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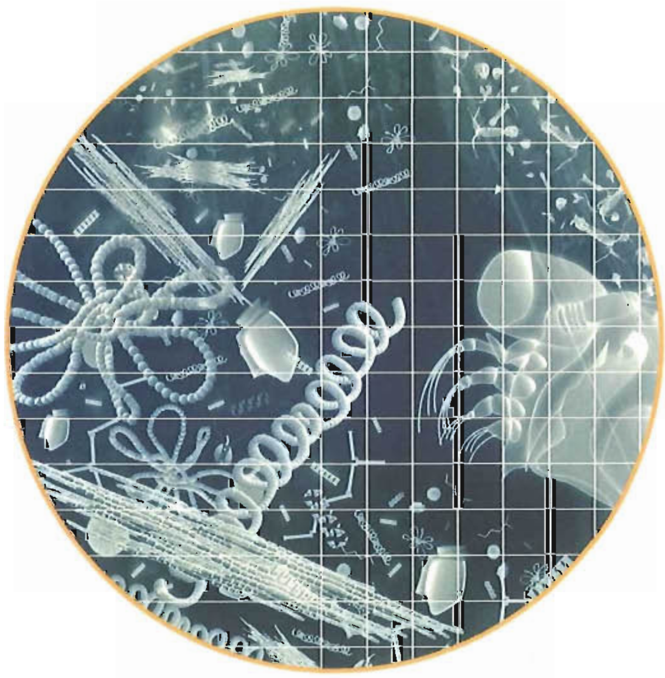
Alg@line IN 2003: 10 YEARS OF INNOVATIVE PLANKTON MONITORING AND RESEARCH AND OPERATIONAL INFORMATION SERVICE IN THE BALTIC SEA

Eija Rantajärvi (Editor)



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INTRODUCTION

During 2003 Alg@line, co-ordinated by the Finnish Institute of Marine Research, celebrates its ten-year anniversary as a full-time joint operational monitoring and information service in the Baltic Sea. The 'ships-of–opportunity' (SOOP) approach, i.e. unattended measurements and sampling on ferries and cargo ships, forms the backbone of Alg@line. In addition to almost real-time reporting of the Baltic Sea algal blooms, the collected data is used for scientific research. The SOOP data, together with other collected data sets, also provides the means for administrative decision makers to evaluate whether the defined targets in the Baltic Sea water protection have been reached and to define future goals.

The dynamic Alg@line project has been realized with innovative co-operation of several research institutes and shipping companies. The free-of-charge platforms and financial donations provided by shipping companies, especially by Silja Line and Transfennica Ltd, has been of high importance for the development of the project. The needs of marine research are constantly shifting which sets new demands on Alg@line as well. Therefore, there are several approaches to develop the project in the near future.

This report describes the background for the Alg@line–project, the way it is working today, and tries to forecast its further development. It also includes some metadata information on the produced SOOP data and the list of publications where Alg@line data have been utilized so far.

SUMMARY

The Alg@line -project was generated in 1993 to improve the coverage of existing pelagic monitoring in the Baltic Sea. The former Baltic Monitoring Programme (BMP) was known to be unable to give sufficient information on the changes in this highly fluctuating ecosystem. The Alg@line -project with 'ships-of–opportunity' (SOOP) approach offered an extensive and inexpensive automated sampling method on board merchant ships and started to develop the information exchange between authorities and dissemination to the media and the public.

As anthropogenic eutrophication is a serious problem in our enclosed brackish water sea, the main emphasis of Alg@line is the adequate monitoring of phytoplankton. The excess of nutrients is first reflected in increased pelagic algal production and subsequently as intensification and enhanced frequency of phytoplankton blooms. At present Alg@line is extending the scope of comprehensive monitoring to zooplankton, which has a central position in the food web as it feeds on phytoplankton, and serves itself as a food supply for pelagic fish. The comprehensive SOOP monitoring of phytoplankton and zooplankton is also a prerequisite for the detection of possible invasions of new and potentially harmful species. In addition the continuously measured hydrographical parameters on board SOOP give valuable high frequency information of the water masses. This is important as the hydrographical processes, such as upwelling, strongly regulate the plankton patterns.

The Alg@line –project meant a fundamental change in phytoplankton monitoring as the 'few-station' sampling on board research vessels was extended to SOOP sampling. As the high heterogeneity of the plankton ecosystem is known the automated sampling is able to give more adequate information on plankton communities by taking the spatio-temporal dimensions better into account. The extensive Alg@line phytoplankton data set forms the basis for research of ecological characteristics of species, to reveal changes in phytoplankton species compositions and to develop an early warning system for harmful blooms. The Alg@line SOOP data has also shown its value in validation of ecological and hydrodynamical models and as a reference data for optical remote sensing measurements.

There is a long-term challenge to restore the good ecological status of the Baltic Sea. To reach this goal several measures have already been implemented e.g. the reduction of municipal and industrial discharges. At present, there is an essential need to create competent follow-up tools for decision-makers to estimate the effects of measures taken on the state of the marine environment. One such tool could be various indicator reports provided by researchers on relevant parameters.

The focus of marine scientific research is constantly shifting and the needs of society vary as well. The ship-of-opportunity platforms facilitate the adequate monitoring of highly fluctuating pelagic ecosystem of the Baltic Sea. If appropriate new sensors were applied to unattended use the scope of marine research would widen considerably. A new and interesting approach in marine research is the development of models and inversion tools. There is a vision that in ten years time new methods, analyses and inversion tools, will offer reliable estimates on ecological state of the sea areas based on the results from a single SOOP transect crossing the Baltic Sea.

Key words: Baltic Sea, monitoring, harmful algal blooms, phytoplankton, unattended sampling, information dissemination, HELCOM, continuous plankton recording

CONTACT INFORMATION

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Email	Algaline@fimr.fi
Alg@line GSM	+358400-609269
Reporting via Internet	http://www.itameriportaali.fi select title 'Algal situation' select 'Send a bloom report' from the navigator
Phytoplankton database	http://www.itameriportaali.fi select title 'Algal situation' select 'Phytoplankton Database' from the navigator

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1. PROBLEMS IN PLANKTON MONITORING

Eija Rantajärvi

COMBINE and Alg@line

As the knowledge on the function of the marine ecosystem increased it became obvious that the old Baltic Monitoring Programme (BMP) was unable to reach the goal of adequate pelagic monitoring in the Baltic Sea. Based on sampling at a few fixed stations and on the hypothesis of a linear response of phytoplankton to eutrophication, it could not provide reliable information on the changes in pelagic environment. The temporal and spatial frequency of the collected data was far too sparse to reveal the possible changes in this highly fluctuating, patchy ecosystem. However, it was not possible to increase the sampling frequency by using traditional sampling techniques i.e. the expensive use of research vessels. The demand for accurate and rapid monitoring was increasing, and in 1992 the old BMP was updated in order to optimise the monitoring strategy. The term COMBINE i.e. 'Co-operative Monitoring in the Baltic Marine Environment' was taken into use. The design of COMBINE was a combination of basic monitoring, fundamental and applied research, and information collection.

During the same year, 1992, the Finnish Institute of Marine Research (FIMR) had started regular recording and water sampling on phytoplankton and related parameters onboard merchant ships crossing the Baltic Sea. The autonomous analyser combination enabling unattended measurements and water sampling onboard ferries was developed at FIMR. The main bulk of phytoplankton biomass occur in the euphotic layer with no distinct pycnocline and the Baltic Sea is densely plied by merchant ships with regular schedules. For these reasons the use of the 'ship-of–opportunity' (SOOP) technique offered a sound tool to improve the frequency of pelagic monitoring. The free-of-charge platforms provided by several shipping companies enabled the increase in sampling frequency with relatively low cost. These SOOP measurements form one part of the new COMBINE programme.

The full-time joint operational monitoring and information service in the Baltic Sea, Alg@line, started to operate in 1993. The unattended measurements and sampling on ferries and cargo ships forms the backbone of Alg@line data collection.

HELCOM and monitoring

The international conventions to protect the marine environment require relevant monitoring programmes to assess the state of the sea. HELCOM (Baltic Marine Environment Protection Commission; Helsinki Commission) co-ordinates marine monitoring programmes (hydrological, chemical, biological) in the Baltic Sea area. The core idea of monitoring is to produce adequate information on the state of the marine environment and changes in it. This knowledge is needed not only for scientific research, but also for the basis of decision-making to estimate the effects of taken administrative measures on the state of the Baltic Sea ecosystem and to define future goals for water protection.

2. THE SHORT HISTORY OF Alg@line

Eija Rantajärvi & Juha Flinkman

On research vessels the continuous underway measurements have long traditions since the 1960s. In the Baltic Sea, Kahru and Nômman from the Estonian Marine Institute were the first ones to extensively use a flow-through system on a research vessel during 1980s. Not until 1990 were the continuous flow-through measurements applied on merchant ships i.e. ships-of-opportunity (SOOP).

The pilot project of SOOP measurements in the Baltic Sea were done in 1990-91 as a joint research project between Finnish and Estonian marine institutes. The passenger ship 'Georg Ots' operating between Helsinki and Tallinn was equipped with a semi-automatic system consisting of a flow-through fluorometer, a thermosalinograph, a navigator and a PC.

In 1992 an unattended analyser system was installed by FIMR on board Silja Lines ferry Finnjet crossing the whole Baltic Proper from Travemünde to Helsinki. Also in the Gulf of Bothnia, a similar system was mounted by the Central Ostrobothnia Regional Environment Centre on a merchant ship crossing the Quark. During the same year an almost similar system was tested on board ferry Konstatin Simonov, operating between Helsinki and St. Petersburg. This was done as a co-operation project of the Krylov Shipbuilding Research Institute (St. Petersburg) and FIMR. The automatic measurements were complemented by discrete water samples for chlorophyll as well as for nutrients analyses.

2.1 Start for Alg@line

In spring 1992 a mass mortality of birds and seals occurred in the eastern Gulf of Finland. One of the possible causes was suspected to be a novel toxic phytoplankton bloom. The ultimate cause for the mass kills will probably stay unsolved. However, the episode revealed obvious shortcomings in co-operation of various authorities and research institutes when rapid information exchange is needed.

The following year, 1993, was a real kick-off year for Alg@line, when the systematic information compilation and delivery service on phytoplankton blooms were started. In the early phase there were weekly telephone meetings between environmental authorities and subsequent reporting on the algal situation. The compilation reports were constructed and sent via fax (Baltic AlgaFax) by FIMR to authorities in Finland, Sweden, Germany and HELCOM as well as to the Finnish media. The SOOP measuring system was completed with automatic refrigerator water sampler, which improved the calibration of the quasi-continuously measured parameters. Now it was also possible to follow almost real-time the succession of phytoplankton species composition along the ship route crossing the Baltic Proper. That was realised by automated water sampling onboard ferries as well as subsequent semi-quantitative species analyses made by a phytoplankton specialist at FIMR. In the beginning, the project was financed by FIMR and the Nordic Council of Ministers.

2.2 Step by step

In 1994 the information provided by Alg@line was complemented with NOAA/AVHRR satellite images: the basic processing of images was done by the Finnish Meteorological Institute and reprocessing by FIMR. The NOAA/AVHRR images provided by Stockholm University (Uve Rud) were also utilized. During cloud-free days these satellite images gave valuable information on the extent of cyanobacterial surface blooms as well as on the surface water temperatures. The surface water temperatures are connected to the hydrographical processes (e.g. upwelling) which regulate the phytoplankton patterns.

In 1995 Alg@line started to deliver information on algal blooms on the Internet. The WebPages were updated weekly during intensive growth season of phytoplankton.

In 1997-98 the ferry company Silja Line donated FIM 1.1 million to the project. This was used to install new measuring devices on ferries and especially to improve the information availability for public by starting the 'Baltic Sea Information Database' on the Internet.

In 1997 the Finnish Ministry of Environment provided funding within the framework of Finnish co-operation with adjacent regions in the East and the South. As a result the Uusimaa Regional environment Centre and the Helsinki City Environment Centre started the SOOP measurements onboard ferries: Silja Lines Wasa Queen (1998, Helsinki-Tallinn) and Silja Serenade (1999, Helsinki-Stockholm). Also the Estonian Marine Institute became involved as an Alg@line partner. During a few years it was possible to publish the WebPages in four languages: Finnish, Swedish, English and Estonian.

During 1998-99 shipping company Transfennica Ltd provided funding for the Continuous Plankton Recorder (CPR) and a comprehensive zooplankton recording pilot project was undertaken in the Baltic Sea (m/s Hamnö Lübeck- Hanko). In the North Sea the CPR, designed to be towed by merchant ships, has been used since 1930s for near-surface sampling of plankton. During the pilot project a significant undersampling was detected due to the smaller size of Baltic plankton compared to their oceanic counterparts. These problems were solved by tests done by FIMR and the Sir Alister Hardy Foundation for Ocean Science in 2000-2001 on board the r/v Aranda.

The shipping company Silja Line has provided annual funding to cover the running costs of SOOP measurements. In 2000 the Finnish Ministry of the Environment also provided some funding to improve the data management as regards the needs of the EU water directive programme.

At the present the Alg@line SOOP measurements form part of the international COMBINE monitoring programme of the Baltic Sea run by HELCOM. They are included in the national monitoring programmes of Finland and Estonia as well as in the mandatory coastal monitoring of the Uusimaa Regional Environment Centre and the City of Helsinki Environment Centre.

3. Alg@line TODAY

Eija Rantajärvi Lotta Ruokanen, Seija Hällfors, Juha Flinkman, Tapani Stipa, Tapio Suominen, Seppo Kaitala & Petri Maunula

Joint Operational Monitoring of the Baltic Sea

As the excess of nutrients is first reflected in increased pelagic algal production and subsequently as intensification and increased frequency of blooms, the main emphasis of Alg@line is adequate monitoring of phytoplankton, especially the harmful blooms. At present Alg@line is extending the scope of comprehensive monitoring to zooplankton, which has a central position in the transfer of energy from primary producers to fish such as herring. The comprehensive SOOP monitoring of plankton is also prerequisite for rapid detection of possible invasions of new and potentially harmful species into the Baltic Sea. In addition to biological parameters, hydrographical parameters, surface water salinity and temperature, are measured with high frequency to give additional information of the water masses. An essential component is the rapid information delivery between environmental authorities as well as for the media and the public. The fast information dissemination is especially important in case of toxic blooms. In the summer of 2002 an operational drift model was implemented to forecast the movement of the large toxic surface accumulations of cyanobacteria. This information is of vital importance in order to give advice for the recreational use of the sea shores.

The project takes actively part in the work of HELCOM, ICES (International Council for the Exploration of the Sea) and EuroGOOS (European Global Oceanographic Observations).

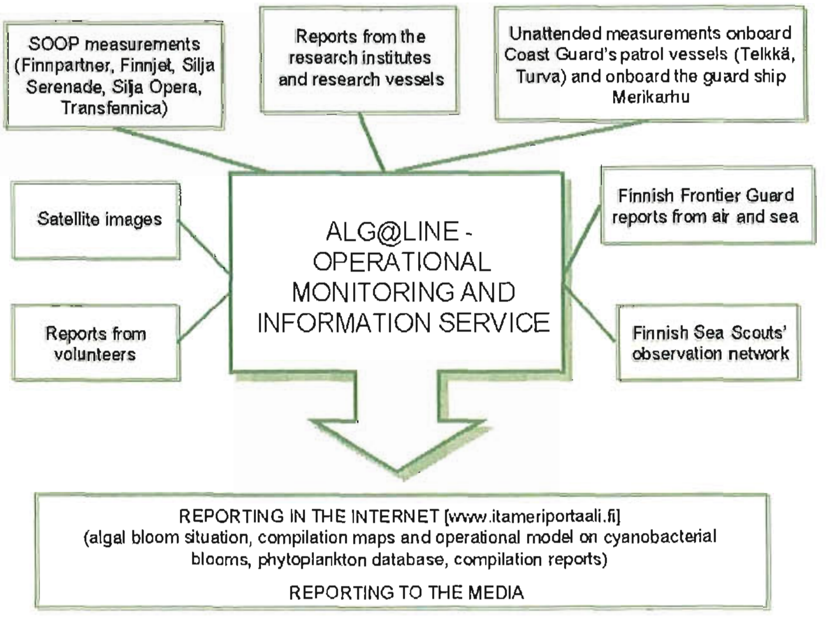

Fig. 1. The activities included to Alg@line.

3.1 Organisations taking part in Alg@line

Institutes	Activities
Finnish Institutes of Marine Research (FIMR)	▪ co-ordinator; compilation of all results on phytoplankton blooms of the Baltic Sea area ▪ maintaining the Baltic Sea Portal ▪ ships-of-opportunity (SOOP) FINNPARTNER; chl *a* fluorescence, salinity, temperature, sampling TRANSFENNICA; modified continuous plankton recorder (CPR) SILJA OPERA; testing (chl *a* fluorescence, salinity, temperature, sampling) ▪ research on r/v Aranda ▪ laboratory analyses (nutrients, chl, phytoplankton, algal toxins) ▪ analyses of satellite images ▪ environmental modelling
Uusimaa Regional Environment Centre	▪ reporting ▪ SOOP: SILJA SERENADE; chl *a* fluorescence, salinity, temperature, sampling ▪ analyses (chl, nutrients, phytoplankton)
City of Helsinki Environment Centre	▪ reporting ▪ SOOP: FINNJET; chl *a* fluorescence, salinity, temperature, sampling ▪ analyses (chl, nutrients, turbidity, algal toxins)
Estonian Marine Institute (EMI)	▪ reporting ▪ SOOP: FINNJET ▪ analyses (phytoplankton)
Finnish Frontier Guard	▪ reporting (maps) of visual observations, occasional sampling ▪ aerial surveys ▪ guard ships ▪ station sampling on guard ship MERIKARHU (chl *a* fluorescence, salinity, temperature, oxygen)
Finnish Environment Institute (FEI)	▪ weekly national reporting on algal blooms in Finnish lakes and coastal sea areas; compilation of coastal observations from volunteers (June-August) ▪ satellite images ▪ models
Southwest Finland Regional Environment Centre	▪ reporting ▪ guard ship TELKKÄ; chl *a* fluorescence, conductivity, temperature, turbidity, sampling ▪ analyses (chl, nutrients, phytoplankton)
West Finland Regional Environment Centre	▪ reporting ▪ guard ship TURVA; chl *a* fluorescence, temperature, salinity, conductivity ▪ analyses (chl, nutrients, turbidity)
Southeast Finland Regional Environment Centre	▪ reporting occasional SOOP: KRISTINA BRAHE; chl *a* fluorescence, salinity, temperature, sampling
Finnish Sea Scouts	▪ reporting of visual observations (algal blooms, birds), measurements (temperature, Secchi depth)
Swedish Meteorological and Hydrological Institute	▪ satellite images

3.2. METHODS

To obtain adequate information on the highly fluctuating state of the Baltic Sea, Alg@line utilises a combination of methods: ships-of-opportunity, satellite imagery, coastguard reports, and the information from sea scouts, other volunteers and the public.

In addition to the data sets collected within the framework of Alg@line, several other information sources provided by research institutes and environmental authorities are used as well. For example, the case studies made on research vessels give more specific and detailed knowledge on the function of the ecosystem and the mechanism of phytoplankton blooms.

3.2.1 'Ship-of-opportunity' (SOOP) approach forms the backbone

The unattended measurements and sampling on ferries and cargo ships make up the main bulk of collected data. Today there are several SOOPs regularly crossing different areas of the Baltic Sea. In addition to the surface water parameters giving direct information of phytoplankton (*in vivo* fluorescence chlorophyll *a*), some hydrographical parameters are recorded (temperature, salinity) with high frequency. The spatial and temporal resolution is 100-300 m and 1-3 days, depending on the schedule of the ferry. The flow-through system pumps the water constantly from beneath the ships' hull at a depth of ca. 5 m while the ship is moving. Simultaneously, water samples are automatically collected to the refrigerator for further analyses. The amount of samples e.g. along one voyage from Helsinki to Lübeck is 24 per week. At the harbour the samples are transported to laboratories for analyses of concentrations of the nutrients and chlorophyll *a* as well as for microscopic analysis of phytoplankton species composition. The extracted chlorophyll concentrations analysed from the water samples are used to convert the continuously recorded *in vivo* (in living cells) fluorescence values to chlorophyll *a* concentrations.

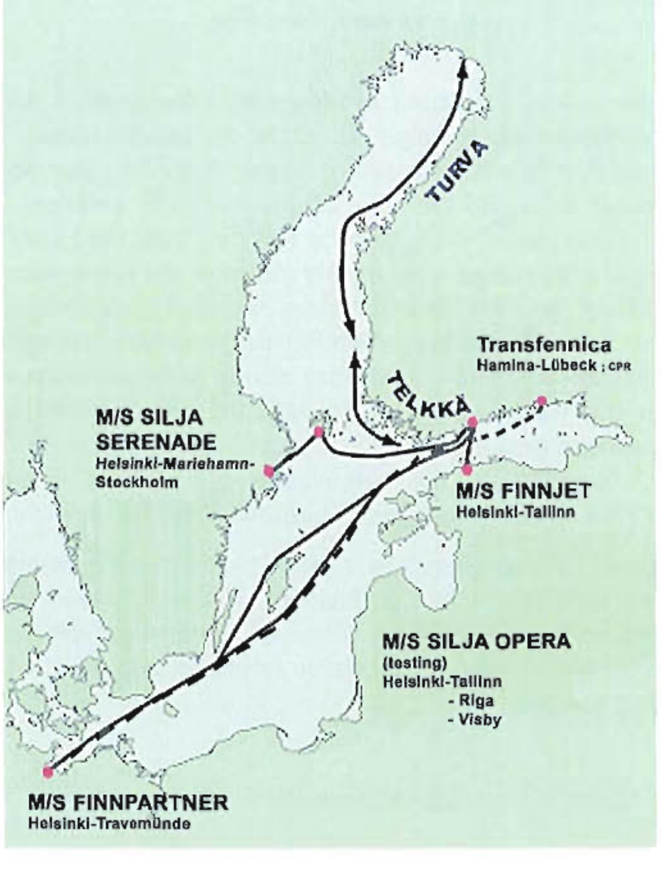

Fig. 2. Routes of the merchant ships and guard vessels with Alg@line sampling.

