective

To develop species-of-interest 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. In a plan for GEOHAB implementation in the Baltic Sea modelling is a natural component.

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. 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. But 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 has been demonstrated.

Details of interactions of individual organisms with the environment may also use modelling based on the organisms' physiology, behaviour, life cycles etc.

Specific activities

Similarly as 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 analysed and ranked for each source of error. The modelling community needs to develop methodologies for estimating errors associated with forcing and initialisation 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 co-operative 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.

5 OBJECTIVES WITH REFERENCE TO GEOHAB SP/IP OBJECTIVES

The overall 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 - thus it is a part of GEOHAB *Program Element 4: Comparative ecosystems*. The relation of different Baltic GEOHAB activities to the overall and specific objectives of GEOHAB are:

Baltic GEOHAB Activity	**Baltic GEOHAB Objective**	**Reference to the GEOHAB 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
Hydrodynamical control of HAB development	to understand the mechanisms how hydrodynamical 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

Baltic GEOHAB Activity	Baltic GEOHAB Objective	Reference to the GEOHAB objectives
		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. Determine 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

6 DATA ISSUES

An agreement upon data management is made before data actually is collected. It is suggested that project leaders within the GEOHAB implementation in the Baltic should sign a document similar or identical to "Unified Consortium Agreement for FP5 projects" used in some EU-funded projects. In addition a "gentleman's agreement" should be made regarding use and publication of data produced by others.

6.1 Methodology

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 GEOHAB-BALTIC to make intercalibrations possible.

6.2 Quality assurance

See "Manual for Marine Monitoring in the COMBINE Programme of HELCOM"

6.3 Validation

See "Manual for Marine Monitoring in the COMBINE Programme of HELCOM"

6.4 Data banking

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

6.5 Data availability

Most data produced within GEOHAB-BALTIC 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 outcoming publications.
4) Data will be available through bi- or multilateral negotiations between producers.
5) Data availability is restricted or prohibited.

Data from real time measurements should be made available to other participants in near real time using the Internet. The international system SNDI (SeaNet Data Interface http://www.minvenw.nl/rws/projects/seanet/) is recommended. As of today (3 Dec. 2001) the following countries with coasts bordering the Baltic participate: Sweden, Germany and Denmark.

7. THE GEOHAB APPROACH TO A COOPERATIVE BALTIC STUDY

7.1 Description of the comparative approach applied

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, hydrodynamical 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.

Compared to terrestrial or bottom rooted systems, mechanisms of species selection in the planktonic system are much more complicated and much more difficult to study. This is mainly due to the peculiarities of fluid as a growth medium and the small size and rapid generation times of the plankton organisms. Therefore, the strengthening of the theoretical basis of phytoplankton species diversity is urgent and empirical studies of population dynamics of different plankton species in various oceanographic conditions are needed. Comparison of the mechanisms of HAB formation in the Baltic Sea with those resolved within other GEOHAB regional programs is necessary in order to understand HABs, but it also contributes to science in a much broader sense, as it increases our knowledge of regulation of species diversity in aquatic systems.

7.2 Identification of the expertise expected to be contributed to project by being affiliated with GEOHAB

Successful... of the Baltic GEOHAB... participation of the following research teams:

Task #3

Water masses, currents, meso-scale hydrodynamics: Group of physical oceanographers, Group of remote sensing experts

Follow up the fate of added nutrients: Group of chemical oceanographers

Follow up patch formation: Groups of pelagial biologists including ecologists and physiologists

Follow up of the fate of the patch: Group to measure sedimentation

Integration of data with models: Group of modellers from #6

7.3 Outline of the mechanisms to be established in the Project to allow international participation (re. obligations for endorsement as a GEOHAB Project)

7.4 Role of ICES and national partners

ICES have in the past been behind the development and implementation of several regional field programmes such as for example: PEX and SKAGEX, GLOBEC Cod and Climate, etc.

ICES is not designed to function as a funding agency, but proposals for regional studies developed by study or working groups are presented to the ICES Oceanography Committee for endorsement. Through subsequent endorsement by ICES Delegates at the ICES Annual Science Conference, the Delegates can either directly commit national resources or commit themselves to work for the identification of resources for implementing the project. Additionally, ICES endorsement of a regional project may be an advantage when applying to the respective national research councils for funding to participate.

Thus it is important for this mechanism to work, and to achieve strong endorsement by the ICES delegates, that SG/WG members actively brief their respective ICES delegates in advance of the ICES Annual Science Conference.

In summary, the added value of organising a co-operative regional study through ICES is:

- ICES provides a recognised organisational platform for regional co-operative research
- ICES provides a mechanism for facilitating access to national funding
- ICES provides a mechanism for involving scientists from outside the study region in a project with the view to exchange experience and share data.
- ICES is a tool for co-ordinated data management
- ICES is tool for development of standard methodology protocols
- ICES can assist with publication
- ICES can organise and sponsor targeted workshops
- ICES can organise and sponsor targeted conferences

The role ICES can fulfil in the implementation of GEOHAB corresponds to the goals in the ICES Strategic Plan:

- understand the physical, chemical, and biological functioning of marine ecosystems;
- enhance collaboration with organisations and scientific programmes that can contribute to fulfilling ICES' vision.

Based on this framework provided by the ICES, IOC and SCOR, and the support from national institutions committed via the ICES delegates as described above, it will be up to the individuals and research teams in the SG to submit the fully developed activities for funding to relevant funding sources.

8 PLAN FOR FUNDING

Programme element	**Possible funding source**
High resolution monitoring of HABs	GEF Baltic Regional Programme, GOOS
Understanding the short-term and seasonal dynamics of the HAB species	National projects
Hydrodynamical control of HAB development	EU-proposals
Studying biology of HAB species	ongoing and future EU-funded projects
Update of the phytoplankton HAB species checklist	ongoing ICES activity
Modelling	EU-proposals

9 WORK PLAN AND TIME SCHEDULE

Endorsement of proposal by ICES i) Baltic and Oceanography Committees; ii) Statutory Meeting Resolution	 i) ASC Oslo in September 2001 ii) ASC Oslo in September 2001
Submission to GEOHAB SSC for acceptance as GEOHAB project	SSC meeting in Shanghai April 2001
SGGIB meeting to refine programme document (plan activities)	fall 2001
Open workshop I	fall 2001
Invited meeting for preparing an EU-proposal	spring 2002
Open workshop II	fall 2002
Submission to ICES ASC and GEOHAB SSC for final approval	ASC and SSC meetings in 2002
Implementation	
- pilot cruise onboard R/V ARANDA	summer 2002

10 FORM FOR SUBMISSION TO GEOHAB SSC FOR ACCEPTANCE AS A GEOHAB PROJECT

To be developed.