ICES Baltic Committee
ICES CM 2004/H: 01

Report of the Study Group on Baltic Sea Productivity Issues in support of the BSRP (SGPROD)

29–31 October 2004
Riga, Latvia

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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https://doi.org/10.17895/ices.pub.9147

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0 EXECUTIVE SUMMARY

The Study Group on Baltic Sea Productivity Issues in support of the BSRP (SGPPROD) met in Riga from 29–31 October 2003 and initiated a discussion of the Terms of Reference, which was finalized by correspondence during the preparation of the Study Group report.

The Group summarized the scientific evidence for links between nutrient inputs and long-term changes in the Baltic Sea ecosystem. The pristine state of the Baltic Sea is poorly known. The eutrophication effects are site-specific and differ between subareas of the Baltic Sea.

SGPROD started a review of the indicator systems currently used for productivity assessment and noted that the HELCOM COMBINE monitoring programme, the EU water framework directive, the HELCOM periodic assessments, and the HELCOM and EEA indicator reports employ different indicator systems that only partially overlap. Currently, monitoring and indicator systems used for assessments are under pressure to change towards establishing Ecological Quality Objectives (EcoQOs) as postulated by the 2003 HELCOM Bergen Declaration. For use in the BSRP, a preliminary set of coastal and open-sea eutrophication indicators was suggested.

Productivity data currently collected in the Baltic Sea were listed. Most of the available data cover standing stocks of nutrients and biota, with only a few direct flux measurements.

Published trophic networks of the Baltic Sea ecosystem often cover too large areas to be useful for ecosystem-based management. Networks should be constructed for spatially homogeneous regions and parameters necessary to calculate trophic transfers should be collected in a database.

Based on information from BOOS/PAPA, the current network of automated monitoring stations in the Baltic Sea was described. Alg@line provided an overview of the current Ship of Opportunity system and planned continuous plankton recorder observations. Experiences at the Narragansett Bay Laboratory with undulating towed samplers were discussed.

1 MEETING OBJECTIVES

The Study Group on Baltic Sea Productivity Issues in support of the BSRP (SGPPROD) was formed to guide the productivity module in the Baltic Sea Regional Project (BSRP). The first meeting took place on 29–31 October 2003 in Riga with 14 participants from Denmark, Estonia, Latvia, Lithuania, Poland, and the USA to address the following Terms of Reference:

a) commence a summary of the evidence for links between land-based nutrients inputs and long-term changes of both productivity and biodiversity in eutrophied areas of the Baltic Sea;

b) commence development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea that are important to ecosystem-based management taking into account the work already undertaken by ACE and the EEA;

c) establish an inventory of available productivity data and characterize their use;

d) identify information gaps along important trophic transfers in the Baltic Sea ecosystem;

e) study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms etc.), in collaboration with BOOS;

f) recommend measures to adapt the existing measurement programmes to improve the assessment of Baltic Sea productivity within the framework of ecosystem-based marine management;

g) prepare a workplan, including a schedule for deliverables, in cooperation with the other BSRP Groups; including considerations of potential contributions to 2006 Theme Session on Regional Integrated Assessments.

After an overview of the BSRP, the meeting continued with presentations about productivity measurements in Large Marine Ecosystems, trophic transfers in the Baltic Sea, monitoring strategies, and data requirements for modelling and assessment. Three subgroups prepared the discussion of ToR a, b, and d, including aspects of ToR e and f. The Study Group report was finished by correspondence, including input from Study Group members that were unable to attend the meeting.

Andris Andrushaitis, Assistant Coordinator for Component 1 (Large Marine Ecosystem Activities) of the BSRP, opened the meeting and welcomed Jan Thulin, BSRP Component 1 Coordinator, and the Institute of Aquatic Ecology, University of Latvia. Andris Andrushaitis thanked the participants for attending the meeting at short notice. He explained that the meetings of SGPROD and the Study Group on Ecosystem Health (SGEH) will kick-off the large marine ecosystem activity part of the BSRP. The Chair of the Study Group, Bärbel Müller-Karulis, gave an overview of the productivity module in the BSRP and wished the Group a successful meeting.