Company or organisation	provided free-of-charge platforms
Silja Line	FINNJET SILJA SERENADE SILJA OPERA
Finnlines	FINNPARTNER
Transfennica Ltd.	Transfennica ship
Finnish Frontier Guard	Guard vessels: Telkkä, Turva

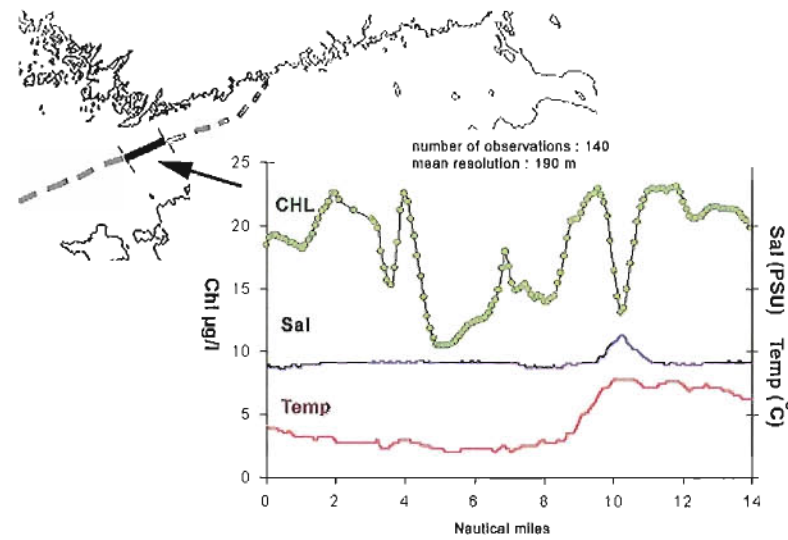

Fig. 3. The frequency of continuously measured parameters (*in vivo* fluorescence chlorophyll *a*, temperature, salinity) is illuminated along the SOOP transect during the spring bloom in the northern Baltic Sea.

The *in vivo* fluorescence values, converted to chlorophyll by frequent calibrations, are used as a relative measure for phytoplankton biomass. It is not an exact estimate as the ratio of *in vivo* fluorescence to chlorophyll *a* is not constant. It varies according the phytoplankton species, the physiological state of algal cells and the time of the day. The problem is minimised by weekly calibrations. During the spring bloom, while diatoms and dinoflagellates dominate, the algal biomass is at its highest, and the algal cells appear quite evenly mixed in the upper water column, the correlation between fluorescence values and chlorophyll values is usually satisfactory. During cyanobacterial blooms, the algal biomass is lower, and the correlation can be weak as the main cyanobacterial pigment is phycocyanin. Furthermore, due to the buoyancy ability of cyanobacteria, the algal cells can be unevenly distributed in the water column, especially in calm weather conditions. However, the information from the quasi-continuous fluorescence measurements can be utilized for the evaluation of cyanobacterial blooms. Furthermore, the compilation of methods gives a more accurate and comprehensive picture of the algal biomass during cyanobacterial blooms.

The continuously measured hydrographical parameters, surface water salinity and temperature, give valuable high frequency information of the features of water masses. This is important as the hydrographical processes, such as upwelling, strongly regulate the phytoplankton patterns. These frequently measured parameters are also of high value for modelling.

For details of the sampling device see Appendix 1.

3.2.2 Finnish Frontier Guard's ships used as platforms for research

The flow-through measuring systems have been installed onboard Coast Guard's offshore patrol vessels Telkkä and Turva by Southwest and West Finland Regional Environment centres. Telkkä operates mainly in the Archipelago Sea and in the northern Baltic proper, whereas Turva operates in the Bay of Bothnia, the Quark and in the Bothnian Sea. There are no regular routes or timetables as the main activity of these vessels is on border surveillance, maritime search and rescue duties.

3.2.3 SOOP sampling of phytoplankton, a renovation in monitoring

The number of phytoplankton samples during the former BMP was only a fraction of that analysed today, on average ten samples per year in a sea basin. The only method to give detailed information of the phytoplankton species composition is microscopic determination. This information is essential to reveal changes in phytoplankton communities, including possible invasions of new species. The method used for analysis, quantitative cell count, gave a very accurate measure of the phytoplankton species composition but only for very few sampling stations. The quantitative analysis is very time consuming which limits the number of counted samples. However, as the pelagic ecosystem fluctuates widely in time and space, and when infrequent sampling is used the results are very hazardous. Thus, the conclusions drawn based on spatially and temporally sparse data sets can be misleading when used e.g. for the evaluation of regional differences and long-term trends of phytoplankton estimates.

The automated sampling collected on board SOOPs has increased the sampling frequency, in space and time. At the present, within the framework of Alg@line, phytoplankton species composition is annually determined in ca. 300 SOOP samples using sample specific semi-quantitative ranking. There all the taxa are identified, and their abundance is estimated using a scale from one to five (very sparse - dominant). In addition approximately 300 samples per year are analysed using the traditional quantitative cell counting method in transects Tallinn-Helsinki and Helsinki-Stockholm.

The extensive Alg@line phytoplankton data set forms the basis of ecological research of species characteristics and enables to reveal possible changes in species composition. In addition, it is a prerequisite for development of early warning systems for novel and potentially harmful blooms.

3.2.4 Continuous Plankton Recorder (CPR), enhancing zooplankton monitoring

The methods used in zooplankton monitoring in the Baltic Sea have not been able to give an accurate picture of species assemblages or their changes. The zooplankton has a central role in the food web as it feeds on phytoplankton, and serves itself as a food supply for pelagic fish. Thus, the state of zooplankton assemblages have direct effects on economically important fish stocks.

CPR is a near-surface recording system towed by the ship, enabling efficient survey of large sea areas during a cruise. The problem of undersampling detected in 1998-99 pilot study in the Baltic Sea has now been solved. The new modified unit is equipped with an electrically driven filter mechanism using a finer mesh size than the standard mechanism. This makes it possible to capture the small Baltic plankton organisms effectively. The mechanism includes also a flow meter, which enables accurate to calculation of the spatial abundance of planktonic organisms. The modified CPR will be installed on a Transfennica ship during summer 2003, aiming at monthly tows across the Baltic Proper up to Hamina in the eastern Gulf of Finland.

For details of the sampling device see Appendix 2.

3.2.5 Finnish Frontier Guards report from air and sea

The Finnish Frontier Guard pilots (aeroplane, helicopter) report visual observations of algal blooms and categorise them by intensity. This information is sent in the form of maps on daily basis during July-August to FIMR. If needed, the helicopter crews collect water samples for phytoplankton species analyses as well. In addition to Frontier Guard pilots the crews of their vessels inform about bloom observations.

The crew of the guard ship Merikarhu make also biohydrographical measurements in the Gulf of Finland.

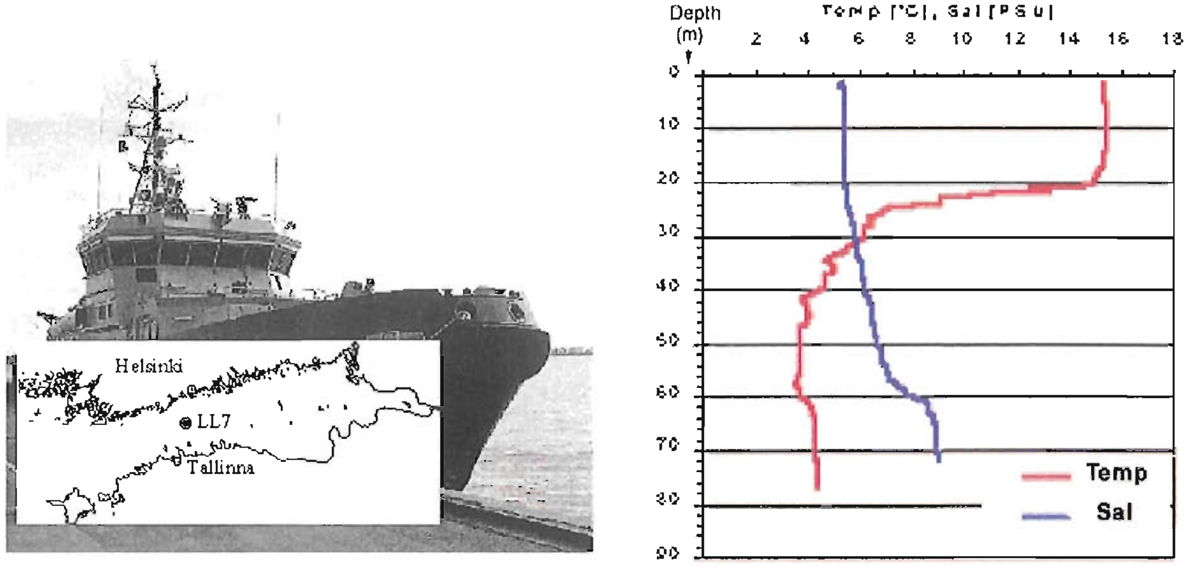

Fig. 4. The Guard Ship Merikarhu measures water temperature, salinity and fluorescence from surface to near-bottom water and collects water samples for oxygen and nutrient analyses in the Gulf of Finland. The main point station (LL7; 59.5 N, 24.5 E) is located between Helsinki and Tallinn.

3.2.6 Finnish Sea scouts

The Finnish sea scouts with about 100 boats form an unique volunteer observation network, which complements the monitoring of coastal and archipelago areas in Finland. This work is done within the framework of Alg@line and is called NODU. This research and environmental education project was started in 2000 and it is co-run by FIMR and the Finnish Sea Scouts. It aims to teach young people better understanding of the characteristics of the sensitive Baltic Sea. NODU puts in to practice the scout ideal by being both socially valuable and in the centre of environmental activity. Alg@line offers to the sea scouts versatile know-how on the state of the Baltic Sea, knowledge on monitoring and research methods as well as the database for observations. On the other hand Alg@line receives additional information of the marine environment such as measured secchi depths, observations on cyanobacterial blooms and bladder wrack densities.

3.2.7 Observations in algal bloom database

Registered authorities and some volunteers (The Finnish Frontier Guards, The Finnish Sea scouts, personnel of regional environmental institutes and FIMR) have been trained to make algal bloom observations (scale from 0 to 3; 0 = no cyanobacteria, 3 = dense visible bloom). The information is sent in electrical form via internet straight to the algal bloom database, or as an SMS message to Alg@line GSM (+358400-609269) or to Alg@line e-mail address (Algaline@fimr.fi). The latter forms are afterwards transferred to the algal bloom database. Additional information can be attached to the messages and it can be published in the Baltic Sea Portal under title 'Algal news'. Annually 50-150 observations are received to the 'Registered user' database from the Finnish Frontier Guards and the personnel of the institutes. The Sea scouts annually provide 100-200 observations, which include surface water temperature, Secchi depth and occurrence of cyanobacteria.

Besides guided volunteers everyone else can report harmful algal blooms. Reporting of bloom observations can be done by Alg@line GSM or via email algaline@fimr.fi or by using the electrical form on the Internet (http://www.itameriportaali.fi; select title 'Algal situation'; select 'Send a bloom report' from the navigator). In addition to reporting a water sample for phytoplankton species analyses can be sent to FIMR or Finnish environmental authorities.

3.2.8 Compilation maps and operational model on cyanobacterial blooms

The compilation maps of summer time cyanobacterial blooms are based on all collected visual observations (Frontier Guards, sea scouts, personnel of institutes, other voluntaries, satellite images) as well as on sampling onboard SOOP. These two different kinds of observation types are denoted in the maps by different symbols, also the intensity of blooms is indicated using a draft scale.

In summer 2002 an operational drift model was implemented at FIMR during the large cyanobacterial blooms. As a significant modification to traditional drift forecasts, this model derives its drift estimate from the sea state-dependent friction between the atmosphere and the wave field, and it can thus better than previously forecast the drift in varying seas. For the Alg@line service the drift forecasts are overlaid on maps of detected cyanobacterial blooms. As a result Alg@line provides a practical estimate to forecast the movement of the large toxic surface accumulations of cyanobacteria. This information is of vital importance in order to give advice for the recreational use of the sea shores for the public.

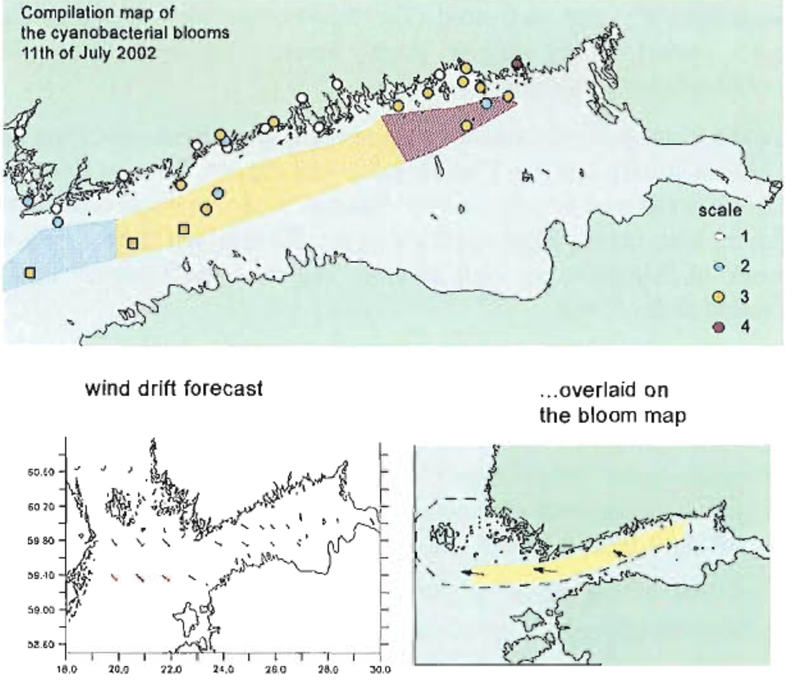

Fig. 5. Operational products implemented by Alg@line and FIMR.

3.2.9 Use of satellite images

The availability of new ocean colour satellites improve the possibilities to monitor mesoscale features to estimate various phytoplankton pigments basin-wide. Nevertheless, as the number of cloudy days is considerably high in the Baltic Sea area, they will never exclude the importance of relevant field data.

In the Baltic Sea satellite images are used to evaluate chlorophyll *a* concentrations as estimate for phytoplankton biomass in the surface water. During the summer months 2002 Alg@line used daily SeaWiFS images provided by Danish Geographic Resource Analysis and Science A/S (GRAS) Company. The calibration was done with a NASA algorithm, which gave some overestimates because of the high turbidity of the Baltic Sea water. However, these images (pixel size is 1 km$^{2)}$ could be used to verify visual observation made by Finnish Frontier Guard pilots and results collected onboard SOOP.

The preliminary calibration of new satellite images (SeaWiFS, MODIS) with Alg@line SOOP data has been carried out in co-operation with FEI, FIMR and the GIS laboratory of Environmental biology, University of Technology in Helsinki. The use of high-frequency ship borne data can solve some of the difficulties concerning turbid waters. The used method can most probably be developed for operational use already in the near future.

Alg@line also takes part in the EC Joint Research Center project in framework of HELCOM, which serves as a preliminary activity in developing a common Baltic Sea algorithm. The final approach is to evaluate the possibility of using satellite data for estimating chlorophyll *a* content in the Baltic Sea.

3.3 Information compilation and delivery service

There was an obvious need to improve the information dissemination on the state of the Baltic Sea as the traditional monitoring programmes were not able to report the scientific results rapidly. The public awareness and the need for information on environmental issues, including the Baltic Sea, have increased markedly during the last ten years. The Alg@line web site was renewed in 2002, partly to answer the pressing need of the public for clear information on the state of the sea. Under the title 'Baltic Sea Portal' (http://www.itameriportaali.fi) serves as a common Web site for all relevant information of the Baltic Sea marine environment in Finnish, Swedish and English. At present, the compilation of information collected within the framework of Alg@line is done at the Finnish Institute of Marine Research (FIMR) and delivered via the Portal, almost daily during the intensive phytoplankton growth period for viewing at 'Algal situation'. If needed, e.g. in the case of toxic blooms, a report is also sent to the traditional media.

During June-August the Finnish Environment Institute (FEI) and FIMR send together a weekly national report of the algal bloom situation in the Finnish lakes and the sea areas to the media. Information for the lake and coastal sea areas part is collected by regional environmental centres as well as by trained volunteers. The chapter concerning algal situation at the Finnish sea areas is based on data collected within the framework of Alg@line as well as from regional environment centres and the trained volunteers and compiled at the FIMR.

'Baltic Sea Portal' – Current news and basic information of the Baltic Sea

At present, the Baltic Sea Portal (http://www.itameriportaali.fi) informs not only about the current algal situation, but also includes basic information of the history, ecology and physical-chemical processes of the Baltic Sea as well as other news connected to the state of the sea. The information delivered via the Portal serves the public, media, students, decision makers as well as scientists.

The current Baltic Sea Portal was started in 2002 and it is in developing phase. The core aim of the Portal is to become the most appropriate platform for all relevant environmental information about the Baltic Sea. The documents produced within the Portal use the so-called Baltic Sea Document System (BSDS), which provides each document with large amounts of metadata. The appropriate metadata forms the basis for the search of the documents. The special ontology build on the BSDS enables semantic search, a function that is most important when the number of documents increases.

At the present the main products provided by the Baltic Sea Portal are: weekly/daily reports on the algal bloom situation during intensive algal growth period including compilation maps of cyanobacterial blooms, relative algal biomass measured along SOOPs routes and weekly plankton species reports from different sea basins. In addition the Portal includes the checklist containing valid names for over 2000 phytoplankton species existing in the Baltic Sea, this service is especially useful for algal systematists and students (http://www.itameriportaali.fi; select title 'Algal situation', select 'Phytoplankton Database' from the navigator). The taxonomic phytoplankton sheets contains further information of species special characters as well as images revealing the high variability of phytoplankton forms. In the Portal one can also find special articles and various compilation reports such as annual algal bloom situations and special assessments of the state of the Gulf of Finland.

In the future the Baltic Sea Portal will extend to include even more comprehensive information of the Baltic Sea characteristics, taken conservation measures, as well as a glossary for specific words related to the subject.

4. FOLLOW-UP TOOLS FOR DECISION MAKING

Eija Rantajärvi

Anthropogenic eutrophication is a serious problem in the Baltic Sea, which is especially emphazised in subbasins, such as the Gulf of Finland. There is a long-term challenge to restore the good ecological status of the Baltic Sea. To reach this goal several measures have already been taken e.g. the reduction of municipal and industrial discharges. The Alg@line SOOP data, together with other collected datasets, provides the basis in order to evaluate whether the defined targets in water protection have been reached and to focus the further goals in the most cost-effective and ecologically sound way.

For the present, there is an essential need to create competent follow-up tools to provide relevant information of the state of the Baltic Sea and changes in it for the basis of administrative decision making. At least two types of follow-up tools can be defined: indicator reports and environmental assessments.

4.1 Indicator reports

Short indicator reports illustrate the annual state of a relevant parameter from various aspects, and the results can also be studied against long-term values. The main conclusions are emphasised using a few compact statements. These reports can also consist of various parameters with causal connection (such as oxygen content of the near bottom waters and cyanobacterial blooms).

The excess of nutrients, which shows as eutrophication, is first reflected in increased pelagic algal production and subsequently as intensification and enhanced frequency of phytoplankton blooms. The varying nutrient ratios can also increase the occurrence of novel and potentially harmful blooms.

Examples of indicator reports on nutrients and phytoplankton:

Horizontal variation of dissolved nutrients in the Baltic Sea in 2002 (Appendix 3.)
Phytoplankton biomass and species succession in 2002 in the Gulf of Finland (Appendix 4.)

4.2 Environmental assessments

The more comprehensive periodic assessments of the state of the Baltic marine environment include more background information about the characteristics of the sea basin, the long-term development, and compiled information based on various indicator reports.

The Gulf of Finland is the markedly eutrophied sub-basin of the Baltic Sea with its subsequent ecological problems. The high nutrient levels are connected mainly to the huge anthropogenic load from St. Petersburg and the River Neva. Furthermore, there is no sill separating the gulf from the Baltic Proper and thus the phosphorus-rich deep waters of the main sea basin can flow freely into the Gulf of Finland and increase its nutrient reserves.

An example of environmental assessment:

State of the Gulf of Finland in 2002 (Appendix 5.)

5. EXAMPLES OF APPLIED SCIENTIFIC USE OF ALG@LINE DATA SETS

Tapani Stipa, Vivi Fleming, Urmas Lips, Lauri London, Jenni Vepsäläinen, Emil Nyman & Eija Rantajärvi

5.1 Phytoplankton spring bloom estimate

In the Baltic Sea the algal growth is strongly affected by seasonality, and the phytoplankton biomass is highest during the spring bloom. Therefore, to evaluate the level of eutrophication in a sea basin the development of a representative estimate to quantify the spring bloom is essential.

During the winter the water is rich in nutrients, but as long the surface water stratification remains weak and the availability of light is limited, the phytoplankton biomass remains low. As the surface water stratifies and the amount of light increases, the biomass of phytoplankton (diatoms, dinoflagellates) increases massively during a short spring period. Although the algal cells appear quite evenly mixed in the upper water column, the spatial and temporal variability is high. Thus, an appropriate sampling resolution is needed to reveal regional differences and long-term changes reliably. The Alg@line SOOP measurements provide a favourable data set with high spatial and temporal frequency to develop the estimate for the spring bloom, which varies in the length and intensity between the years as well as the sea basins.

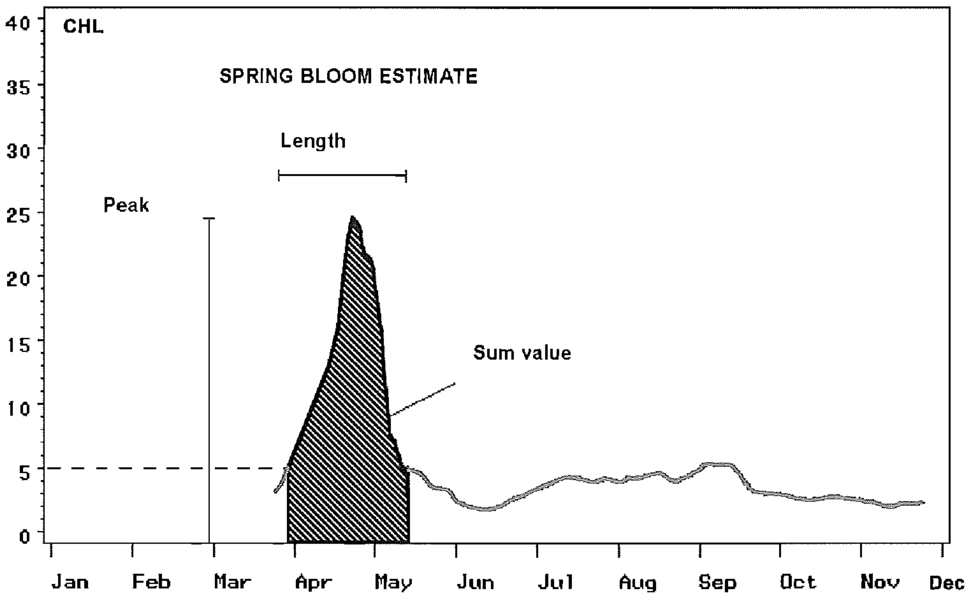

Fig. 6. The SOOP data set on chlorophyll *a* (µg l^{-1}, seven day moving average) in the western Gulf of Finland during the spring bloom in 1992. The quantity of the spring bloom can be counted by setting threshold levels for the beginning and the end of the bloom, and integrating the chlorophyll curve and thus calculating the sum value. The sum value stands for the intensity and length of the bloom and enables the comparison of the quantity of spring bloom between the years and the sea basins when the thickness of euphotic mixed layer remains even.

5.2 Upwelling studies

Temperature and salinity data collected automatically along the SOOP transect Tallinn – Helsinki were used for the identification of upwelling events at the opposite coasts of the Gulf of Finland. The upwelled water, since it originates from the deeper layers, is usually cold. The upwellings can transport water rich in nutrients from the deeper layers to the upper euphotic layer, where the phytoplankton can take use of it. The upwellings appear when along-shore winds are blowing: the eastern winds cause upwellings near the Estonian coast and the western winds near the Finnish coast. The water temperature data recorded onboard a ferry allows the detection of how much water from the deeper layer was transported to the euphotic layer and how intense was the related nutrient flux was. The method developed is based on the comparison of the near coast water temperature and the mean water temperature across the whole Gulf of Finland.

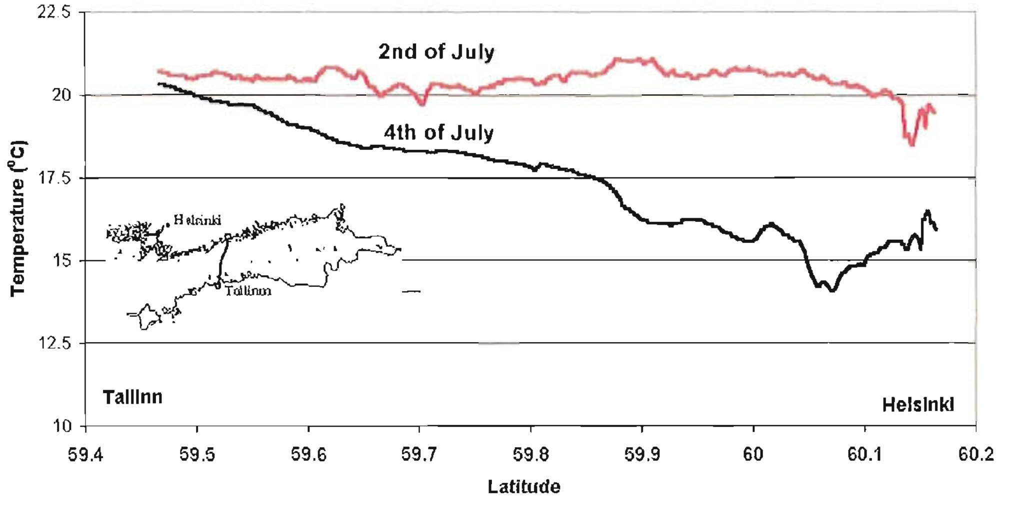

Fig. 7. In case of upwelling the temperature decreases: the temperature profiles before (the 2nd of July) and during (the 4th of july) an upwelling event in 1999 along the transect Tallinn – Helsinki.

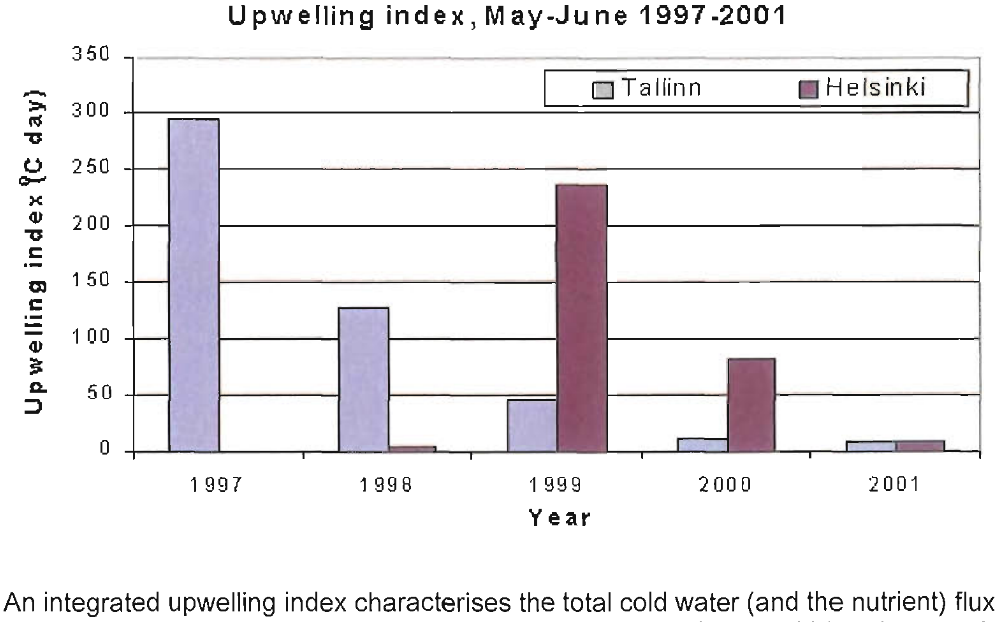

Fig. 8. An integrated upwelling index characterises the total cold water (and the nutrient) flux intensity during the certain time period. The upwelling activity in May-June of 1997-2001 varies greatly between the years.

5.3 Models

Numerical models can at best be as good as the assumptions they are built on. The typical ecosystem structure in numerical models used for research purposes is nowadays quite complicated, including a size-structured ecosystem, mixotrophy and variations in the cellular quota. The total number of state variables prognosed by these models can be up to one hundred. All conversions between state variables require parameterisations and functional dependencies, which due to the complexity of biological systems are not always well resolved by laboratory experiments, however detailed the experiments themselves might be.

Therefore, the basin-scale ecosystem models must be validated to make sure that their behaviour agrees with observations. Enter the problem of data availability: numerical models can produce an estimate for the state of the Baltic Sea ecosystem with a spatial separation of kilometres and a temporal resolution of tens of minutes. Hardly any observational data can match this information flow.

The Alg@line SOOP data, however, comes relatively close to these requirements. Its spatial coverage of the whole Baltic Sea, as well as the multitude of parameters that can be measured every week, makes it possible to follow at least the main succession features of the ecosystem. As the most coarse measure of validation, these seasonal, basin-wide features seen in the data should match those modelled.

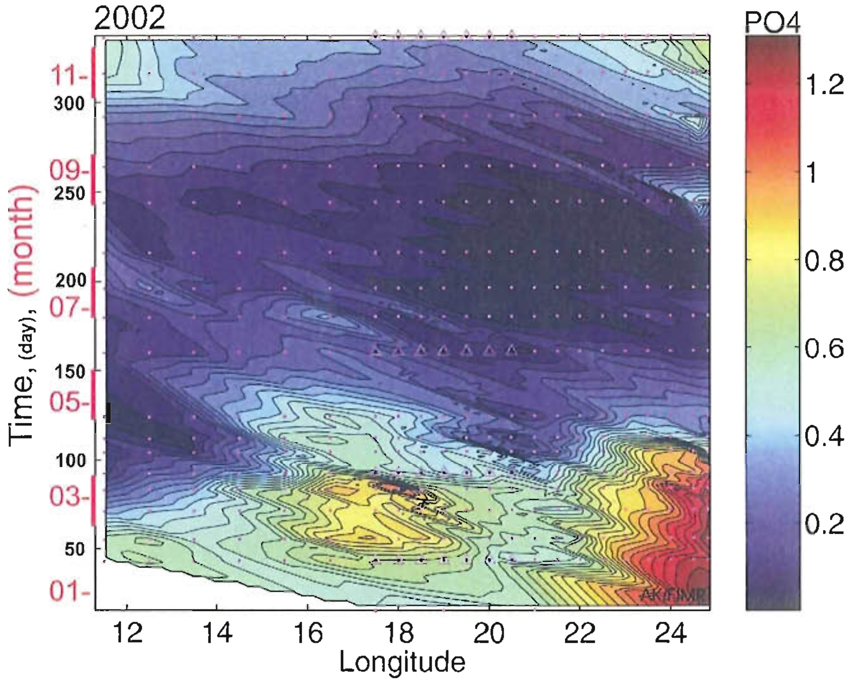

Fig. 9. The good spatio-temporal coverage of SOOP measurements is illuminated by the Hovmöller diagrams. The annual differences in nutrient conditions can easily be found, which helps to focus the research on scientifically interesting locations. The diagrams may also provide guidance to the study of physical-biological interactions from e.g. the analysis of temperature and salinity structure in relation to the plankton biomass. For details see appendix 3.

The Alg@line dataset is currently being used for the validation of Baltic Sea ecological models within NoComments project. There the Hovmöller diagrams of nutrients, based on SOOP sampling results, are compared to the corresponding diagram derived from the model results. Differences e.g. in the timing of the spring bloom and summer dissolved inorganic phosphate concentrations can be compared. Also, Alg@line SOOP data provides some basin-wide information of the coverage of phytoplankton standing stock in the oligotrophic summer season, which has been used to validate the net effects of regenerated production during this period.

The HABES Gulf of Finland pilot project has focused on predicting the timing and magnitude of annual late summer cyanobacterial blooms in the region. The modelling of bloom formation is based on fuzzy logic principles, which permits expert knowledge to be used along with accurate data to produce a reliable prediction of bloom events. At the moment the model is developed for the common bloom forming cyanobacteria in the northern Baltic Sea, the toxic *Nodularia spumigena*. Future goals include a species separation in the model between *N. spumigena* and *Aphanizomenon* sp.. The main factors influencing the formation of a harmful algal event included in the model are: excess phosphorus after the spring bloom, pre-bloom period phosphorus input by turbulent mixing and upwelling, surface layer temperature, wind speed and direction, growth rate and wind forced current scenarios. The test runs with the model have been done with Alg@line SOOP data for the years 1997-2001. The bloom magnitude was shown to be predicted with a reasonable accuracy and the model could clearly separate years of low and high bloom intensity.

5.4 Optical remote sensing

The Alg@line SOOP data has been successfully used as reference data for optical remote sensing measurements.

The project studying the usability of various satellite instrument data (SeaWiFS, MODIS and MERIS) for monitoring of coastal waters and lakes in Finland as well as the Baltic Sea is ongoing by the Finnish Environment Institute, Helsinki University of Technology / Laboratory of Space Technology and Finnish Institute of Marine Research. The combination of Alg@line SOOP data and satellite data enables accurate calibration of satellite measurements over wide areas on a daily basis. The Alg@line data from the route Helsinki-Lübeck with four weekly transects crossing the Baltic Sea have been utilized. The shipborne chl *a* data was calculated to correspond with SeaWiFS and MODIS pixels on the ship route. The use of high-frequency ship-borne data solved some of the difficulties concerning turbid waters.

The optical properties of the turbid water areas have a clear influence on the functionality of the remote sensing water quality algorithm, especially if all of the turbidity is not caused by the phytoplankton, as in the Baltic Sea. Difficulties to the chl *a* estimation are caused by yellow substance, suspended matter and atmosphere. This means that the remote sensing algorithms for chl *a* require a calibration to the local conditions.

SeaWiFS and MODIS instruments have shown the possibilities of the combined use of the remote sensing data and SOOP measurements to estimate basin-wide phytoplankton biomass. Optical satellite data together with fluorometer data provides a practical and novel tool for operative determination of chl-*a* concentrations. The combined use of both methods ensures that spatially covered information on the chl-*a* concentrations can be provided with competent accuracy.

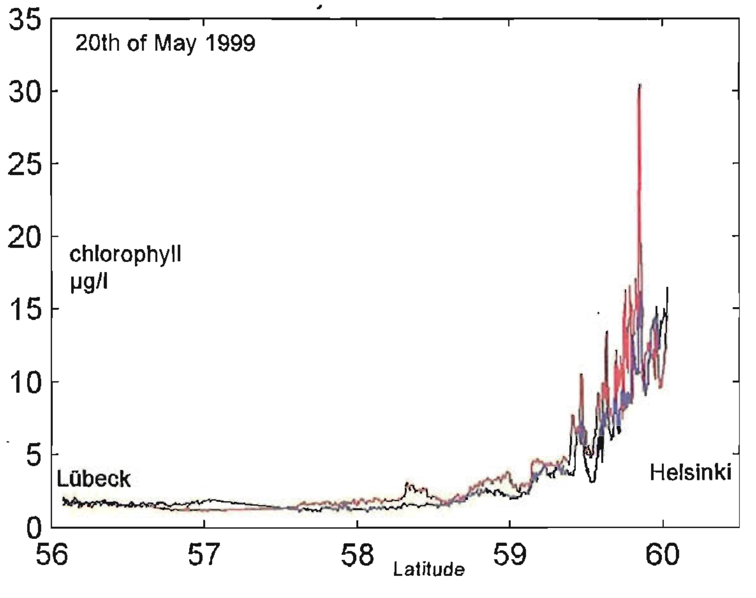

Fig. 10. The Alg@line SOOP chlorophyll values (blue) and satellite (SeaWiFS) estimated values on the ship route on the 20th of May 1999. The SeaWiFS estimates followed the fluorometer measurements closely. Generally, the algorithms describe the behaviour of the chl *a* fluctuations well on different days and on varying sites along the ship route.

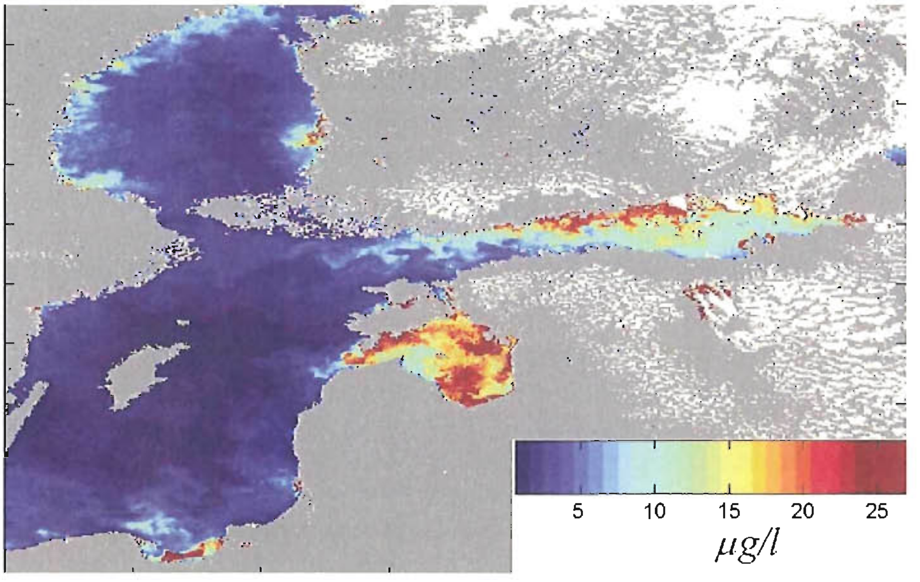

Fig. 11. SeaWiFS estimated chlorophyll map for the Baltic Sea on the 20th of May 1999.

In the GIS laboratory of Environmental biology, at the University of Helsinki, the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data were studied against shipborne Alg@line data. The aim of the study was to test the correlation between the remote sensing signal and the *in situ* measurements and to develop retrieval algorithms for chlorophyll a concentrations for the Baltic Sea. The MODIS images were processed using HDF Look-MODIS, GRASS and Excel programs. The Alg@line chlorophyll data were used as ground truth data. Different MODIS band ratio reflectances where combined with Alg@line field data using linear regression. Two days from April and May in 2001 were examined. The spring of 2001 was moderately cloudy. On 9th May there was only light cloud cover thus the correlation between images and ground measurements was higher than on 20th April when there were more non-transparent clouds.

6. Alg@line IN 2010?

Eija Rantajärvi, Tapani Stipa, Samuli Neuvonen, Tapio Suominen, Seppo Kaitala, Harri Kankaanpää, Jukka Seppälä, Matti Perttilä, Mika Raateoja & Hannu Haahti

There is an urgent need to improve the management and usability of the large Alg@line data sets. The central aim is the creation of a database, which can be expanded, step by step, to include more sophisticated functions e.g. for visualisation of data.

The ship-of-opportunity platforms facilitate the adequate monitoring of the highly fluctuating pelagic ecosystem of the Baltic Sea. At present, the SOOP phytoplankton measurements on board Alg@line ships are already supplemented with various physical parameters (salinity, temperature) as well as chemical laboratory analyses (nutrients), to give additional information of the water masses. CPR has expanded the effective monitoring on zooplankton as well. The scope of marine research would widen essentially and the appropriateness of measurements increase if new sensors such as FRRF (Fast-Repetition-Rate-Fluorometry), *in vivo* fluorescence of phycocyanin (main cyanobacterial pigment), *in situ* nutrients, CO_2, CDOM and turbidity, were applied to unattended use.

The possibilities of optical remote sensing are also increasing. However, as the number of cloudy days is considerably high in our sea areas, they will never exclude the importance of field data. The relevant ground truth data is also needed for calibration of satellite images, which is especially essential in high turbid waters of the Baltic Sea.

A new and interesting approach in marine research is the development of models, new analyses and inversion tools.

6.1 Usability of Alg@line data

6.1.1 Developing a database

The Algabase –project, initiated unofficially in spring 2002, aims to create a database system for efficient management of all Alg@line data. At present the basic work for the structure for the relational database has been done, but there is no further funding to put it to practice.

The need for a proper database became obvious as the diversity and the amount of collected data increased. The existence of a centralised database would facilitate the management, usability and quality control of the data. The value of the Alg@line data will even increase by time as the time-series extend which emphasizes the importance of proper management and storage of data.

At present, the Alg@line data is gathered from several partners as various types of files via e-mail or FTP and later stored on CD-ROMs. Because of this the use of data is laborious and slow considering the approach of fast information dissemination and the needs of scientific research. Algabase aims to create an integrated relational database with an easy-to-use interface for all the productive partners of Alg@line. It would enable partners to insert their own data in to the database and also to retrieve the ones collected by other partners. In addition it would increase the possibilities to make data queries and to easily combine different types of observations. The new database with a user-friendly interface would facilitate the approach of fast reporting by improving the accessibility of the data for all the partners. Furthermore, it would enable the development of sophisticated reporting routines. On top of the database an exporting tools could be built, which make it easier to produce formal reports for different purposes e.g. for the needs of various instances (HELCOM, ICES, EDMED, EDIOS). The interface could also be enabled with visualisation tools or even upgraded to a Geographical Information System (GIS) by incorporating spatial and map functions using available software.

6.1.2 GIS – tells more than a thousand words

In the case of Alg@line the Geographic Information System could be used both in data visualisation and in analyses. Visualisation means the conversion of geospatial data into graphic presentations, such as maps. This approach to visualise the Alg@line data serves not only the scientific reporting but also public announcements delivered via the Internet or traditional media. It makes it easier to analyse the geospatial data and to provide more 'readable' information for decision makers and for the public. The visualisation process can also be interactive: the user has the possibility of changing the map properties in order to get the needed information.

Within the Alg@line project a variety of visual presentations are used mostly in order to increase the informative quality of communications e.g. by providing maps on cyanobacterial surface blooms. However, at present the results of SOOP measurements are shown separately for each ship, although more important for the user is to get all the relevant data from a specific sea area. For example all the shipborne data collected by different partners for weekly basis could be presented on the same map. When realized the centralised Alg@line database facilitates the approach of optimal data visualisation. By providing access to all Alg@line data the common database would make possible to perform the data queries where different types of observations can be easily combined.