2 BSRP PROJECT OVERVIEW

Andris Andrushaitis introduced the goals of the BSRP, which is part of a series of GEF funded Large Marine Ecosystem projects. The BSRP aims to:

- Develop and apply an ecosystem-based management strategy to the Baltic;
- Facilitate strengthening of regional institutions through capacity building efforts;
- Inform and engage stakeholders and decision-makers on the project approach and objectives;
- Assess and evaluate the socio-economic effects of the ecosystem-based management for farming, fishing and coastal communities.

The first ideas for the project were discussed already in 1995, and GEF funding for the project was applied for in 1998 and approved by GEF in 2001. After the presentation of the final project documentation, the project won ultimate approval by GEF and the World Bank on 25 February 2003 and with the signing of a grant agreement between HELCOM and the World Bank the first phase of the project implementation started on 17 March 2003.

The BSRP is organized in four components: Large Marine Ecosystem Activities (Component 1, managed by ICES), Land and Coastal Management Activities (Component 2, managed by HELCOM and the Swedish University of Agricultural Sciences), Institutional Strengthening and Regional Capacity Building (Component 3, supervised by the ICES Baltic Sea Steering Group and supervised by the HELCOM Project Implementation Team), and Project Management (Component 4, managed by the Project Implementation Team and the Baltic Sea Steering Group). Component one consists of five modules (fisheries, ecosystem health, productivity, socio-economy, and a GIS data center) each corresponding to a coordination center, and several lead laboratories (Figure 1). The total budget of the BSRP Component 1 for the period 2003–2005 is 7.5 Mio USD, of which 2.76 Mio USD will be contributed as cash, the remainder constitutes in-kind contributions of ship-time, equipment, and work-time.

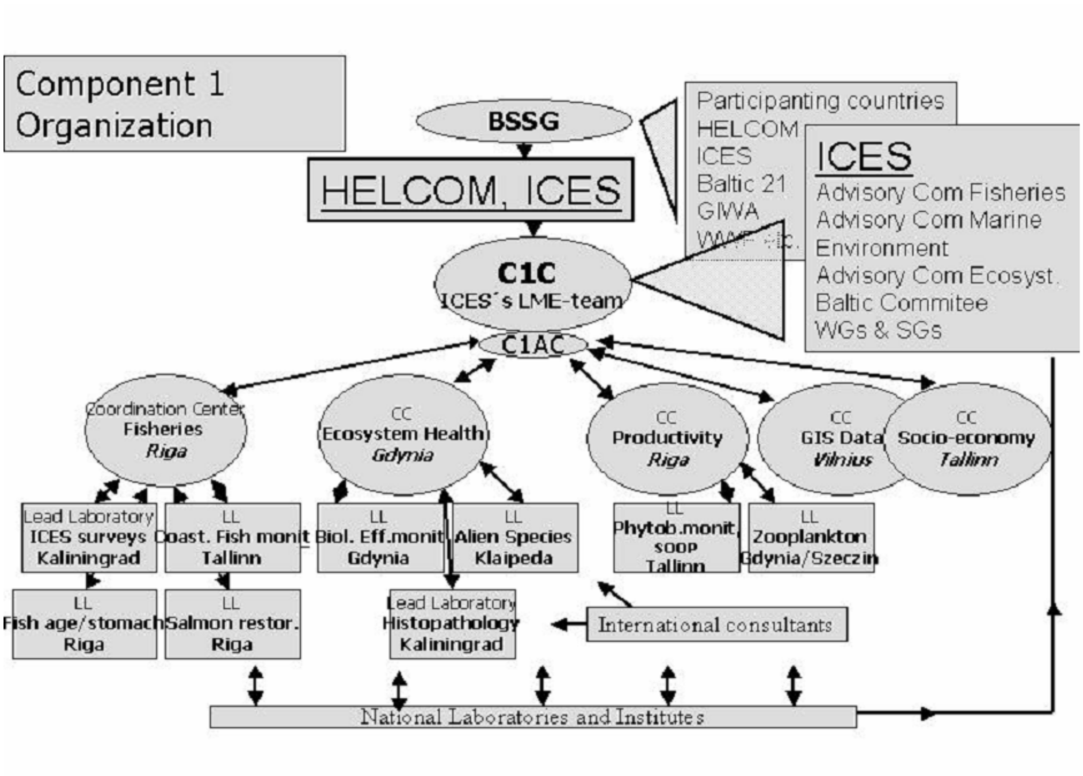

Figure 1. Organization of the Large Marine Ecosystem Activities (Component 1) in the BSRP.