A proper GIS interface includes basic tools for data importing from the database to a GIS file format and for visualisation. It can enable scientific analysis, such as basic statistics (averages, standard deviation etc.), all based on the geographical components of the data. In addition, GIS facilitates the combined analyses of different data types (e.g. phytoplankton species, chl *a*, nutrients, temperature), which could be overlaid and desired combinations of attributes calculated for a selected sea basin. Nevertheless, one has to keep in mind that these scientific analyses are always interactive and can never be totally automated. The need of experienced persons with wide understanding of the causal connections of the Baltic Sea ecology can never be underestimated.

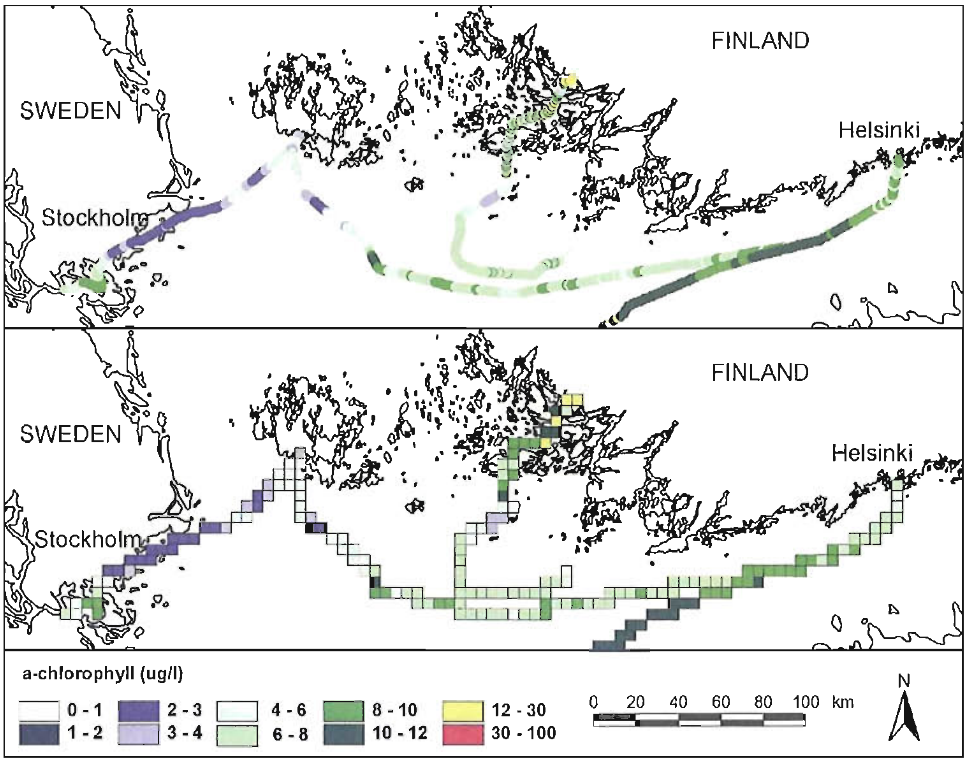

Fig. 12. An example of visualisation of all ship-borne data (Silja Serenade, Finnpartner, guard ship Telkkä) from the northern Baltic proper between 22nd and 25th July in 2002. All chl *a* measurements are presented as a successive points (above) and data averaged by 5 × 5 km grid (below).

6.2 New sensors onboard

6.2.1 Phytoplankton and algal toxins

The present SOOP recordings on *in vivo* fluorescence of chlorophyll *a* provides a measure for relative phytoplankton biomass. It is not an exact estimate as the ratio of *in vivo* fluorescence to chlorophyll *a* varies due to phytoplankton species composition and physiological status of cells.

In order to receive complementary information the inclusion of devices measuring variable fluorescence (e.g. Fast-Repetition-Rate-Fluorometry, FRRF) to SOOP measurements would enable also to record the photosynthetic rate and physiological state of phytoplankton. Variable fluorescence is connected to the physiological activity of phytoplankton cells and can give information of the response of phytoplankton to environmental circumstances such as availability of nutrients.

For cyanobacteria, most of the chlorophyll *a* is in pigment complexes showing low fluorescence yield. As a result the recording of *in vivo* fluorescence of chlorophyll *a* is not the most appropriate measure for cyanobacterial blooms. Fortunately, phycobilin pigments of cyanobacteria have autofluorescence, and can be used instead. There is a plan that a pilot project to record *in vivo* fluorescence of phycocyanin on board SOOP could be performed in the near future. If successful it offers a better tool to detect intensity and coverage of cyanobacterial blooms in the Baltic Sea.

The sampling onboard SOOPs could also provide material for cyanobacteria phylogeny studies, which increase the knowledge on variability of different cyanobacterial genotypes as a function of time and space.

The SOOP sampling can also offer an important source for algal toxin monitoring and research. At present, some cyanobacterial toxins are analysed during summer from a few SOOP samples collected from the coastal areas of the Gulf of Finland. There is a plan that the analyses could be expanded to cover the whole Baltic Proper and to include the two most common algal toxins, nodularin (cyanobacteria) and okadaic acid (diatoms). Ideally, the analyses should be performed using the same particulate phytoplankton material that is used for phytoplankton microscopy. Hopefully, a pilot experiment on expanded monitoring of algal toxins within Alg@line framework will be realized already during 2003.

6.2.2 Other optical measurements

Coloured dissolved organic matter (CDOM) found in Baltic Sea is derived mainly from terrestrial sources and acts as a rather conservative tracer. CDOM dominates the light attenuation in the blue part of the spectrum, and is one of the key components in remote sensing algorithms. Automated analyses of CDOM concentrations can be carried out by fixed-wavelength fluorometers, additionally spectral fluorometers can be used in discrimination of different forms of CDOM (terrestrial/marine). The latter devices can be also used in the detection of different oil and phenol types.

Inherent optical properties of water, such as spectral light absorption and scattering, could be measured *in situ* at frequencies suitable to the Alg@line concept. Obviously in the near future the spectral resolution of the contemporary devices will be enhanced. These devices, when coupled with spectral models, could be used e.g. to derive absorption spectra of CDOM and phytoplankton. Further, this spectral data can be used in the estimation of concentrations or in ground truthing the remote sensing signals.

Arbitrary measurements of light scattering can be done with turbidimeters. Obtained turbidity values can be related to the amount of suspended particulate matter in water i.e. phytoplankton, soil, sediments, faecal matter and other particles, and can be used as an index related to water clarity.

6.2.3 Nutrients

At present the SOOP water samples are automatically collected to the refrigerator for later laboratory analyses of nutrients. The samples are kept in cold and dark before analyses, from hours to a couple of days depending on the sampling site. Although the nutrient analyses seem to give reliable results, unpredictable changes can occur when the storage time increases. Also the small-scale changes in nutrient concentrations most probably stay unnoticed. Therefore, the recent developments of *in situ* nutrients sensors are a great step forward. At the moment some equipment are available, but their reliability in unattended use is still somewhat questionable. However, after having more experience from new sensors it might be realistic to include an *in situ* nutrient analyzer to the SOOP equipment in the future.

6.2.4 Carbon dioxide

The carbon dioxide processes in the oceans have received much attention during the past decade because of the progressing green house effect. Although the role of marginal seas is negligible as a global carbon source/sink, the study on the CO_2 -processes in the Baltic Sea can yield new information on the eutrophication and primary production.

The crucial problem when estimating the seasonal CO_2 -budget of the Baltic Sea has been the lack of spatially and temporally frequent data. That would be needed both on total carbon concentration and on the CO_2 -partial pressure in the surface layer. At the present there are plans to install an automatic CO_2 -measurement unit by the Institut für Ostseeforschung (Warnemünde) during 2003 on board the Alg@line's SOOP crossing the Baltic Sea.

6.3 New steps in optical remote sensing

The new satellite instruments such as MODIS (Moderate Resolution Imaging Spectroradiometer) and MERIS (The Medium Resolution Imaging Spectrometer) are more advanced for monitoring of turbid waters, such as the Baltic Sea. They provide better spatial resolution and, most importantly, more appropriate optimal wavelengths to expand the scale of detected phytoplankton pigments and to separate the effect of turbidity. The delay of MODIS satellite images from NASA is now about one week. However, the Finnish Meteorological Institute (FMI) is constructing a MODIS instrument data ground receiving station in Sodankylä, northern Finland. It starts to operate in spring 2003 enabling operative monitoring with MODIS satellite images. Multivariate calibration methods will be tested for chlorophyll *a* retrieval from MODIS channels, and season specific algorithms will be developed to estimate other pigments (e.g. phycobilins) and biomass of chemotaxonomic phytoplankton groups. Also analogous calibrations are planned in FerryBox project with Envisat MERIS instrument data, which will be available during the summer of 2003.

In the calibrations of the new satellite images the Alg@line shipborne data serves as adequate and essential reference data. The possibilities to use SOOP data for verification and calibration of satellite data would widen essentially if new sensors such as CDOM and turbidity are taken to use.

6.4 New approaches in scientific research

A new interesting approach in the field of marine research is the development of new analysis and inversion tools, which are expected to allow the estimation of the ecological state of large sea areas from considerably scarce measurements.

Moreover, new towed and/or acoustic instruments will enable the modellers to invert the state of the higher trophic levels in the whole Baltic Sea. At present, Alg@line provides comprehensive shipborne surface layer measurements of phytoplankton and zooplankton as well as of some hydrographical parameters. While the SOOP results are complemented with measurements made on board research vessels, it is possible to follow the phytoplankton and zooplankton assemblages down to their abyssal hideouts. Hence expanding the knowledge on ecological interactions between primary producers and their grazers.

It can be expected that in ten years the development of ecosystem models will have already been integrated with fish stock modelling. Then, maybe within the Alg@line project, there could also be weekly fish stock surveys along the SOOP tracks, which can be analysed with the models and thus an on-line fish stock assessment system could be maintained.

There is a vision that in ten years time new methods, analyses and inversion tools, will offer reliable estimates on ecological state of the sea areas based on the results from a single SOOP transect crossing the Baltic Sea.

7. SOME METADATA INFORMATION FROM THE 'SHIPS-OF-OPPORTUNITY'

Vivi Fleming

The high frequency measurements made onboard several Alg@line SOOPs have already produced a large amount of valuable data.

The number of observations of the semi-continious SOOP measurements and the number of analyses made from the water samples are given in Tables 1-3. The information is provided from the SOOP ships Finnjet, Konstantin Simonov, Finnpartner, Silja Serenade and Wasa Queen and is divided according three large sea areas.

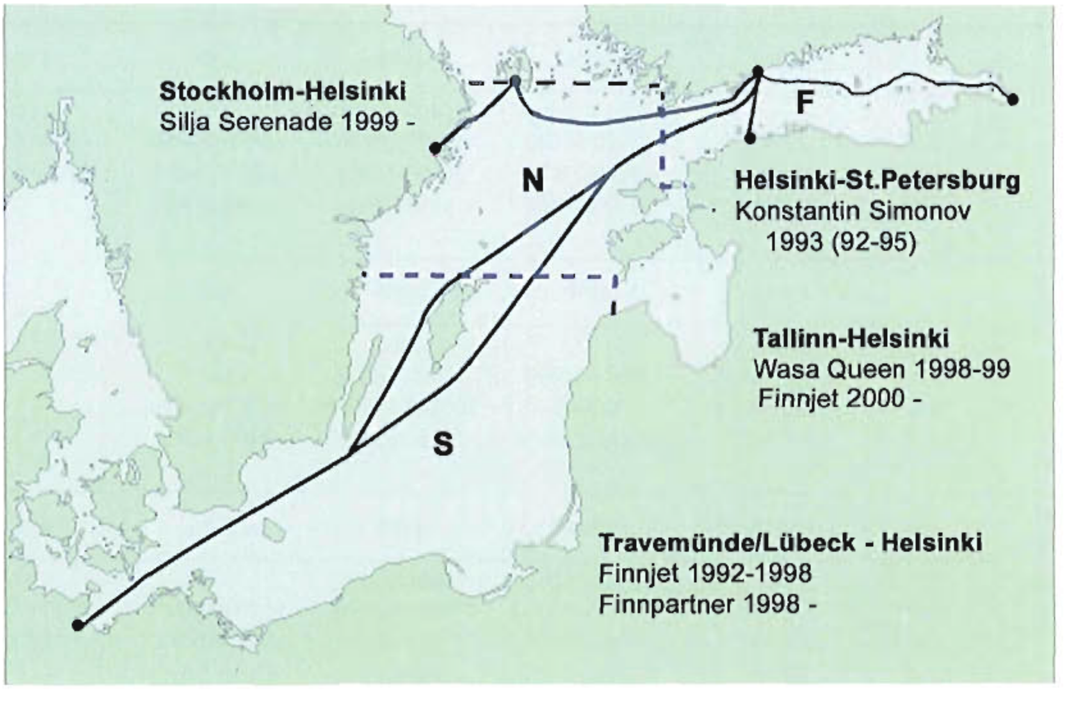

Fig. 13. The main SOOP routes of Alg@line and operational years. The symbols for sea areas are also given (Gulf of Finland (F), northern Baltic (N), southern Baltic (S)).

Table 1. The number of observations of the semi-continious SOOP measurements (Finnjet, Finnpartner, Konstantin Simonov, Silja Serenade, Wasa Queen). If the number of observations in different parameters (*in vivo* fluorescence of chlorophyll *a*, temperature, salinity) varies, the minimum and maximum numbers are presented; if the number of all parameters is equal, only one number is given.

Gulf of Finland (F)		1993	1994	1995	1996	1997
months	1-2	-	2900-4600	1000-1100	-	5600-7800
	3-5	25000	18000-19000	22000-30000	8300-14000	27000-36000
	6-9	38000	29000-32000	19000-24000	34000-42000	32000-33000
	10-12	12000	14000-16000	1800-4300	9000-13000	-

Gulf of Finland (F)		1998	1999	2000	2001
months	1-2	2000	-	-140	-4500
	3-5	20000-23000	49000-130000	47000-120000	52000-73000
	6-9	30000-33000	120000-240000	50000-120000	55000-90000
	10-12	3300	72000-79000	21000-67000	2100-7600

Northern Baltic (N)		1993	1994	1995	1996	1997
months	1-2	-	10000-14000	2400-2700	-	-14000
	3-5	52000	41000-45000	45000-60000	28000-40000	46000-62000
	6-9	76000	66000-73000	36000-44000	60000-76000	59000-60000
	10-12	23000	29000-34000	3800-8800	16000-22000	-

Northern Baltic (N)		1998	1999	2000	2001
months	1-2	3600	-	-1300	-8000
	3-5	41000-46000	79000-81000	12000-13000	140000
	6-9	57000-64000	300000	100000-160000	120000-160000
	10-12	-7700	190000-200000	45000-46000	3800-14000

Southern Baltic (S)		1993	1994	1995	1996	1997
months	1-2	-	42000-56000	8600-9300	-	-51000
	3-5	190000	140000-150000	140000-190000	99000-140000	160000-220000
	6-9	270000	220000-250000	120000-150000	230000-290000	220000
	10-12	70000	93000-110000	12000-24000	65000-84000	-

Southern Baltic (S)		1998	1999	2000	2001
months	1-2	120000	-	-5900	-29000
	3-5	130000-150000	92000-10000	120000	140000-150000
	6-9	190000-210000	230000	230000-430000	230000-360000
	10-12	-26000	10000-140000	99000-100000	13000-45000

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Gulf of Finland (F)		1993	1994	1995	1996	1997
months	1-2	-	-3	-2	-2	-12
	3-5	12-13	7-19	10-20	17-30	22-50
	6-9	35-77	19-37	15-36	42-84	48-83
	10-12	14-16	10-11	3	24-35	-

Gulf of Finland (F)		1998	1999	2000	2001
months	1-2	-9	-	6	6-12
	3-5	102-142	42-111	42-233	48-139
	6-9	83-283	54-262	37-336	30-331
	10-12	33-61	24-101	18-115	24-83

Northern Baltic (N)		1993	1994	1995	1996	1997
months	1-2	-	-4	-6	-5	-10
	3-5	22	23-50	28-48	28-34	28-52
	6-9	29-75	36-70	33-83	37-74	43-74
	10-12	12-14	28-29	10	20-30	-

Northern Baltic (N)		1998	1999	2000	2001
months	1-2	-13	-	4	5-10
	3-5	30-52	35-57	53-116	42-67
	6-9	25-134	57-181	43-168	25-142
	10-12	11	24-89	15-62	20-50

Southern Baltic (S)		1993	1994	1995	1996	1997
months	1-2	-	-17	-16	-17	-26
	3-5	97-98	70-159	81-145	46-63	94-164
	6-9	100-255	124-229	118-283	89-180	88-176
	10-12	46-51	80	35	52-77	-

Southern Baltic (S)		1998	1999	2000	2001
months	1-2	-26	-	6-7	13-26
	3-5	78-149	90-91	76-103	102-128
	6-9	77-203	94-186	83-164	64-177
	10-12	34-36	50-95	39-63	52-62

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Gulf of Finland (F)		1993	1994	1995	1996	1997
months	1-2	–	–	–	–	–
	3-5	8	18	11	20	47
	6-9	45	20	14	37	166
	10-12	2	3	1	8	59

Gulf of Finland (F)		1998	1999	2000	2001
months	1-2	–	1	–	–
	3-5	79	77	103	66
	6-9	171	160	171	141
	10-12	33	24	65	38

Northern Baltic (N)		1993	1994	1995	1996	1997
months	1-2	–	–	–	–	–
	3-5	12	32	19	21	29
	6-9	26	34	35	30	26
	10-12	2	4	5	6	10

Northern Baltic (N)		1998	1999	2000	2001
months	1-2	–	–	–	–
	3-5	22	21	19	27
	6-9	19	25	38	43
	10-12	–	–	–	11

Southern Baltic (S)		1993	1994	1995	1996	1997
months	1-2	–	–	–	–	–
	3-5	48	81	48	33	44
	6-9	114	106	102	82	49
	10-12	9	20	17	21	26

Southern Baltic (S)		1998	1999	2000	2001
months	1-2	–	1	–	1
	3-5	63	53	54	32
	6-9	61	55	98	34
	10-12	2	–	7	23

8. PROJECTS WHERE Alg@line DATA HAVE BEEN UTILIZED

The Alg@line SOOP data (1998-99) are used in a project at FIMR which focuses on ecology and morphological variation of the invasive dinoflagellate *Prorocentrum minimum* in the Baltic Sea. The data were also used in a project (1999-2000) which focused on genetic and morphological diversity of cyanobacterium Aphanizomenon flos-aquae in the Baltic Sea and four coastal lakes.

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	6-9	29-75	36-70	33-83	37-74	43-74
	10-12	12-14	28-29	10	20-30	-

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	10-12	11	24-89	15-62	20-50

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	10-12	46-51	80	35	52-77	-

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months	1-2	–	1	–	–
	3-5	79	77	103	66
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months	1-2	–	–	–	–	–
	3-5	12	32	19	21	29
	6-9	26	34	35	30	26
	10-12	2	4	5	6	10

Northern Baltic (N)		1998	1999	2000	2001
months	1-2	–	–	–	–
	3-5	22	21	19	27
	6-9	19	25	38	43
	10-12	–	–	–	11

Southern Baltic (S)		1993	1994	1995	1996	1997
months	1-2	–	–	–	–	–
	3-5	48	81	48	33	44
	6-9	114	106	102	82	49
	10-12	9	20	17	21	26

Southern Baltic (S)		1998	1999	2000	2001
months	1-2	–	1	–	1
	3-5	63	53	54	32
	6-9	61	55	98	34
	10-12	2	–	7	23

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The Alg@line SOOP data from the year 1994 were used at FIMR to test the appropriate sampling frequency for the evaluation of long-term trends in phytoplankton estimates. The analysis was done for spring and summer bloom periods in the western Gulf of Finland and in the Arkona Sea. Also the relationships between phytoplankton species composition and environmental factors were studied in the central and eastern Gulf of Finland using SOOP data from year 1993. Variability in the phytoplankton community was investigated using multivariate analyses.

The Alg@line SOOP data from years 1993–2000 were used at FIMR to study the long-term and seasonal distribution of dinoflagellates in the Northern Baltic Proper and the Western Gulf of Finland. The study had three main objectives, namely to discover which external factors control the occurrence of the dinoflagellate taxa, to uncover patterns of co-occurring taxa in the dinoflagellate community, and to reveal trends in temporal and spatial distribution of dinoflagellates.

The Environment Cluster funded project 'Cost effective water protection in the Gulf of Finland' (1998-2002) has utilized Alg@line SOOP data in the ecosystem model development and validation. The model has been further used in the evaluation of the ecological effects archived by various water protection measures. As a by product of the project, cyanobacteria bloom forecast system has been built up at the FEI. The winter nutrient concentrations, produced by FIMR and Alg@line, were used as starting values for the forecast.

The ongoing projects where satellite estimates based on Alg@line data are utilized: 1. The detection of algae in the Baltic Sea by using optical remote sensing data from spring to late August (2002) funded by the Maj and Tor Nessling foundation. 2. Assessment of the usability of ENVISAT MERIS, AATSR and ASAR data in monitoring of coastal waters and lakes in Finland (nationally funded project / TEKES, 1999-2002). Part of the ESA ENVISAT AO-400 project 'Assessment of the usability of ENVISAT MERIS, AATSR, ASAR data in monitoring of coastal waters, inland lakes and snow in Finland'. 3. Assimilation of remote sensing data to physical models in environmental monitoring and forecasting (ASSIMENVI) (nationally funded project / TEKES,2001-2004). 4. Operative remote sensing methods for environmental monitoring (OPERENVI) (nationally funded project / TEKES, 2002-2003).

The 'NoComments' project, funded by the Nordic Council of Ministers (2000-02), use Alg@line dataset for the validation of Baltic Sea ecological models. The diagrams based nutrient analyses of SOOP water samples are compared to the corresponding diagram derived from the model results.

The CHARM (Characterisation of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types; 2001-04) project will develop recommendations on typology, reference conditions and monitoring strategies for implementing the EC Water Framework Directive in the coastal zone of the Baltic Sea. The scientific objectives of the study are to develop a common methodology for establishing coastal types in the Baltic Sea by identifying the key factors triggering ecosystem alteration and their relative importance and key indicators for ecosystem functioning in relation to alteration of the coastal ecosystems. In addition, quantitative ecological relationships and empirical models that describe the relationship between anthropogenic pressure and key indicators in the coastal zone and ecological reference conditions for Baltic coastal water bodies will be developed.

The objectives of the HABES project (Harmful Algal Blooms Expert System; 2002-04) are to improve and extend the understanding of the interaction between physical and ecological factors determining the initiation and fate of harmful algal blooms; to provide an expert system and a knowledge base, publicly accessible through the Internet, based upon existing and newly-acquired knowledge on harmful algal blooms. It is an EU funded project producing models, based on fuzzy logic, predicting harmful algal events in European coastal areas. The Alg@line has been used to verify alleged relationships between *Nodularia spumigena* mass occurrences and environmental circumstances.

The HABILE project (Harmful Algae Bloom Initiation in Large European Marine Ecosystems; 2002-04) has evaluated the environmental conditions for *Nodularia* blooms. The study is based on the specific data sets collected on board Alg@line SOOP in the Baltic Proper and in the western Gulf of Finland during 1997-2001.

The 'FerryBox' project (2003-05) within the framework of EuroGOOS compares the use of SOOP in different types of seas (enclosed, coastal, shelf, oceanic, oligotrophic, eutrophic). The data collected is used for calibration and checking of existing oceanographical models and developing of more accurate ones e.g. to predict the effectiveness of measures to reduce eutrophication. It is also provides background data for the European Water Framework Directive. In addition of Alg@line, SOOPs are operational in several sea areas e.g. in the North Sea, in the Dutch Wadden Sea. The system will be installed also to ferries operating in the Mediterranean Sea, in the Irish Sea and in the Bay of Biscay.

The Alg@line SOOP data from route Helsinki–Travemünde during summer 1997 is used to analyse arial variation in nutrients, hydrography and chlorophyll a concentrations, in a study made at the University of Helsinki in 2003.

8.1 Publications where Alg@line data have been utilized

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Automatic Flow-through Analysers on board Ship-of-Opportunity (SOOP)

Petri Maunula

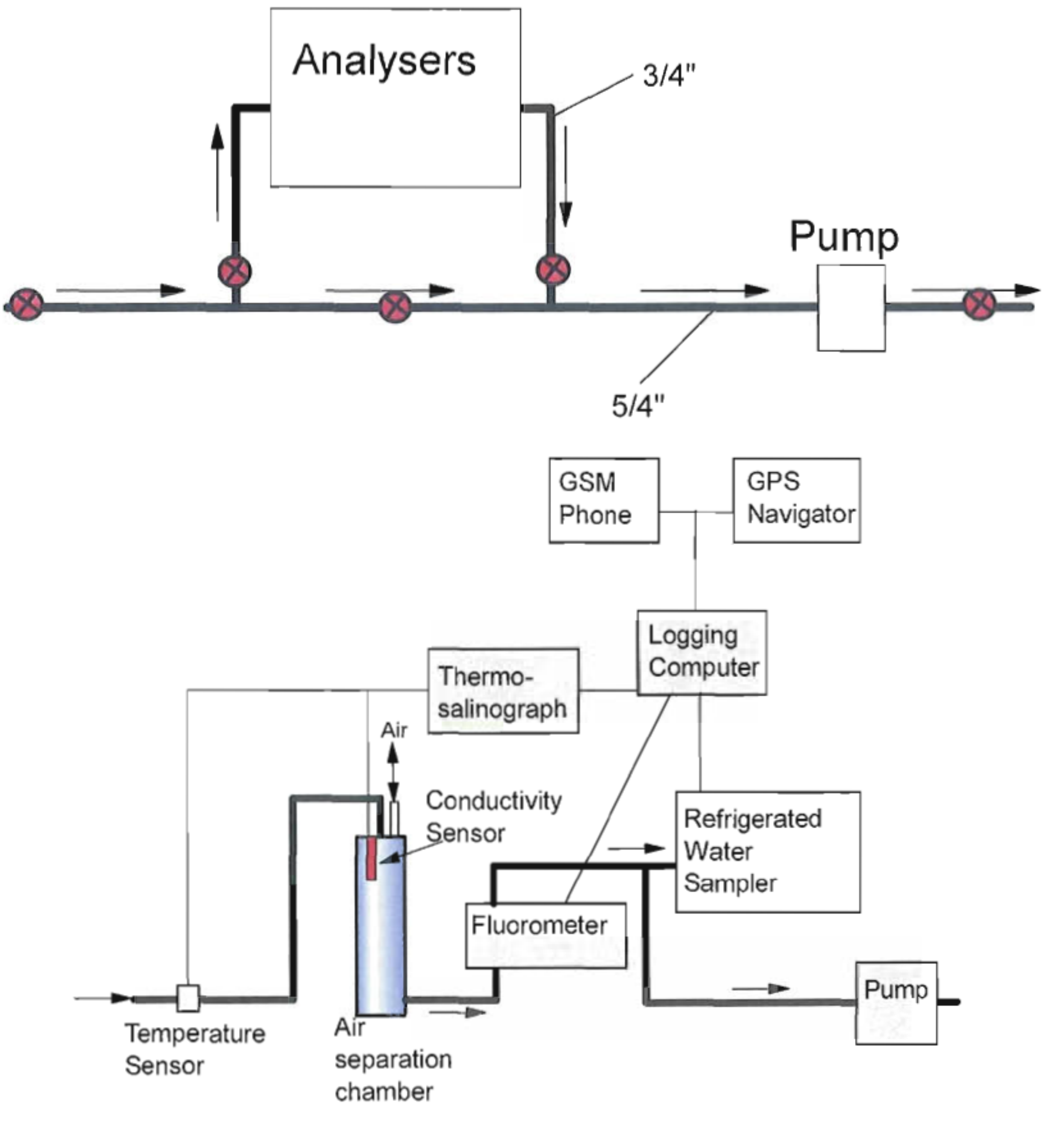


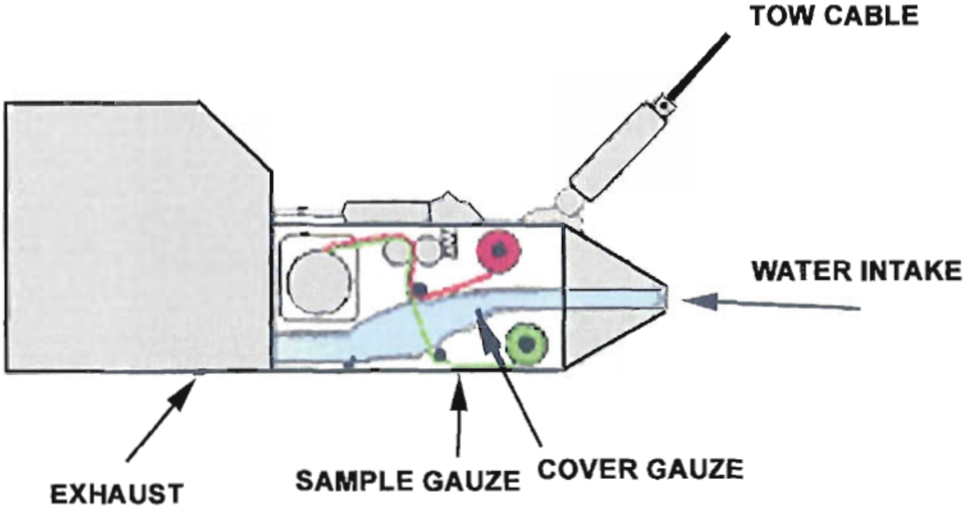
Fig. 1. The schematic diagram of the analyser system.

	Model	Manufacturer	Retailer (Finland)
Fluorometer	Turner 10-AU-005 Fluorometer 10-AU-074 Manual 10-AU-020 Flow-through cuvette 10-AU-115S Cable 10-AU-600 Lamp 10-037R Filters 10-AU-022 Box	Turner Designs 845 W Maude Av Sunnyvale, CA 94086 USA +1 408 749 0994	Navarc OY Tornikatu 9 A 1 21200 Raisio, Finland +358 2 437 1097
Sampler	ISCO Refrigerated Sampler 3700 R	ISCO Inc.-Environmental Div. 531 Westgate Bl Lincoln, Ne 68528 USA +1 800 228 4373	OY Sarlin AB PL 750 00101 Helsinki, Finland +358 9 504 441
Thermo-salinograph	Aanderaa (PT100) Display 3315 Temp-sensor 3444 Sal-sensor 3210	Aanderaa Instruments Fanaveien 13B 5050 Nesttun, Norway +47 5513 2500	Navarc OY Tornikatu 9 A 1 21200 Raisio, Finland +358 2 437 1097
GPS	Shipmate RS 5510	Simrad Shipmate AS Østre Allé 6 DK-9530 Støvring, Denmark +45 98 373 499	AT-Marine OY PL 60 02610 Espoo, Finland +358 9 5494 2600
GSM	Nokia 6080 GSM Nokia cellular data card Modem Cable, antenna etc.	Nokia	Teleska OY Pakilantie 92 00670 Helsinki, Finland +358 9 777 10201
PC	IBM compatible, at least 486 NI-serial port card		
Software	MLM; logging MLX; data transfer MLA; viewing, editing		FIMR
Pump	Grundfos CRN 2	Grundfos Pumput OY AB Mestarintie 11 01730 Vantaa, Finland +358 9 878 9150	Grundfos Pumput OY AB Mestarintie 11 01730 Vantaa, Finland +358 9 878 9150
Pipes	Steel pipes, >1" diameter		
Hoses	Laminated plastic, 3/4" diameter		

Continuous Plankton Recorder (CPR) of FIMR – technical details

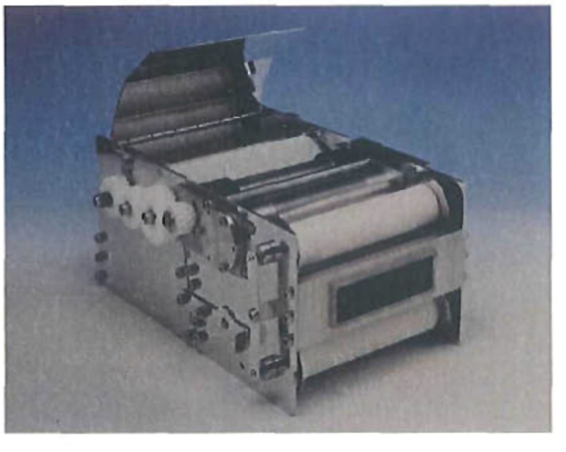
Juha Flinkman

Standard CPR body is equipped with an Autonomous Plankton Sampler (APS) manufactured by Chelsea Technologies Group. It differs from original CPR filter mechanism, which is mechanically driven by a propellor mounted on the back of the CPR body, and advances the gauze constantly. The APS is driven by an electric motor powered by onboard batteries. The unit advances the gauze in steps like film in a camera at preset intervals, so that each sample is distinct from the prvious one. The APS also has flowmeter, and integral processor, so that each advance of the gauze, and flowmeter readings are stored with date-time label. This facilitates accurate geographical placing of each sample, as well as precise abundance calculations.



The illustration is of a standard CPR mechanism. The APS is similar in basic function, only difference is the electric motor and batteries unit housed within the filter cassette.

CPR body complete with APS.



APS Unit.

INDICATOR REPORT

Horizontal variation of dissolved nutrients in the Baltic Sea in 2002

Anniina Kiiltomäki, Eija Rantajärvi & Tapani Stipa

The temporal and spatial variation of dissolved nutrients (phosphate, nitrate and nitrite) was studied in 2002 for this water quality report. The temperature and chlorophyll *a* values were viewed as additional parameters. The Alg@line SOOP data were used, the amount of samples along one voyage from Helsinki to Travemünde was 24 per week.

The values from the year 2001 are used as a reference data.

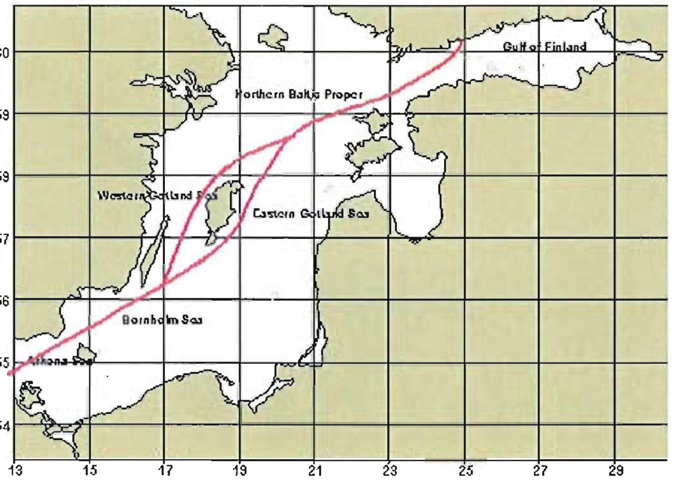


Fig. 1. Route of the merchant ship Finnpartner with Alg@line sampling (Travemünde-Helsinki). In the text the Baltic Sea is divided to following sub-areas: the Arkona Basin (longitude 14.5°-17°), Bornholm Basin (14.5°-17°), Gotland Basin (17°-21°), Northern Baltic Proper (21°-23°) and the Gulf of Finland (23°-24.97°).

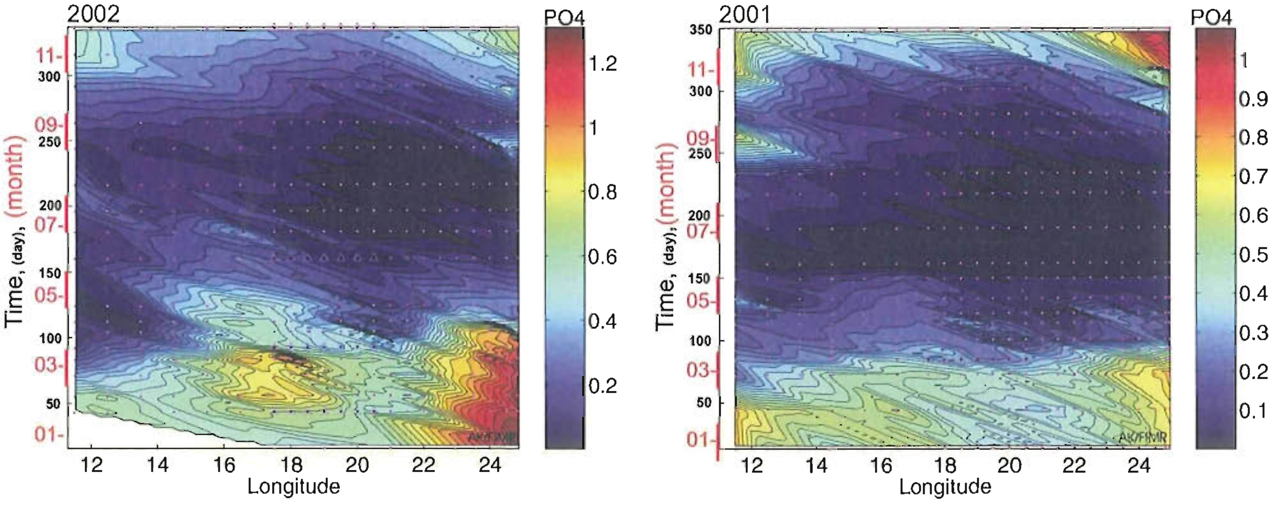


Fig. 2. The annual variation of phosphate (PO_4 µmol l^{-1}) as a function of position and time along the ship route (see Figure 1.), for years 2002 and 2001. The water sampling locations are indicated with red points, and with triangles when the west route was used. Cumulative day number and months are used as a temporal scale.

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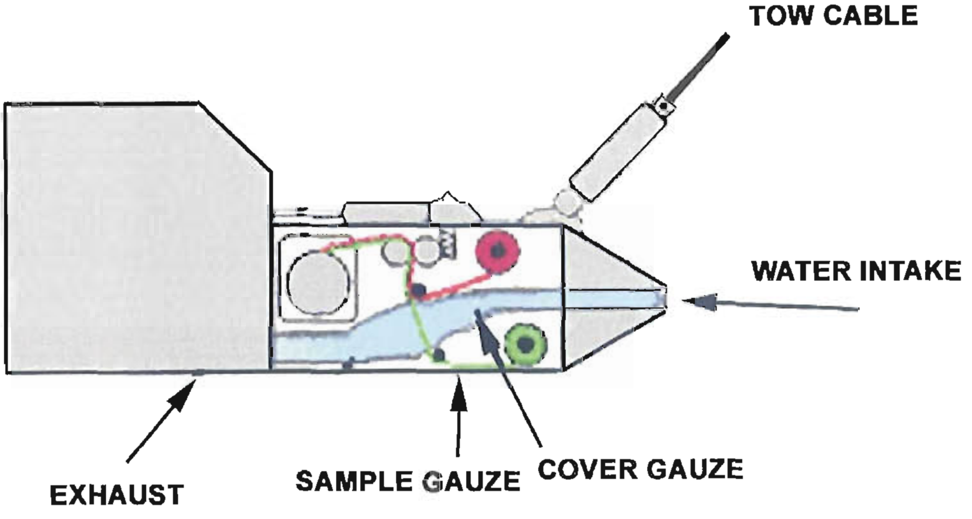

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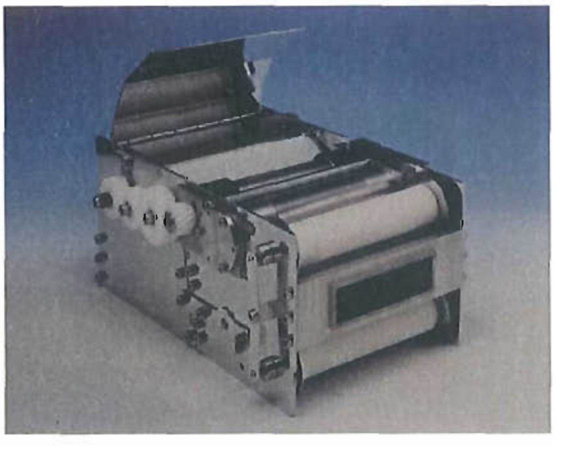
CPR body complete with APS.



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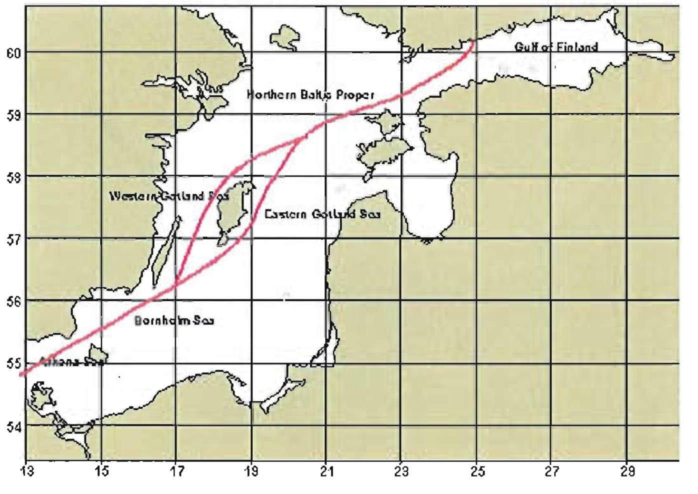

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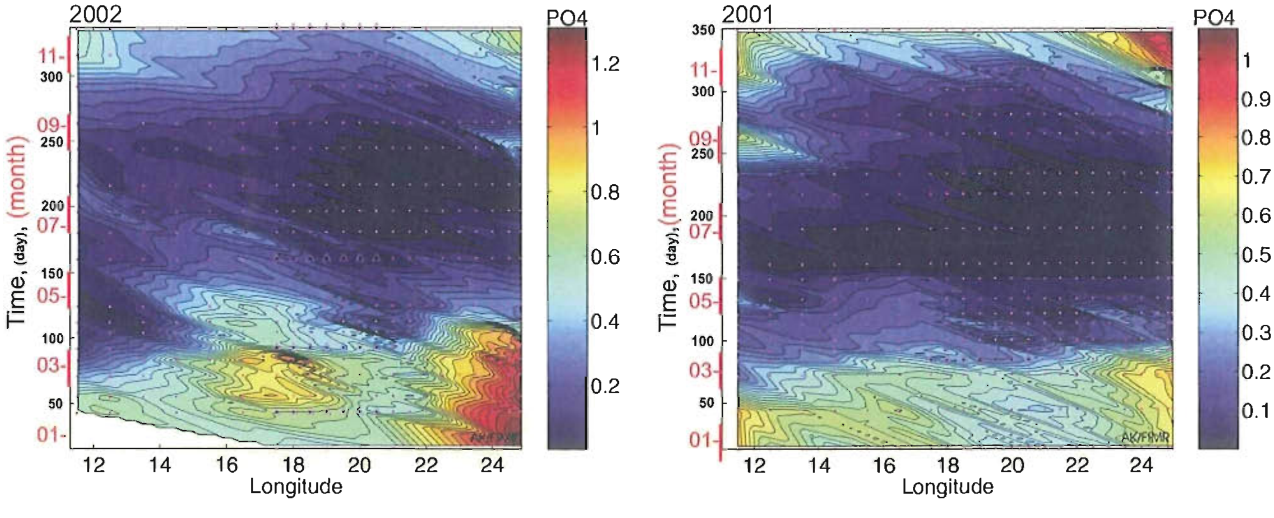

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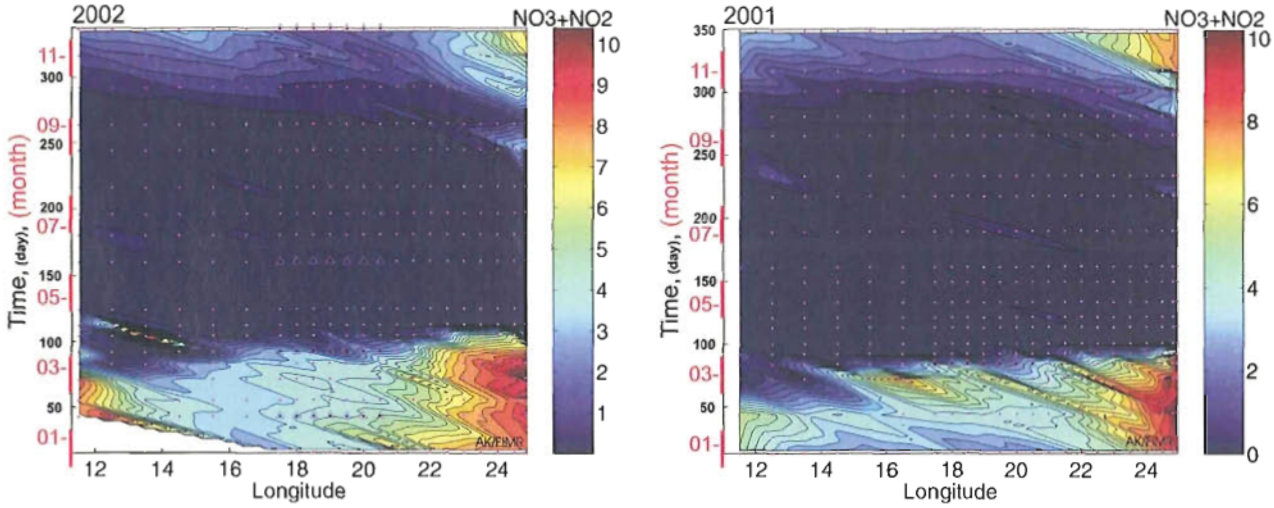


Fig. 3. The annual variation of nitrate and nitrite (NO_3+NO_2 µmol l^{-1}) as a function of position and time along the ship route, for years 2002 and 2001.