ICES began the implementation of the Large Marine Ecosystem Activities with the formation of a Planning Group on the Implementation of the Baltic Sea Regional Project and the formation of four Study Groups to support the BSRP (Study Group on Baltic Fish and Fisheries Issues in the BSRP (SGBFI), Study Group on Baltic Sea Productivity Issues in support of the BSRP (SGPROD), Study Group on Baltic Ecosystem Health Issues in support of the BSRP (SGEH), Study Group on Baltic Ecosystem Model Issues in support of the BSRP (SGBEM)). Goals of the productivity module, which SGPROD will support, are, among others, to assess productivity levels in the coastal and off-shore ecosystems of the Baltic, to further the use of innovative technologies in productivity monitoring, as well as to describe the links between land-based nutrient inputs and productivity.

Bärbel Müller-Karulis further explained the goals of the productivity module in Component 1 of the BSRP. Productivity in the Baltic Sea ecosystem will be characterized both with respect to support of higher trophic level production, as well as with regard to changes in ecosystem functioning caused by eutrophication. The productivity module will contribute to integrating an ecosystem-based approach to fish stock assessments and to developing ecosystem-based management recommendations and tools for the Baltic Sea.

Planned actions in the productivity module are divided into open-sea and nearshore activities. In the open sea areas, the BSRP aims to upgrade monitoring methods by expanding the use of ships of opportunities (Ship of Opportunity Programme (SOOP)) and automated equipment (buoys, continuous plankton recorders, satellite observations) for productivity measurements. Productivity monitoring will be integrated with fish stock monitoring and assessment and data collection will be included into fishery surveys. Nearshore activities focus on the coastal zone, which is a recipient for eutrophying substances, as well as a recruitment and feeding area for fish. Phytobenthos monitoring will be expanded both to be used as an indicator for coastal eutrophication as well as to characterize recruitment areas for fish. Pelagic productivity parameters (e.g., zooplankton) will be integrated into the coastal surveys, to describe the feeding conditions for juvenile herring. With respect to eutrophication, coastal zone activities will be conducted in the recipient areas of catchments, which were selected for management activities in Component 2 of the BSRP. The project aims at providing a tested set of eutrophication indicators that allow monitoring the efficiency of nutrient load reductions.

Brian MacKenzie, Chair of the ICES Baltic Committee, added a short overview of the ICES structure and the role of SGPROD. The Baltic Committee is the parent committee of SGPROD and six other study and working groups that deal with fishery issues, harmful species, ecosystem health, and modelling. Other relevant groups addressing exclusively Baltic topics are the Baltic Fisheries Assessment Working Group (WGBFAS), the Study Group on Closed Spawning Areas of Eastern Baltic Cod (SGCSA), and the Study Group on Ageing Issues in Baltic Cod (SGABC). ICES aims to contribute to regional integrated ecosystem assessments by 2006, requiring a more interdisciplinary approach that includes not only fish stock assessments, but also biodiversity and eutrophication issues. Brian MacKenzie advised the group to focus its work on the lower trophic levels of the foodweb and to interact with the other existing groups.

3 PRESENTATIONS

3.1 Assessing the productivity of Large Marine Ecosystems

Mark Berman gave an overview of the Large Marine Ecosystem (LME) concept. Within the LME concept, five modules – productivity, pollution and ecosystem health, fish and fisheries, governance and socioeconomic - comprise a framework for ecosystem-based management. The productivity module typically assesses the capacity of the lower trophic levels, from primary producers to zooplankton, including supporting studies of oceanographic variability. Several automated methods have been used in the productivity module. The continuous plankton recorder (CPR) was developed in the 1930s to measure zooplankton abundance. Long-term data from the Northwest Atlantic CPR routes, showed distinct patterns in the spatial and seasonal zooplankton distributions. However, only relatively large plankton is retained in the CPR mesh and absolute abundances or biomass data cannot be derived from classical CPR samples. Satellite oceanography provides a synoptic view of sea surface temperature and color, but information is limited to the surface layer. Fixed site samplers (buoys) have mainly been applied to measure temperature, conductivity, pH, dissolved oxygen and chlorophyll *a*. They provide high temporal resolution, but maintenance cost of buoy systems are high, and buoys are difficult to moor in deep water. Fixed stations can be combined with undulating towed samplers, like the Nv-shuttle, that measure similar parameters with a high spatial resolution. In addition, the Nv-shuttle can be equipped with a continuous plankton recorder and with a fast repetition rate fluorometer, providing simultaneous estimates of chlorophyll *a* and primary production. Mark Berman emphasized the importance of joining various measurement techniques for productivity monitoring, for example combining satellite information with chlorophyll *a* data from towed instruments, or the use of fixed stations and towed instruments, which was implemented for the management of Narragansett Bay. Mark Berman also recommended including primary production measurements in productivity monitoring, because phytoplankton biomass does not always characterize the ecosystem state properly.