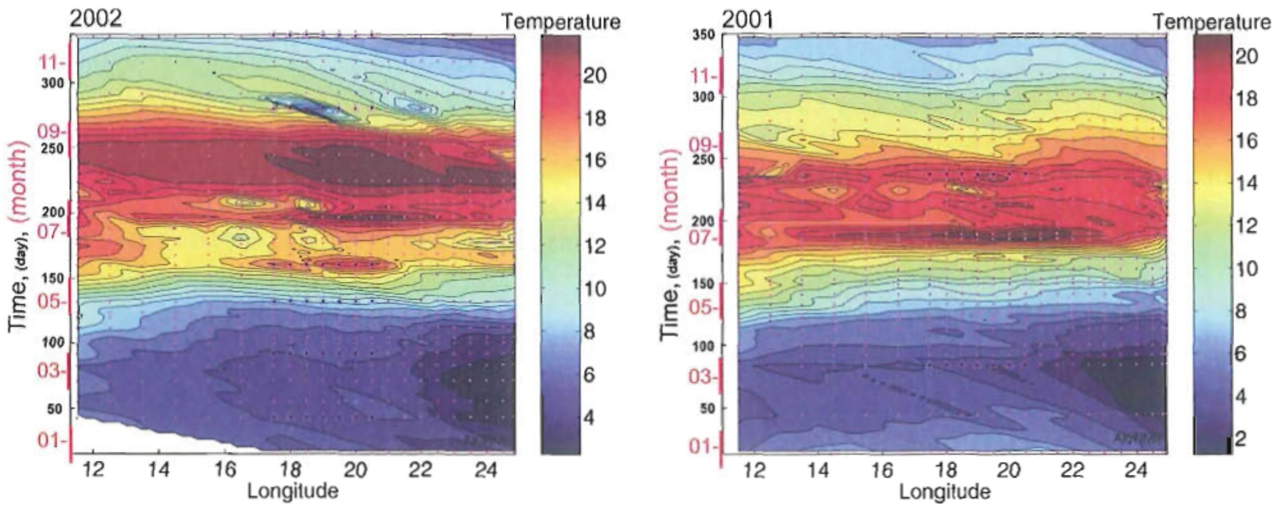


Fig. 4. The annual variation of temperature as a function of position and time along the ship route, for years 2002 and 2001.

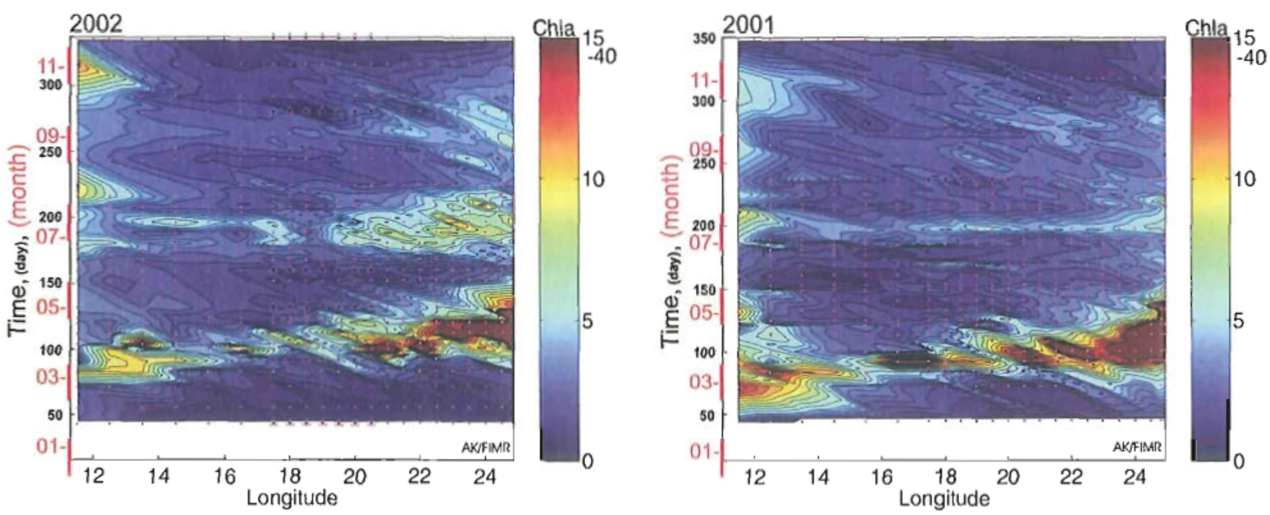


Fig. 5. The annual variation of chlorophyll *a* (mg m^{-3}) as a function of position and time along the ship route, for years 2002 and 2001.

☹ In 2002, the phosphate values were higher throughout the year than in the reference year 2001.

☺ The highest winter nutrient values were measured at the entrance and in the Gulf of Finland.

☺ In the Gotland and Bornholm basins and in the Gulf of Finland an increase in phosphate values in the turn of June/July was probably due to upwellings.

Results and assessment

Relevance of the indicator for describing developments in the environment

Nutrients as such indicate the level of eutrophication in a sea basin. The amount of nutrients (together with the amount of light and the variation in temperature) form the basis for phytoplankton succession.

Chlorophyll *a* concentration is a relative measure of phytoplankton biomass in the water. Since high nutrient concentrations increase the intensity and frequency of phytoplankton blooms, chlorophyll *a* can be used as an indicator of the eutrophication level in a sea basin.

Assessment

The Baltic Sea is strongly affected by seasonality: during the winter the water is rich in nutrients, but as long as the surface water stratification remains weak and the availability of light is limited, the phytoplankton biomass remains low. As the surface water stratifies and the amount of light increases, the biomass of phytoplankton increases massively during a short spring period. When the dissolved nitrogen is depleted from the surface water the algal biomass decreases significantly. The amount of phosphate left over varies between the years. When the sea water gets warmer during summer, the blue-green algae become more common. The occassional upwellings of deeper, nutrient rich water can stimulate the algal growth.

Phosphate (PO_4; µmol l^{-1})

In 2002 the annual concentration range of phosphate varied 0.01-1.4. The highest winter nutrient concentrations were measured at the entrance and in the Gulf of Finland (0.8 -1.4). From the middle of March to the early beginning of May the concentrations decreased < 0.4 in the whole study area.

Exceptionally, in the Gotland and Bornholm basins, clearly elevated concentrations were measured from the middle of February (0.8-1.0) until the end of April (0.5-0.7). In the same area an increase was detected again in the end June to the beginning of July and a weaker one in the Gulf of Finland as an exception compared to other areas. That was probably due to the upwellings.

There is a difference between the years 2002 and 2001 in the phosphate minimum values. In 2001 the phosphate was depleted in middle of June in all areas, in 2002 the decline in phosphate level occurs notably later.

Nitrate and nitrite ($NO_3 + NO_2$; µmol l^{-1})

In 2002 the annual concentration of dissolved nitrogen varied 0-11.2. The highest winter levels of nitrogen concentrations were found in the Arkona Basin, at the entrance and in the Gulf of Finland (6.5-11.2). In the Gotland and Bornholm Basins the winter concentrations increased only up to 3 – 5.5. Concentrations decreased < 1 in the middle of April almost in the whole study area. Exceptionally, in the Arkona Basin the concentration decreased < 1 already in the middle of March, but increased again strongly towards the end of April.

In 2002 nitrate and nitrite concentrations decreased later < 1 than in the reference year 2001

Temperature

In 2002 the temperature variation was from 2 °C to 23 °C, and three periods of rapid changes were detected. Temperature started to increase in the middle of March reaching its highest values in the middle of August. The first period of rapid temperature change was detected in the turn of June/July:

the amount of decrease was 1 - 4 °C in the Gulf of Finland, and > 2 °C around the longitudes 18.5° and 16.5°. An other rapid change occurred in the same longitudes, 18.5° and 16.5°, in the end of July: a decrease of 3-6°C. The third period of rapid change was in the middle of October, in the Western Gotland Basin. Simultaneously, the temperature decreased also in the Northern Baltic Proper. The rapid changes of temperature were most probably due to upwellings.

In 2002, compared to 2001, the surface layer started warm up earlier but more slowly and stayed warm longer in the autumn.

Chlorophyll a (mg m^{-3})

In 2002 the annual concentrations of chlorophyll *a* varied 0.4-39. The high spring blooms values were first detected in the Arkona Basin (7-10), then in the Northern Baltic Proper and in the Gulf of Finland (12-22, max 39), and weakler ones in the Gotland Basin (2-12). From the end of April to the beginning of the June the concentrations decreased to 1-3. The period of the clear water was short and an increase in concentrations (3-10) were recorded from the middle of June to the middle of August especially in the Gulf of Finland and in the Northern Baltic Proper. In the same areas in autumn a slight increase was detected again.

Metadata

Technical information

1. Source: Finnish Institute of Marine Research, contact persons Anniina Kiiltomäki and Tapani Stipa.

2. Description of data:
Original unit of measure: nutrients µmol l^{-1}
Original unit of measure: chl *a* mg m^{-3}
Original unit of measure: temperature °C

Original purpose of the data: Phytoplankton monitoring of FIMR, Alg@line project

3. Geographical coverage:
The western Gulf of Finland, the Baltic Proper.

4. Temporal coverage: 2001-2002.

5. Methodology and frequency of data collection:
Automated flow-through sampling system on merchant ships, sampling depth ca. 5 m,
Weekly-biweekly-monthly sampling during the period January-December

6. Methodology of data manipulation: None.

Quality information

7. Strength and weakness (at data level):
Strength: Medium temporal and spatial sampling frequency. Weakness: storage time of samples from a few hours to a couple of days depending on the sampling site

8. Reliability, accuracy, precision, robustness (at data level):
Measurement uncertainty: Chl *a*: 0.5 mg m^{-3} if the concentration < 5.0 mg m^{-3}, 1.0 mg m^{-3} if the concentration > 5.0 mg m^{-3}.
Measurement uncertainty: temperature 0.1 °C
Measurement uncertainty: Phosphate 30-20 %
Measurement uncertainty: Nitrate and nitrite 20-14%

9. Further work required (for data level and indicator level): -
Acknowledgement: This work has been partly funded by the Nordic Council of Ministers (NoComments project)

INDICATOR REPORT

Phytoplankton biomass and species succession in the Gulf of Finland in 2002

Lotta Ruokanen, Seija Hällfors & Eija Rantajärvi

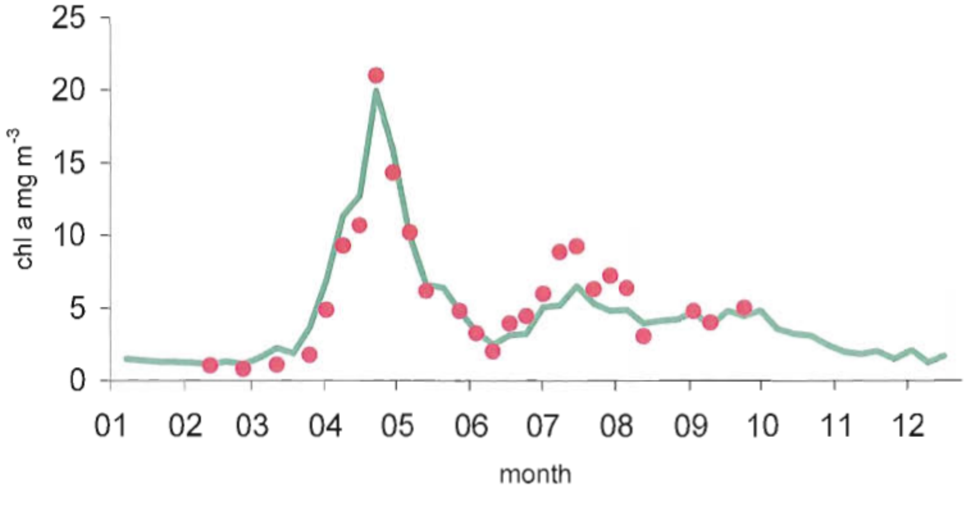


Fig. 1. Annual variation of surface layer phytoplankton biomass (measured as chlorophyll *a* mg m^{-3}) in the western Gulf of Finland. The green curve represents the average for 1992-2001, the red dots the 2002 measurements.

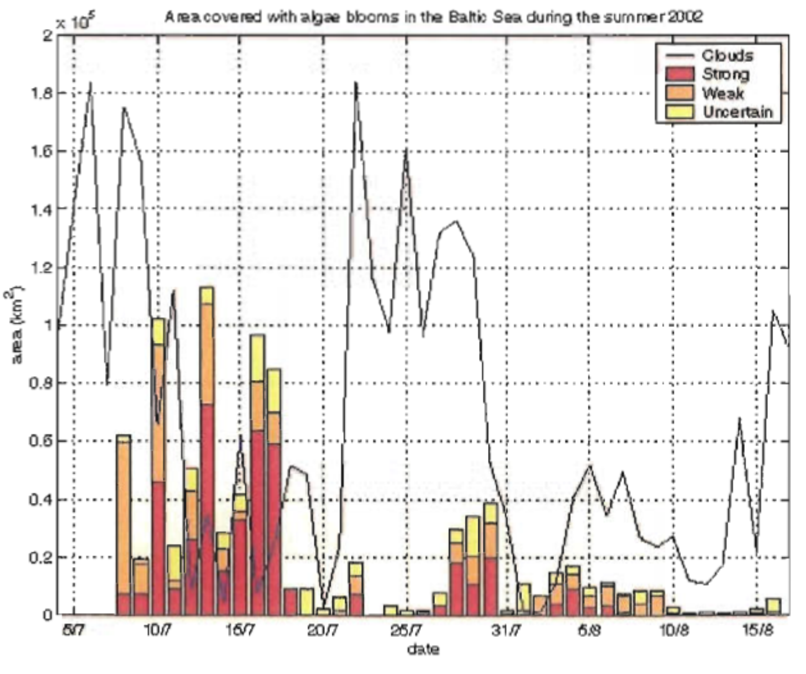


Fig. 2. Area covered with algal blooms (km^2) in the Baltic Sea during summer 2002 by NOAA, AVHRR satellite images. The intensity of blooms is also represented, the blue curve stands for areal coverage of clouds. Data: SMHI.

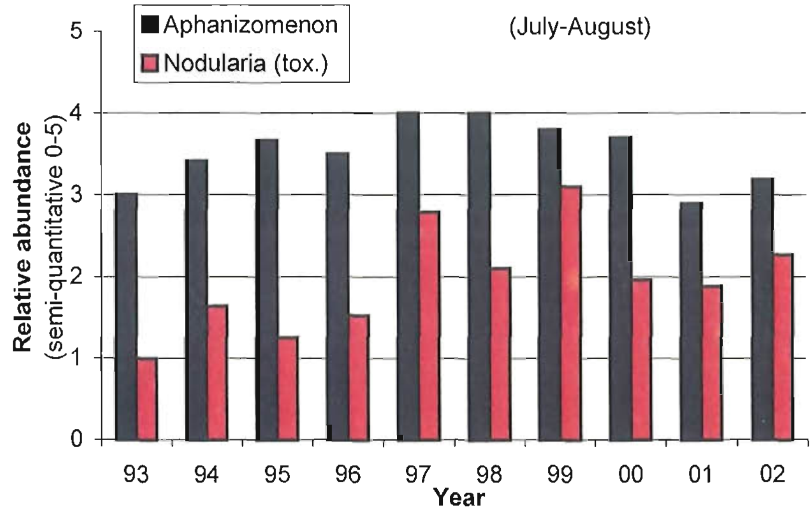


Fig. 3. Relative abundance of most abundant cyanobacterial species (the mean abundance value from samples collected in July-August) in the western and central Gulf of Finland in 1993 – 2002. The ratio of *Aphanizomenon* and *Nodularia* can be compared per year. The ranking is sample specific (0 = not detected, 1 = very sparse, 2 = sparse, 3 = scattered, 4 = abundant, 5 = dominant). The detailed definition of the method can be found in Rantajärvi et al., Hydrobiologia 363: 127 – 139, 1998.

☹ In 2002, the cyanobacterial (blue-green algal) blooms were clearly more intense than during the summers 1999 and 2001 and almost as intense as in 1997. The chlorophyll *a* level from the beginning of July until the beginning of August in 2002 was clearly higher than the average in 1992-2001.

☹ A clear long-term (1993-2002) trend was observed when the ratio of two most abundant cyanobacteria species was compared. The relative abundance of the toxic *Nodularia spumigena* had increased in relation to the non-toxic *Aphanizomenon flos-aquae*.

Results and assessment

Relevance of the indicator for describing developments in the environment

Chlorophyll *a* concentration is a relative measure of phytoplankton biomass in the water. Since high nutrient concentrations increase the intensity and frequency of phytoplankton blooms, chlorophyll *a* can be used as an indicator of the eutrophication level in a sea basin.

Varying combinations of environmental factors form the basis for phytoplankton species composition. Thus, the annual species succession reflects changes in the marine environment. Also the occurrence of potentially harmful species can be revealed.

Assessment

The strong stratification built up during a couple of years in the Gulf of Finland broke down during the autumn storms 2001. In the same process phosphate phosphorus, dissolved from bottom sediments to deepwater, was transported up to the surface water. This predicted good growth conditions for cyanobacteria for the summer 2002. The spring bloom was about the average duration and intensity as compared to last ten years. The summer minimum occurred just before mid June and after that the biomass started to increase. The summer maximum was observed around mid July and the phytoplankton biomass was clearly higher than the average of the 1990s. The maximum ceased towards the beginning of August, and phytoplankton biomass returned again to average values in August and September.

In the the spring bloom the phytoplankton species composition was the normal combination of diatoms and dinoflagellates. In the early summer there were still high levels of phosphate phosphorus in surface waters in the basin. Phytoplankton was very sparse in the beginning of June; some diatoms, nanoflagellates, cyanobacteria (blue-green algae) and prymnesiophyceans occurred scatteredly. Amount of non-toxic filamentous cyanobacterium *Aphanizomenon flos-aquae* started to increase in the second week of June, when also the first visual observations of cyanobacteria, still mixed into water were made. Cyanobacterial growth accelerated towards the end of June but strong winds kept the surface waters mixed and cool. During the second week in July, as the weather calmed and surface waters warmed up, extensive cyanobacterial surface aggregations built up. These aggregations grew to cover most of the offshore basin. The fraction of the toxic species *Nodularia spumigena* increased in the phytoplankton flora as cyanobacteria grew more abundant. By the third week in July *Nodularia* was the most abundant species of cyanobacteria in offshore areas of the basin, although the cyanobacterial amount and total phytoplankton biomass decreased. During the last week in July strong winds dispersed finally the surface aggregations.