3.2 Trophic transfers

Andris Andrushaitis pointed out, that a recent review on primary productivity in the Baltic Sea was published by Wasmund *et al.* (2001). The study showed large spatial differences both among sub-basins of the Baltic Sea, as well as between river plumes and open areas. While primary productivity is mostly determined with the ^{14}C method, the oxygen method allows simultaneous measurement of plankton community respiration. Studies in the Gulf of Riga have shown that the Gulf is a net heterotrophic system with primary production exceeding community respiration only during the spring bloom period.

Within the HELCOM COMBINE monitoring, primary production is treated as a supporting parameter to characterize the physiological state of the phytoplankton community as well as to follow trends in primary productivity. Measurements of potential primary production are made in incubators using the ^{14}C method. Daily primary production may then be estimated according to the light profile determined in the water column.

There is evidence for a doubling of the primary production during the last two decades (Wasmund *et al*., 2001). The recent annual phytoplankton primary production of the whole Baltic (including bays and river plume areas) has been estimated as 62 10^6 tC yr^{-1} corresponding to 150 gC m^{-2} yr^{-1}. The highest phytoplankton productivity levels are characteristic for large river plumes off the south-eastern coast: Oder (422 gC m^{-2} yr^{-1}, Daugava (300 gC m^{-2} yr^{-1}), and Vistula (283 gC m^{-2} yr^{-1}). Still, due to the limited area, inclusion of river plumes only has a minor effect on the estimation of overall primary production in comparison with an estimate based on open-sea data.

References

Wasmund, N., Andrushaitis, A., Lysiak-Pastuszak, E., Müller-Karulis, B., Nausch, G., Neumann, T., Ojaveer, H., Olenina, I., Postel, L., Witek, Z. 2001. Trophic status of the south-eastern Baltic Sea: a comparison of coastal and open areas. Estuarine, Coastal and Shelf Science, 53, 849–864.

Christian Möllmann reported on long-term changes in Central Baltic mesozooplankton and their importance for fish stocks. The presentation displayed that during the 1990s the climate over northern Europe developed to on average warmer conditions accompanied with increased westerly winds. This has been shown by climate indices, such as the North Atlantic Oscillation (NAO) Index and is suggested to be at least partly because of the anthropogenic greenhouse effect. For the Central Baltic Sea this resulted in increased water temperature, decreased salinity and amplified circulation. Altered physical conditions resulted in a change in dominance in the calanoid copepod community from *Pseudocalanus* to *Acartia*.

Further, the presentation investigated the influence of changes in atmospheric forcing on copepod dynamics, identifying maturation and reproduction processes to be responsible for the decline of the calanoid copepod *Pseudocalanus*. Results from recent investigations using a Video Plankton Recorder (VPR) showed the halocline in Baltic deep basins to be the reproductive area of this species, and how this habitat is degraded during stagnation periods characterized by low salinity and oxygen levels.

As an example of how changes in the copepod community can affect fish stocks and their productivity, the influence of the decline in *Pseudocalanus* on the growth of Baltic herring was demonstrated.

Additionally, calculations of the population consumption from 1977 to 1997 exemplified the large variability in trophic transfers from zooplankton to fish.

Michael Olesen reported on copepods, their role in the transfer of primary production to pelagic fish and on nutrient load, trophical structure and productivity (for a detailed presentation, see Annex 1). Laboratory studies had demonstrated why about 2/3 of fecal pellets produced by Baltic Sea copepods might degrade in a 15 m deep mixed layer before sinking out. Furthermore, taking into account, that non-pellet bound fecal material seems to comprise > 50% of the total egestion, a recycling of fecal material from copepod within the mixed layer of about 90% can be anticipated

Field studies had shown that less than 10% (Baltic Sea) and up to 20% (Kattegat) of the fecal pellets are produced by copepod sediments, while this ratio is close to 100% under oceanic conditions with large copepod species. This means, that each unit of limiting nutrient processed by copepods has been recycled up to nine times in the Baltic Sea, but only four times in the Kattegat before leaving the mixed layer. Copepods therefore act as a link between nutrients and productivity in the Baltic Sea, while they function both as nutrient sink and link in the Kattegat.