Calm periods followed and in the beginning of August large, but discontinous, cyanobacterial aggregations were observed again. *Aphanizomenon flos-aquae* was clearly more abundant than *Nodularia spumigena*. By mid August cyanobacterial surface aggregations disappeared, phytoplankton biomass had decreased to 1990s average and both numbers of species and cells were poor. Nanoflagellates dominated the species composition and the cyanobacteria were getting sparse, *Nodularia spumigena* and *Anabaena* spp. had disappeared completely. In August surface water temperatures in all Finnish offshore areas were several degrees above the usual. The longlasting sunny weather and the decrease in algal concentrations made offshore waters in the basin clearer but at the end of August there were still local blooms observed in nutrient rich and sheltered bays in the coastal waters. During the end of August, some local blooms of nontoxic dinoflagellates coloured the water red-brown. Different from the year 1997, no large surface aggregations were observed after mid August and most of the cyanobacterial aggregations kept offshore in the basin. In September the phytoplankton biomass followed the ten years' average. Nanoflagellates dominated the species composition, but diatoms appeared in higher numbers indicating the oncoming autumn.

Metadata

Technical information

1. Source: Finnish Institute of Marine Research, contact persons Lotta Ruokanen and Seija Hällfors.

2. Description of data:

Original unit of measure: mg chl *a* m^{-3}

Semiquantitative phytoplankton analysis are based on the relative abundance (1-5) of the species. In the cyanobacterial bloom map, visual observations are included.

Original purpose of the data: Phytoplankton monitoring of FIMR, Alg@line project

3. Geographical coverage:

Gulf of Finland, Archipelago and Åland Sea, the Baltic Proper.

4. Temporal coverage: 1992-2002.

5. Methodology and frequency of data collection:

Automated flow-through sampling system on merchant ships, sampling depth ca. 5 m, weekly sampling during the period March-October.

6. Methodology of data manipulation: None.

Quality information

7. Strength and weakness (at data level):

Strength: Very high both temporal and spatial sampling frequency. Weakness: -

8. Reliability, accuracy, precision, robustness (at data level):

Measurement uncertainty: Chl *a*: 0.5 mg m^{-3} if the concentration < 5.0 mg m^{-3}, 1.0 mg m^{-3} if the concentration > 5.0 mg m^{-3}.

9. Further work required (for data level and indicator level):

Sophisticated statistical analysis.

ASSESSMENT

State of the Gulf of Finland in 2002

Matti Perttilä

A draft to be presented at the Trilateral Gulf of Finland Meeting

19-20 March 2003 St. Petersburg

The beginning of the year 2002 in the Gulf of Finland was characterized by the breakdown of the salinity stratification. During the continued stratification that ended late 2001, the oxygen depletion had weakened the populations of the bottom animals, leading also to accumulation phosphate from the sediments into water. The breakdown of the stratification quickly improved the bottom oxygen conditions, but also transported large amounts of phosphate into the surface layer by means of vertical mixing and upwelling.

Because of the high phosphate content in the surface layer, already in spring the first visions were made that the late summer's blue-green algal blooms would be intensive. During late summer, warming of the surface waters, together with occasional upwellings, further accelerated the bloom. As a result, the bloom extension and intensity corresponded those of the record year so far, 1997.

There are every year 400-800 observed oil and bilge spills in the whole Baltic Sea area. The total number of spills is probably much greater. According to HELCOM, more oil enters each year in the Baltic Sea from illegal outlets than from accidents. The Finnish authorities observed 75 oil spills in 2002, which is less in the two prior years. However, as the amount of transported oil through the Gulf of Finland is expected to increase from the present 69 million tons up to 131 million tons in 2010, the problem of illegal outlets probably continues.

The concentrations of the classical organochlorines PCBs and DDTs in fish tissue, as well as those for the heavy metals lead, cadmium and mercury, remained roughly on the same level as in the previous year. In the long run, however, the slowly decreasing trend in organochlorine concentrations is evident.

Hydrography, oxygen conditions and nutrient cycling

The year 2002 started in the Gulf of Finland with favourable oxygen conditions. In 2001, the whole Gulf hydrography was characterized by strong stratification, with near-bottom salinities increasing steadily until August-September, when maximum salinity, minimum oxygen (close to zero), maximum phosphate and maximum silicate concentrations were observed. The stratification was broken down towards the end of 2001 due to heavy northerly storms, and in consequence, near-bottom oxygen concentration increased, while phosphate and silicate decreased. On the other hand, as the result of the strong vertical mixing, surface water phophate-P increased by 30 to 50 % compared with the previous winter. Due to the strong increase in phosphate, inorganic N:P ratio decreased and free bioavailable P was present in the surface layer after the spring bloom. In the deep water of the Gulf of Finland, the nitrate concentration was continuing the slow decrease which had started in the early 1990's (Figs. 1 and 2).

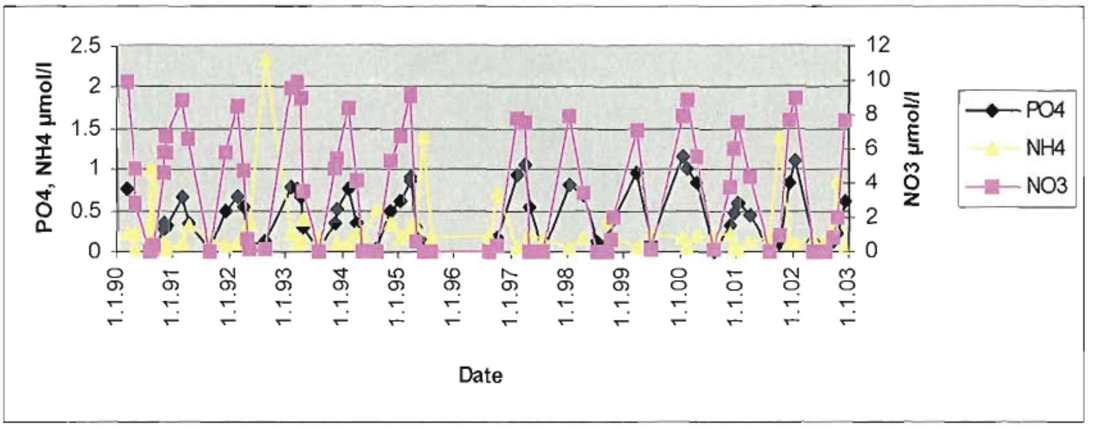


Fig. 1. Seasonal nutrient cycling in the surface layer (<10m) of LL7 (FIMR / H. Haahti 2003).

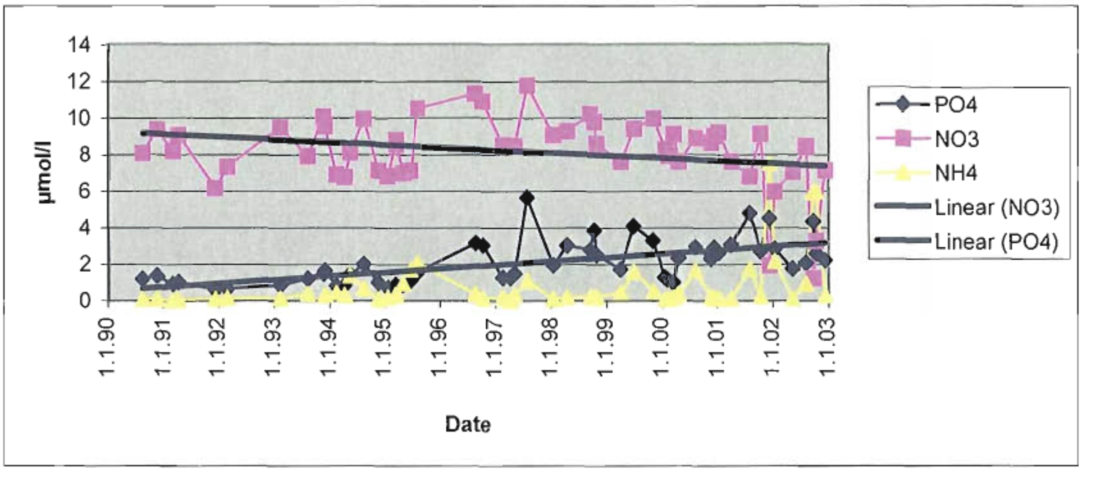


Fig. 2. Nutrient development in the deep water (>75m) of LL7 (FIMR / H. Haahti 2003).

In the summer of 2002 near-bottom oxygen conditions were, in general, better then during the previous summer, especially in the northern part of the Gulf (Finnish side, Fig. 3). However, a large anoxic bottom area was found in the southern Gulf of Finland (Estonian side), extending from the westernmost Gulf to the Bay of Narva. The salinity stratification in this area was strong, the deep water values (> 80 m) varying between 9 and 10 psu.

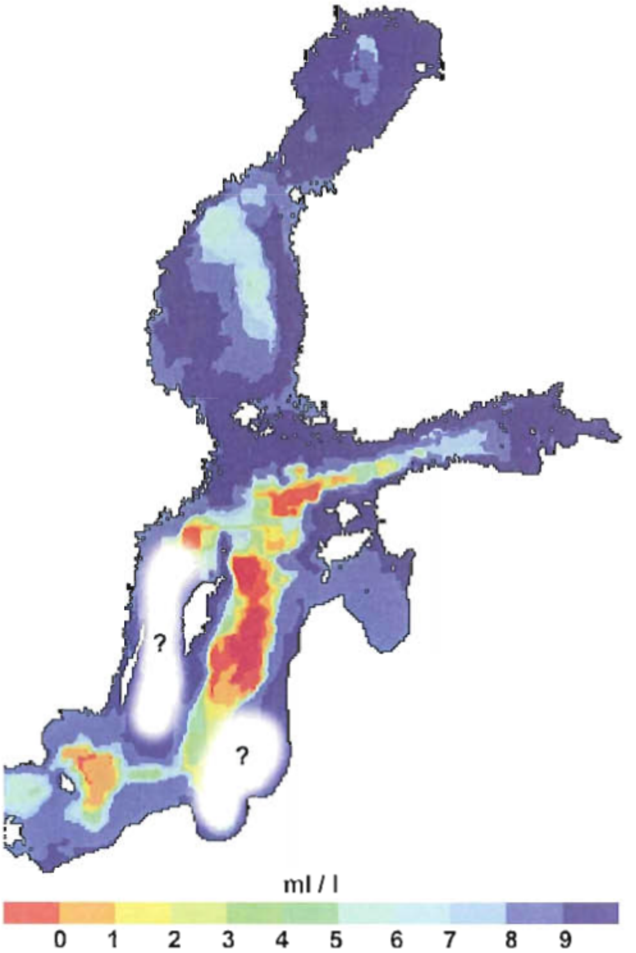


Fig. 3. Near-bottom overall oxygen concentrations in August 2002 in the Baltic Sea (based on FIMR data). The small anoxic/hypoxic coastal basins by the northern coast are hidden by the DAS-programme adjusted for open sea areas. (No data for the easternmost Gulf of Finland) (FIMR/Jan-Erik Bruun)

Additionally several separate coastal basins with poor oxygen concentrations close to sediment surface were found along the southern Finnish coast of the Gulf. In these areas the salinity stratification is much weaker than in the open Gulf, but deep water exchange with the open Gulf waters is limited by islands, reefs and sills.

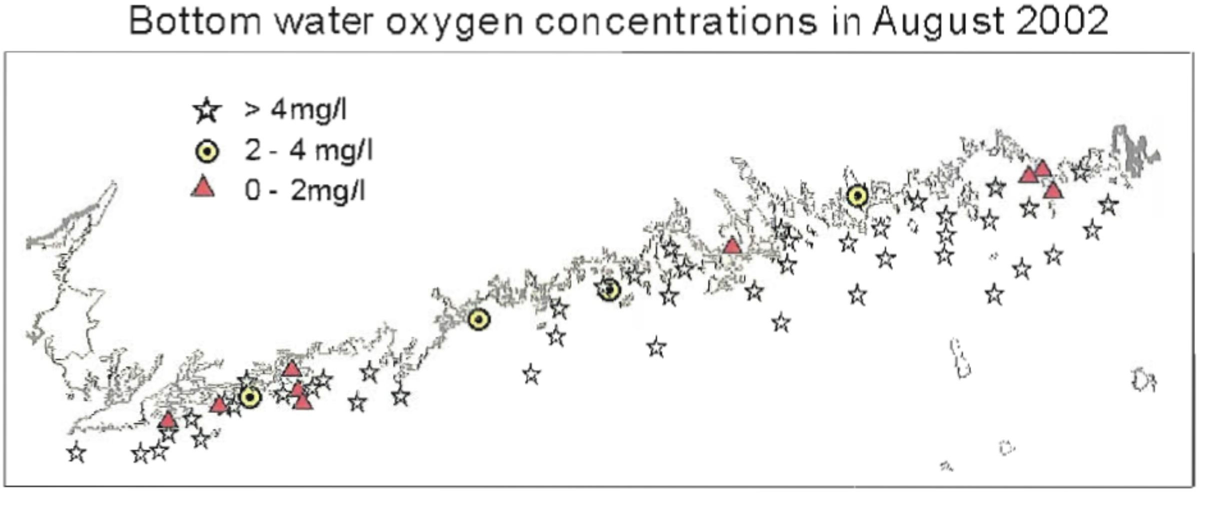
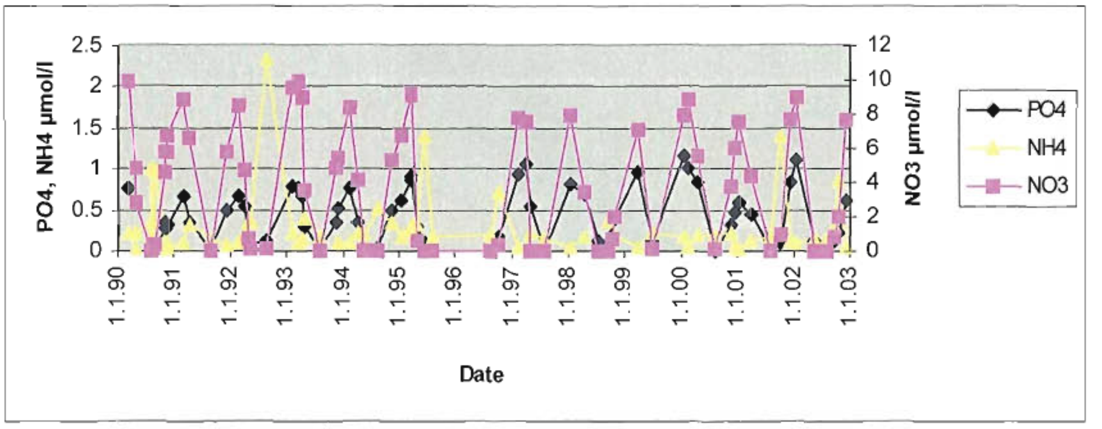


Fig. 4. Observed anoxic deeps (data from FEI, FIMR, Finnish Regional Environment Centres).



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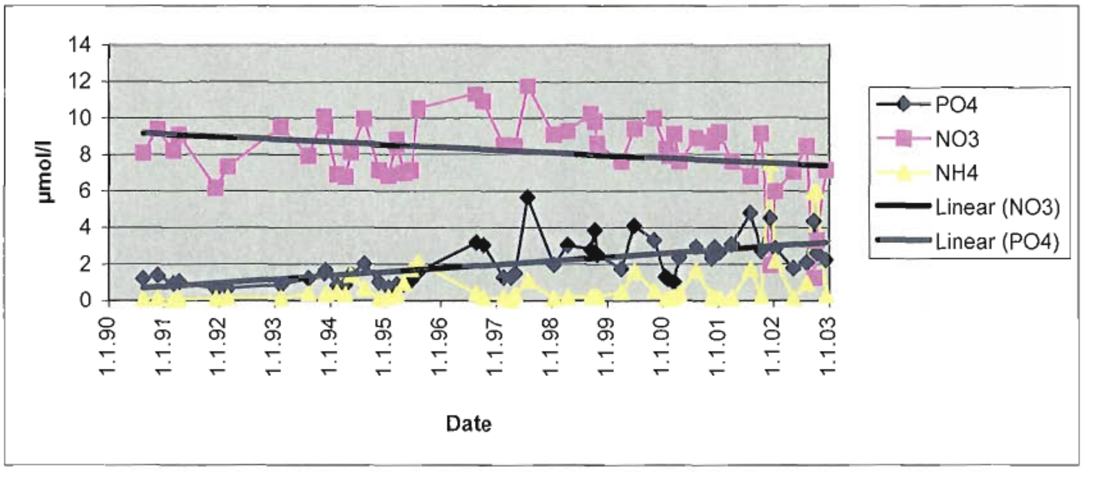

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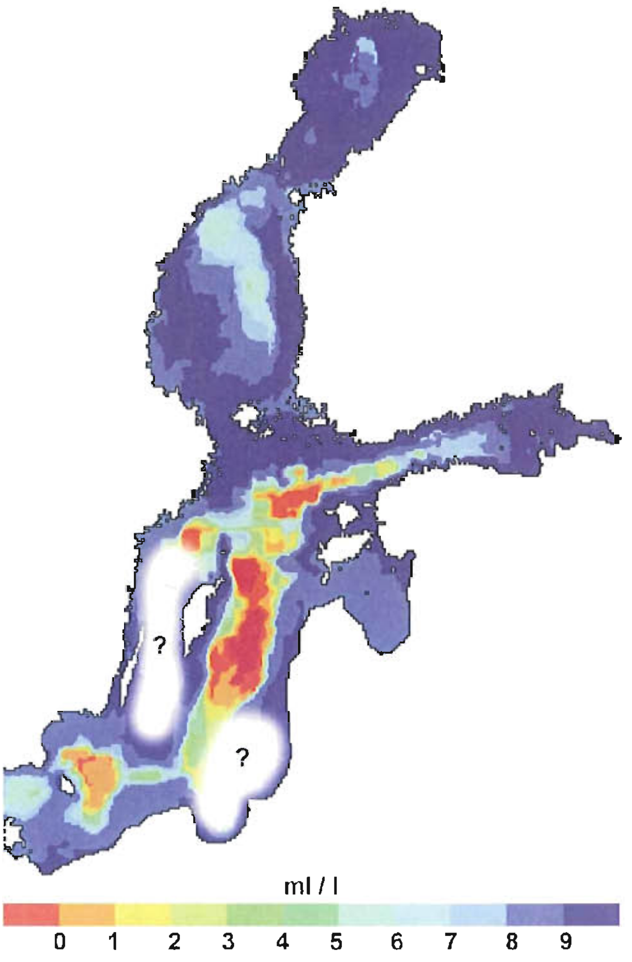

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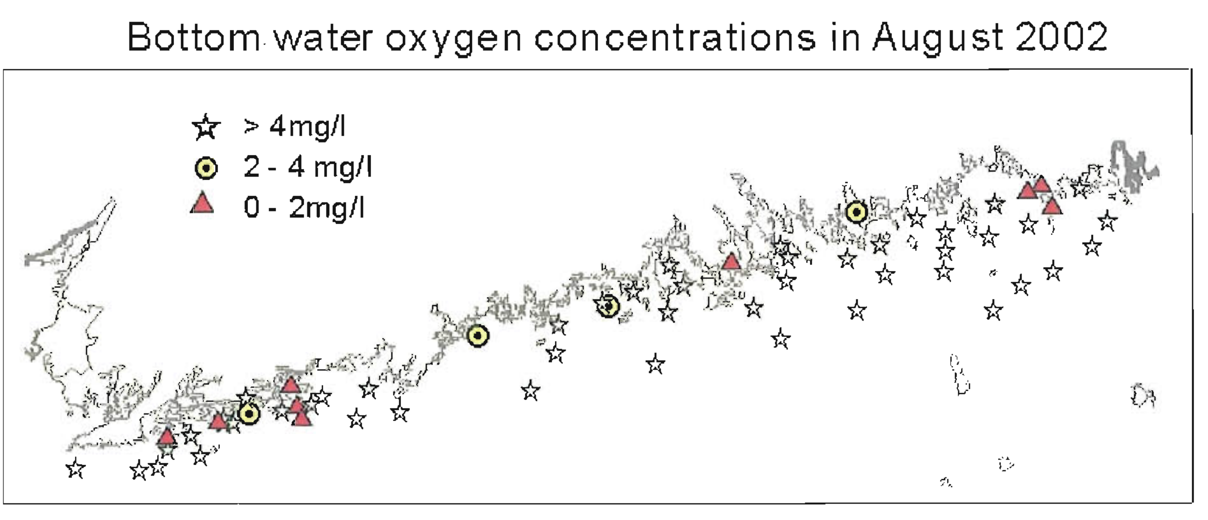

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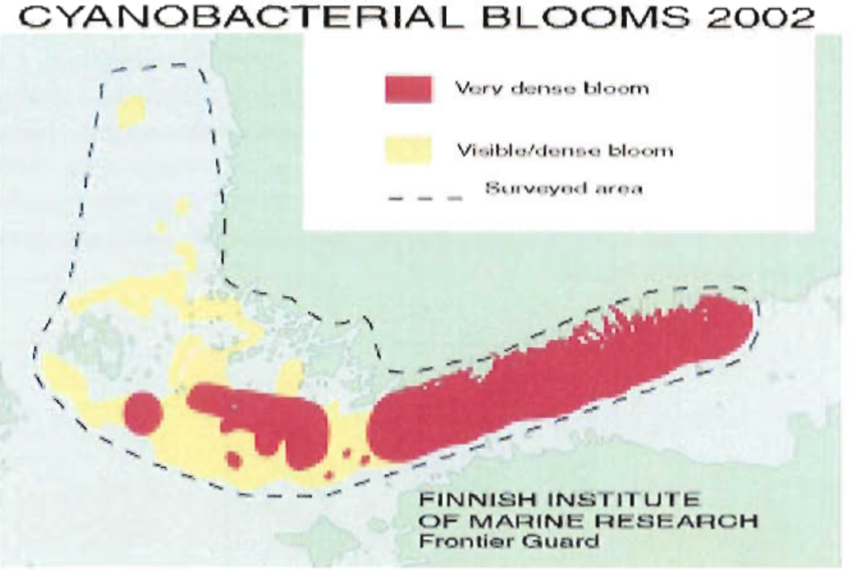