Copepod activity is between 3–4 times higher in the Baltic Sea than in the Kattegat. This might be either due to higher interspecies competition in the Kattegat, or due to low predation pressure, which in turn allows the copepods in the Kattegat to overexploit their phytoplankton resource, leading to lower copepod biomasses.

In the Baltic Sea, fish landings reach almost 1% of new production. The ecological efficiency, i.e., the transfer to higher trophic levels, therefore seems to be remarkably higher in the Baltic Sea than most other sea systems. Since regenerated production prevails in the Baltic Sea these findings conflict with the widespread paradigm that short food chains are more efficient in the transfer of organic matter to fish than foodwebs consisting of many levels.

Recycling efficiency varies widely even between subsystems of the Baltic Sea. Therefore, primary production is linked only weakly to nutrient discharges and primary production alone is therefore not suitable for assessing eutrophication. However, beyond routine monitoring, knowledge of primary production is necessary to understand how ecosystems behave with respect to the interaction between loading, trophical structure and fish production. In order to achieve an understanding of system productivity, primary production data has to be combined with measurements of sedimentation, system metabolism, and nutrient inputs.

Georg Kornilovs introduced the research and data collection at the Latvian Fisheries Research Institute. The main research field of the pelagic fish sector of the Latvian Fisheries Research Institute is connected with the collection of biological data for the assessment of Baltic herring and sprat stocks as well as for the provision of recommendations on sustainable exploitation of the resources of pelagic fishes within the economical zone of Latvia. In general, this work and the biological data available are similar to those of other national fisheries laboratories not presented at this Study Group meeting. Firstly, this biological material includes description of the catches of Latvian pelagic fishery. The samples from Latvian pelagic fishery are collected on a monthly basis and the biological analyses of these samples include the following parameters: length, weight, sex, stage of gonadal development, age, and population. About 12 000 herring specimens and 6 000 sprat specimens are analysed each year. For the assessment of herring and sprat stocks these data are compiled with the data of other national laboratories by the ICES Baltic Fisheries Assessment Working Group (WGBFAS).

Secondly, the scientists of the pelagic fish sector carry out national surveys and participate in the international surveys that are necessary for the assessment of pelagic fish stocks and for the estimation of the recruitment. They participate in the international October and May hydro-acoustic surveys in the Baltic Proper. The latter survey is not carried out regularly. Besides, they perform the hydro-acoustic survey of herring in the Gulf of Riga together with Estonian colleagues. To describe the reproduction conditions of pelagic fishes regular ichthyoplankton surveys are performed in the Baltic Sea and in the Gulf of Riga. In the 1980s it was stated that the eutrophication of the Baltic Sea had a negative influence on the area and on the distribution of herring spawning grounds in the coastal zone. In the 1980s the spawning grounds and the success of embryonic development of herring were investigated in the Gulf of Riga. In the 1990s there were irregular investigations of herring spawning grounds in the Latvian coastal zone of the Baltic Sea.

The pelagic fish sector performs additional zooplankton and pelagic fish feeding studies aiming to obtain information on the reproduction and feeding conditions of pelagic fishes. These investigations are carried out on seasonal basis. The data sets started for zooplankton in the early 1960s and for pelagic fish stomach content analysis in the mid-1970s. In the Gulf of Riga, zooplankton research has revealed that herring year-class strength depends on the feeding conditions for herring larvae in May, and this relationship is used for prediction of recruitment of Gulf of Riga herring that at present is the only relationship used for the fish stocks in the Baltic Sea.

Maris Pliksh gave an overview of fish stock assessment in the Baltic Sea.

The fish stock assessment in the Baltic is carried out by ICES Baltic Fisheries Assessment Working Group (WGBFAS). The analytical assessments are performed only for main commercial fish stocks (Figure 2):

1) Western Baltic Cod (SD 22–24);
2) Eastern Baltic Cod (SD 25–32);
3) Herring in the Main Basin (SD 25–29 and 32, excluding Gulf of Riga);
4) Herring in the Gulf of Riga;
5) Herring in the Bothnian Sea (SD 30);
6) Herring in the Bothnian Bay (SD 31);
7) Sprat (SD 22–32);
8) Flounder (SD 24 and 25).

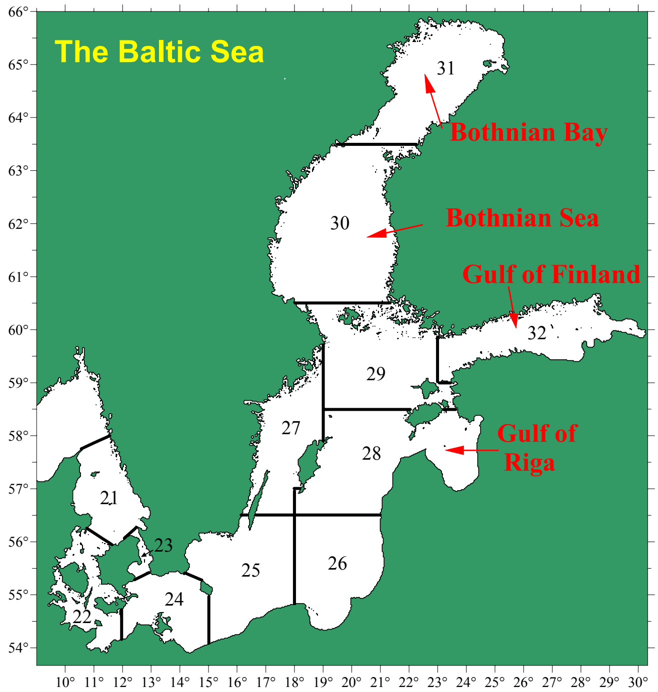

Figure 2. The Baltic Sea. ICES Subdivisions.

Assessment

For stock assessments age-structured models are used – Extended Survival analyses (XSA) that is a standard assessment tool in ICES. The main results obtained include historical total stock biomass (TSB), spawning stock biomass (SSB), fishing mortality (F) and recruitment historical development trends. In the traditional single stock assessment, the used models do not couple with any environmental data.

The data used in the model for specific stock include statistical and biological information from commercial landings as well as data from research surveys. The data from commercial landings are usually collected at quarterly or monthly intervals on ICES Subdivision basis and are obtained from sampling on-board commercial vessels or harbors. The necessary data set include:

1) Total catch in tonnes and numbers by stock and gear;
2) Mean weight-at-age in catch;
3) Age composition of landings/catch in numbers by age groups;
4) Model tuning data – fleet effort and catch per unit of effort by age.

The following data are obtained from research surveys:

1) Mean weight-at-age in the stock;
2) Maturity ogives;
3) Abundance indices of recruits;
4) Model tuning data – stock abundance indices by age groups.

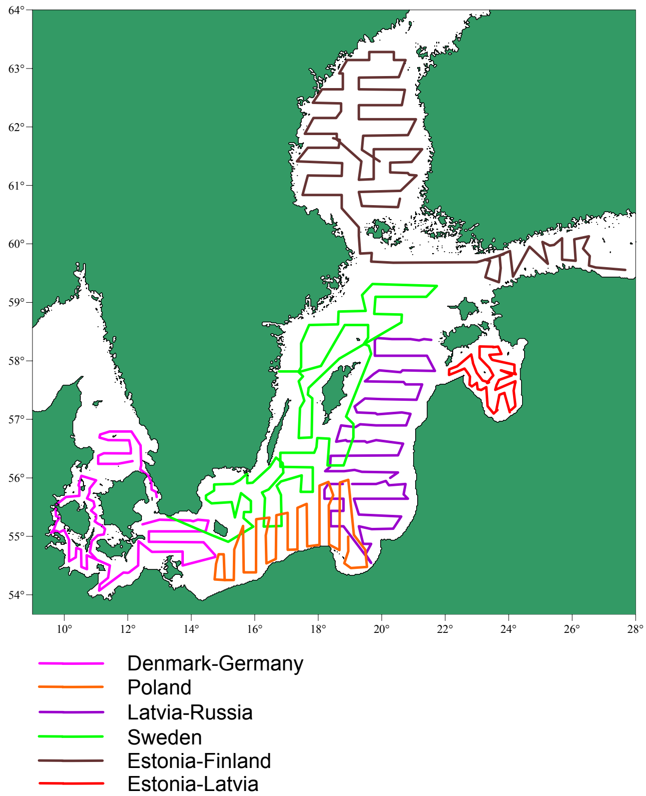

Figure 3. Area coverage in BIAS survey, autumn 2003.