Fig. 6. Cyanobacterial blooms in the Gulf of Finland and the north-eastern Baltic Proper in 2002 (maximum extension) (Alg@line)

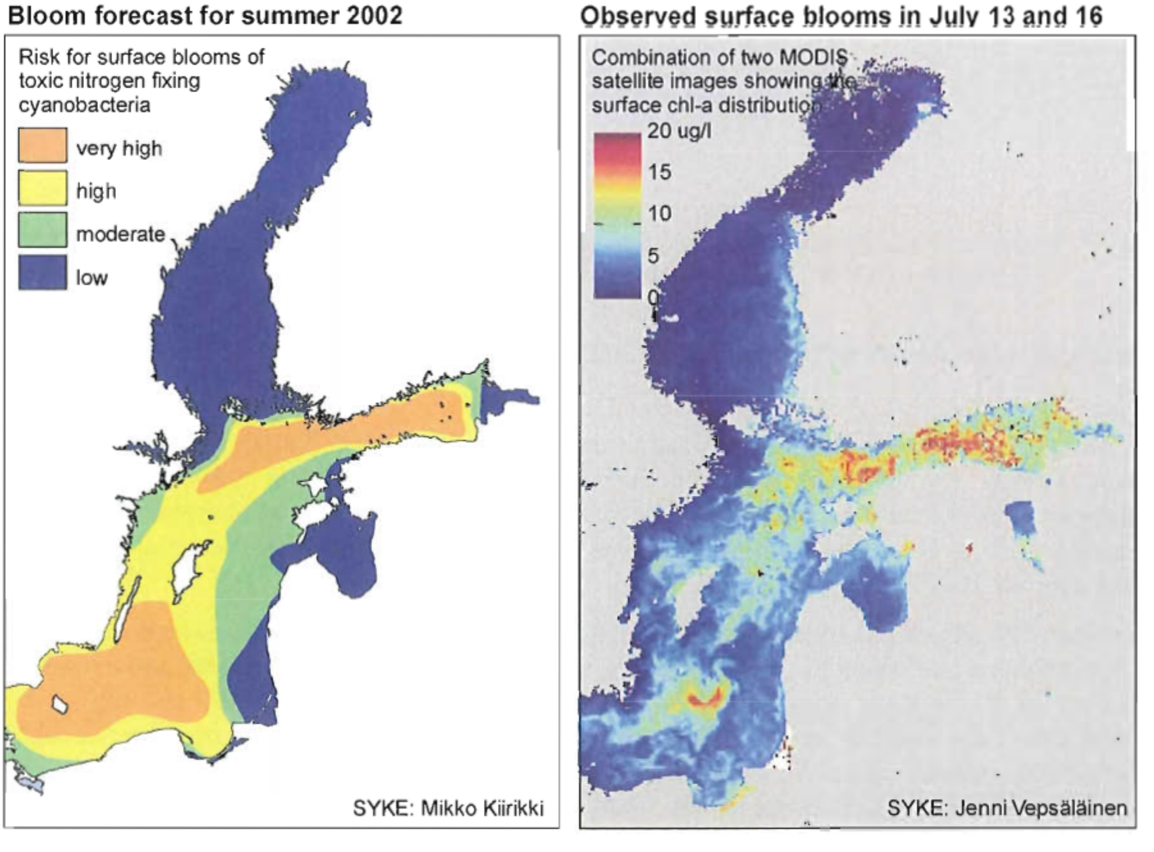

Fig. 7. Cyanobacterial bloom forecast and satellite observation for 2002 (data from FIMR, FEI, Finnish Regional Environment Centres)

The development in 2001 – 2002 resembled in many ways the development that lead into the record bloom on 1997. In both years 1997 and 2002 the initial levels of surface water phosphate phosphorus in the beginning of summer was high, thus increasing the growth potential of cyanobacteria. Followed by exceptionally calm, sunny and hot summers, the successful growth of algae came out in extensive

The favourable hydrographic condition in the northern side continued until summer 2002, at which period the oxygen concentrations reached its maximum in the open Gulf of Finland. In late summer the stratification, as indicated by salinity development (Fig. 5), started to strengthen. As a consequence, oxygen content in the bottom-near layer decreased rapidly, being again close to zero in October. In December 2002, the near-bottom layer of saline water had reached the eastern Gulf of Finland at the depth of 60 m. Oxygen concentrations were below 3 ml/l in the whole open Gulf. Reason to the observed inflow of saline water from the Baltic Proper may be the high atmospheric pressure which have persisted over the southern Finland almost continuously since July 2002 and caused exceptionally low water levels in the Gulf of Finland.

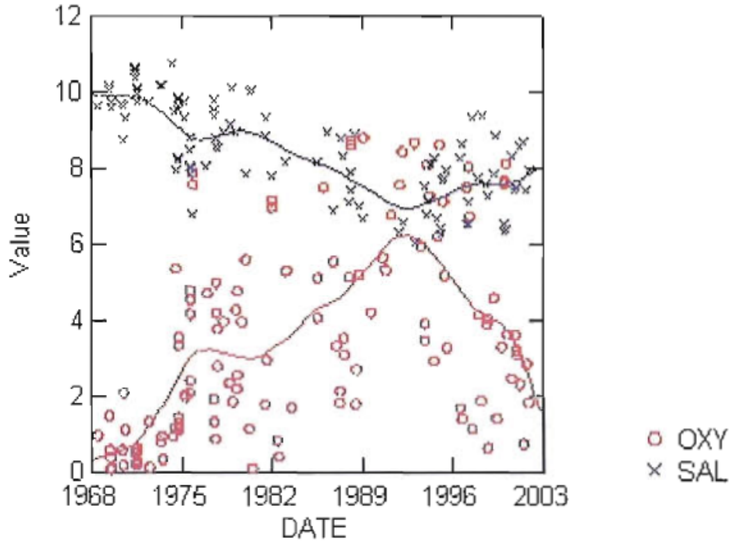

Fig. 5. Oxygen and salinity development in the bottom-near layer (d>60m) in January 2001 – October 2002 in the Gulf of Finland. Oxygen concentrations given in ml/l, salinity as PSU.

Intensity of cyanobacterial blooms in the Gulf of Finland were similar to the record summer 1997

The strong stratification built up during last years in the Gulf of Finland disappeared 2001 during the autumn storms. The phosphate released during anoxic conditions from the sediment was then transported up to the surface. After the spring bloom there were still plenty of phosphate phosphorus in the surface waters. These conditions favoured the formation of extensive cyanobacterial blooms during the hot summer 2002 (Figs. 6, 7).

Cyanobacterial growth accelerated towards the end of June, however strong winds kept algae mixed in the water column and cooled the surface waters. Occasional upwellings transported more nutrients up to surface in the northern coast of the Gulf of Finland. As the weather calmed and surface waters warmed up in early mid-July extensive cyanobacterial surface aggregations built up. These consisted of the non-toxic *Aphanizomenon fos-aquae* and toxic *Nodularia spumigena* and spread out to cover most of the open gulf. By the third week in July *Nodularia* turned to be the most abundant cyanobacterium, even if the total amount of cyanobacteria decreased. In the end of July strong winds mixed the surface aggregations to water column. However, while the weather became calm some large, but discontinuous accumulations formed again in the Gulf of Finland. *Aphanizomenon* was clearly more abundant than *Nodularia*. By mid-August the extensive surface aggregations disappeared.

In the end of August some local blooms were still observed in nutrient rich and sheltered bays of the Gulf of Finland. Surface water temperatures in all Finnish offshore areas were at the time several degrees higher than usual.

cyanobacterial surface accumulations. However in year 2002, unlike in year 1997, the algae mats kept mostly offshore from the Finnish coast and after mid-August no large surface aggregations occurred.

PCB and DDT decreasing, mercury and lead as usual

In accordance with the COMBINE Program of HELCOM, the concentrations of the organochlorines PCB and DDT in the Baltic Sea herring is monitored annually since early 1980's at five catch areas in the northern Baltic Sea. 2-year old female herring have been used for the monitoring of the contaminant concentrations.

The organochlorine time series (Fig. 8) shows the development of the total PCB concentration (sum of 7 main representative PCB components), as well as that of the total DDT concentration (DDT plus the metabolites DDE and DDD) in the Baltic Sea herring muscle. In the long run, the concentrations are obviously slowly decreasing, while large annual variations are seen.

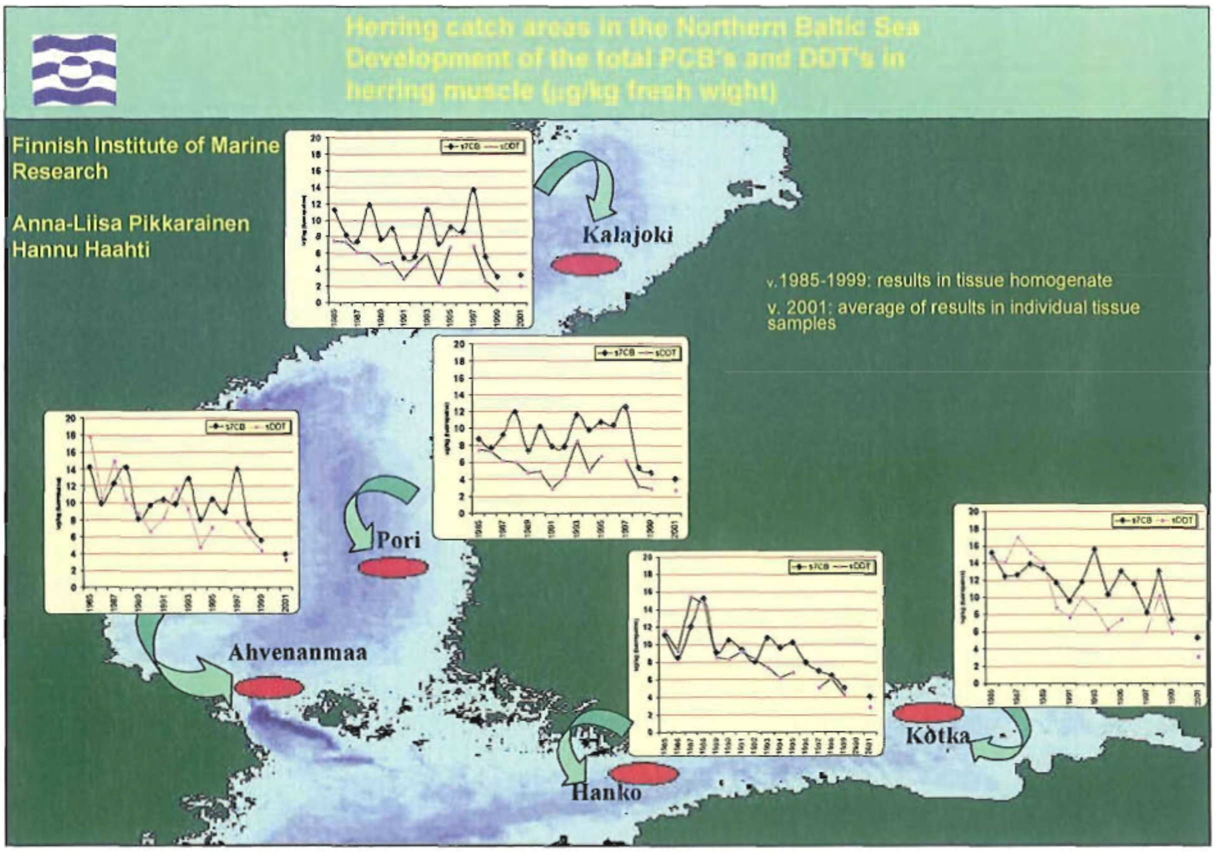

Fig. 8. Concentrations of the total PCB and total DDT in the 2-year Baltic Sea herring muscle (□g/kg fresh weight).

Trace element (cadmium, copper, mercury, lead, zinc) concentrations in the Baltic Sea herring muscle have been monitored since 1979 in herring at the same areas.

Mercury concentration on the average are slightly lower in the Gulf of Finland than in the Gulf of Bothnia or Åland Sea. The concentrations are stabilizing after a sudden rise in mid 1990's (Fig. 9).

In older herrings, both the organochlorines and the mercury concentrations have been at a considerable higher level (two- even fivefold) compared to the 2-year old individuals used for the regular monitoring. This repeats the earlier observations and indicates an almost linear accumulation of the lipid-soluble contaminants (organochlorines and methylated mercury) with age. However, the observed contaminant concentrations are only 2-10% of the concentrations allowed for fish for human consumption.

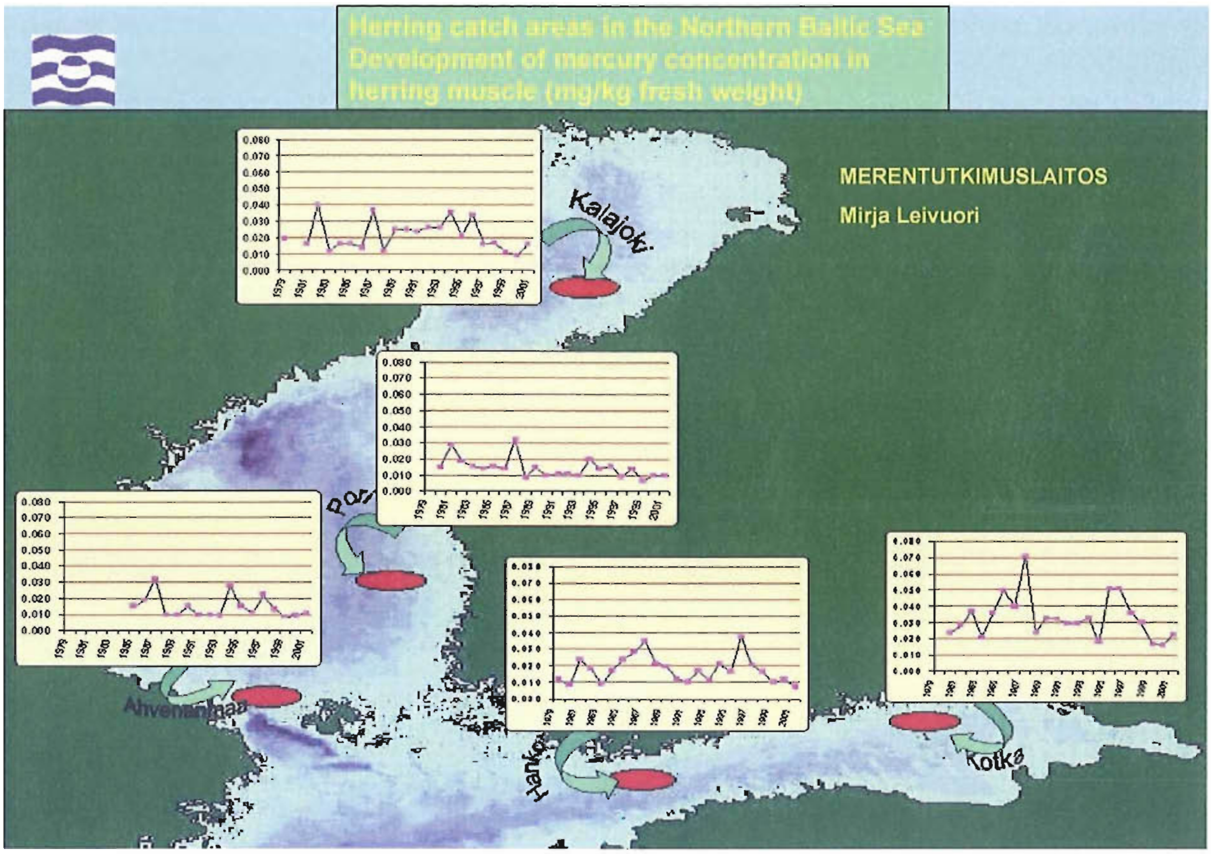

Fig. 9. Development of the mercury concentrations in the 2-year Baltic Sea herring muscle (mg/kg fresh weight).

Increasing oil transport constitutes a serious threat

There are every year 500400-800 observed oil and bilge spills in the whole Baltic Sea area. The total number of spills is probably much greater because all Baltic Sea countries do not have equipment for aerial observation and aerial surveillance cannot be conducted 24h/day. According to HELCOM, more oil enters each year the Baltic Sea from illegal discharges than from accidents. Most of the illegal oil spills are observed in the international waters of the Gulf of Finland (Fig. 10). The Finnish authorities observed 75 oil spills in 2002, which is 32 spills less than in the previous year. Estonian authorities reported 3 spills in 2002.

In addition to the large number of illegal oil spills, the increasing oil transport through the Gulf of Finland forms a serious threat to the marine and coastal environment. In 2002, 68.4 million tons of crude oil was transported through the Gulf. It has been estimated that the amount of transported oil will be more than 100 million tons by 2005. In combination with the already dense ship traffic across the Gulf between Helsinki and Tallinn, the increasing oil transport means increased collision risk.

The debate on oil transportation has been intensive mainly due the newly opened Primorsk oil harbour, The accident of tanker Prestige was wrecked and later sunk by a storm in the Bay Biscay off the Portuguese – Spanish coast, but the accident might have happened already earlier when the ship was steaming in the Baltic Sea. and severe ice conditions in the Gulf of Finland. Late in the year, other tankers not in accordance with the strictest Finnish ice classification rules were used for oil transportation from the Russian harbours. These issues raised the awareness of threats related to oil transportation in the Gulf of Finland.

HELCOM is investigating the feasibility of designating the Baltic Sea or parts of it as particular sensitive sea area (PSSA). PSSA would promote maritime safety by fostering environmental awareness, for instance by registration of the area in sea charts. The experts agree on the need to unify the rules for Baltic ice classification of ships. IMO has been preparing guidelines for ships operating in arctic ice-covered waters but currently no international regulations are in place to demand special construction features of a ship sailing in icy waters.

The accident cases, the Prestige (November 2002) and the Erika (December 1999), have accelerated preparation on EU legislation in the field of prevention of marine pollution. In December 2002 were given proposals for regulations to speed up the phasing-out of single hull oil tankers and ban the use of single hull tankers in transportation of most persistent oil in EU. From the beginning of 2004 the Baltic Sea will be almost entirely the inland sea of the European Union.

It is foreseen that the present rate of oil transport will roughly double to 131 million tons annually in 2010.

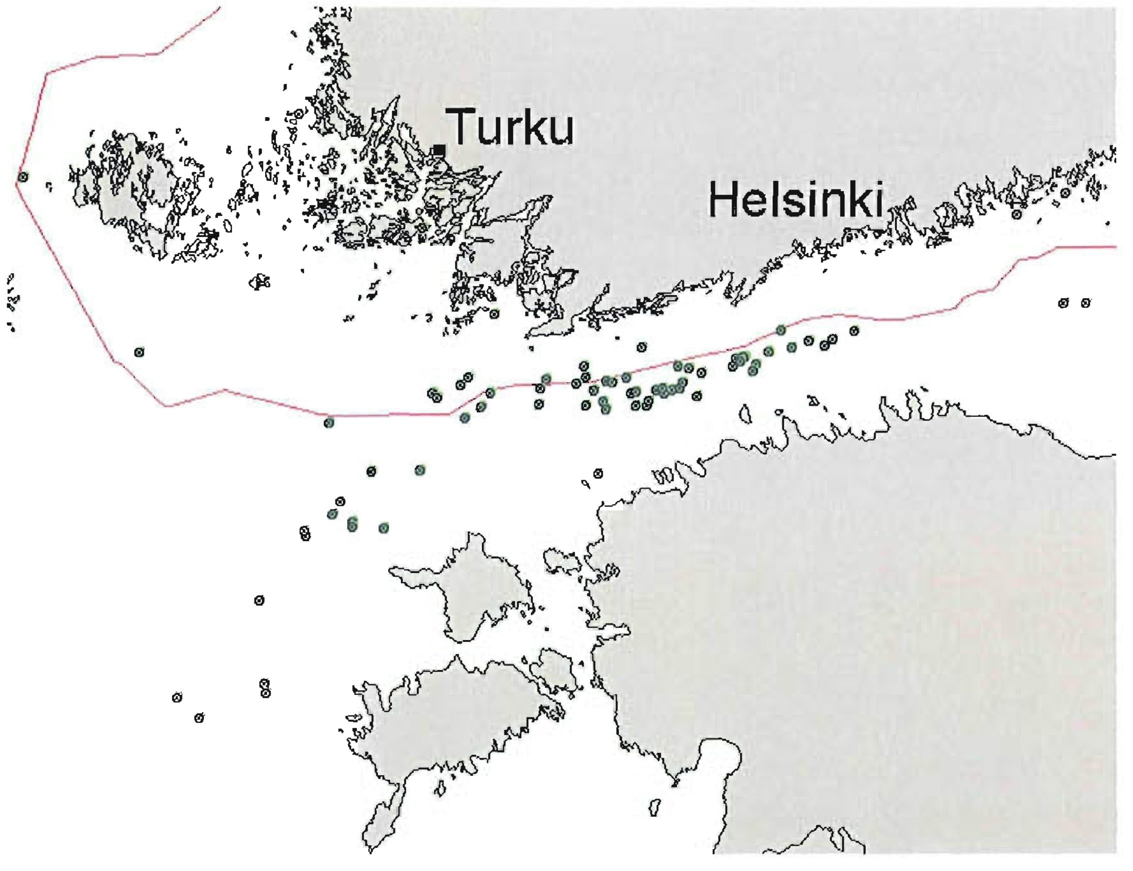

Fig. 10. Observed oil spills in 2002 in the Gulf of Finland (FEI 2003)

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No. 48

Alg@line in 2003: 10 years of innovative plankton monitoring and research and operational information service in the Baltic Sea

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