For the assessment of cod, herring in the Main Basin, and sprat two surveys are of major importance:

1) Baltic International Acoustic Surveys (BIAS) that provide biological and tuning data for sprat and herring. The survey is internationally coordinated and takes place in September –October (Figure 3). Besides some countries have additional survey in May (sprat survey), covering the same area with the exception of the northern Baltic. The information and data from the May survey in the stock assessment so far have not been used, but could be considered as the additional tuning time-series for sprat stock assessment.

2) Baltic international Trawl Surveys (BITS) that provide stock biological and tuning data of cod. The survey is internationally coordinated, based on random haul position selection and takes place in the first quarter, usually in March (Figure 4). Since 2001, all countries in surveys using the standard survey gear – TV3 trawl. According to ICES recommendations it is proposed the BITS survey in the fourth quarter (November). So far, not all countries were able to carry out this survey. As a result available information is not used in stock assessment. However taking into account the problems with cod stock assessment it is an intention to work up the cod abundance indices from autumn survey as a second tuning fleet data.

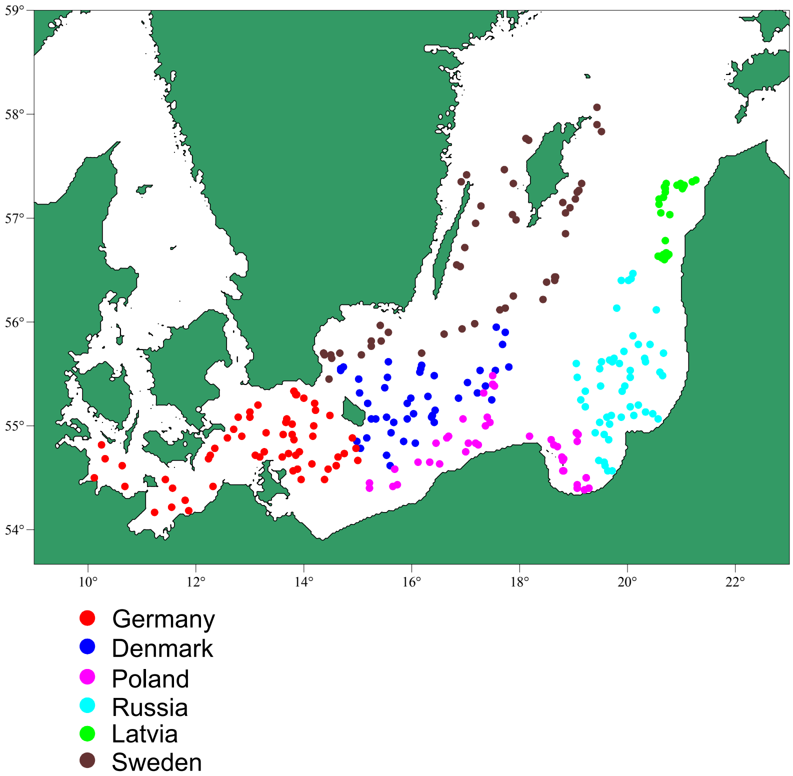

Figure 4. Trawl positions in BITS survey, spring 2003.

All available data from acoustic surveys are recorded in the Baltic Acoustic Database (BAD), whereas trawl surveys are recorded in a BITS database, which is maintained at ICES. The databases also include available hydrographic data (salinity, temperature, oxygen saturation) if they are obtained during surveys.

Main deficiencies in the assessment

- Age readings, especially for cod revealing two schools of age interpretation;
- Insufficient sampling intensity of discards;
- Unreported landings (especially the case for cod);
- Precision of reported sprat and herring landings due to mixed fishery on this species;
- Mismatch between assessment and management units (cod, herring);
- International survey used for calibration of pelagic fish stocks does not cover the whole area.

Short-term prediction

Short-term prediction is based on initial stock size as estimated from XSA analyses and supplemented with recruitment estimates from other sources, e.g., surveys, GM, or relationship with environmental parameters. Short-term prediction produces stock development and catch option tables for next three years. Based on these predictions ICES provides advice for stock management. Although there are several good relationships between environmental parameters and recruiting year-class strength (e.g., cod recruitment versus reproduction volume, sprat recruitment versus temperature), only for the Gulf of Riga herring the recruitment abundance prediction is based on environmental data, e.g., zooplankton abundance and temperature (Figure 5).

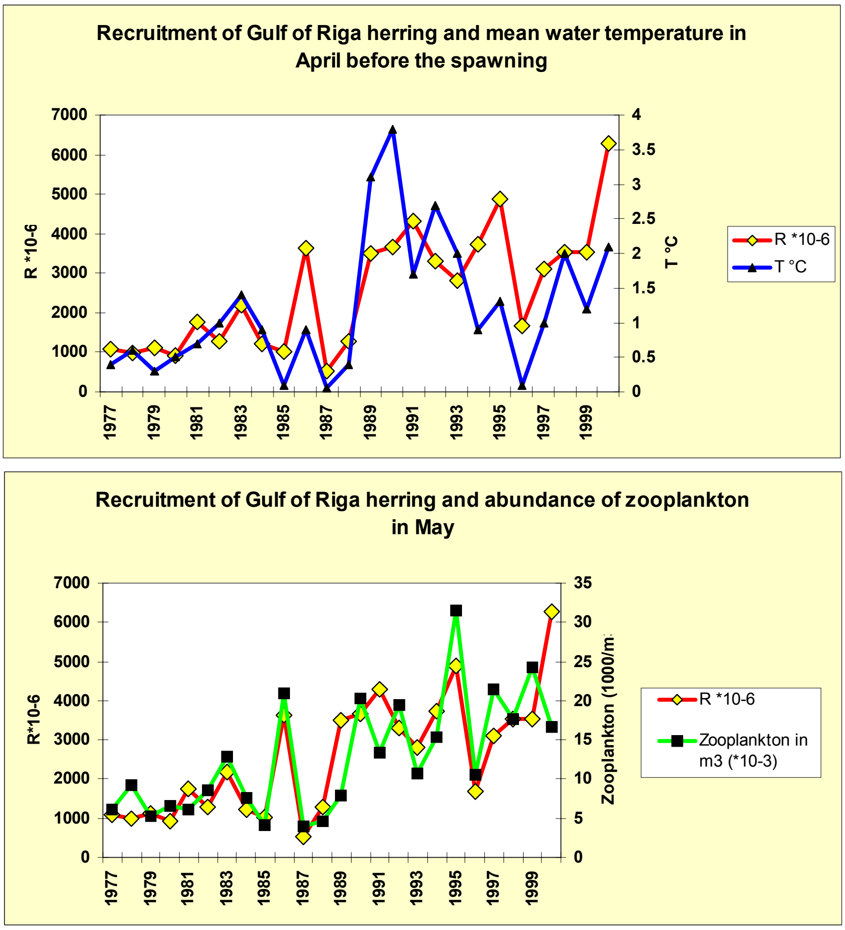

Figure 5. Gulf of Riga herring recruitment dependence from environmental parameters (ICES, 2003).

Medium-term prediction

Medium-term prediction (10 years) based also on initial stock size as output from XSA but also includes some stochastic variation of stock-recruitment relationship, mean weight-at-age, and maturity ogive. Stock recruitment relationship for the Baltic fishes is poorly estimated obviously because the recruiting year-class strength in Baltic is determined rather by environmental factors than by parental stock size. However, no environmental effects in projections are taken into account because prediction of environment situation is not available at present.

3.2.1 Monitoring

Juris Aigars reported on currently ongoing activities related to marine monitoring strategy:

The Water Framework Directive (WFD) brought pressure on existing monitoring activities coordinated by HELCOM and the need to revise the existing monitoring program became apparent. As a result HELCOM MONAS formed a project group, MONPRO, and tasked it to critically update the existing monitoring program (COMBINE) in order to meet the challenges presented by the WFD, without loosing elements, which currently are superior to WFD requirements.

Another activity started as an initiative of the European Commission, which – realizing that the one nautical mile zone used in WFD to define coastal waters is too narrow a stretch when marine waters are considered – initiated the development of a Marine Strategy. Since no sea is located solely in EU territorial waters, this Marine Strategy is not intended as directive. The main idea is to try to extend the requirements of WFD further into the sea when possible.

Jonne Kotta described zoobenthos-related activities in Estonian coastal sea. Estonian coastal water monitoring aims to survey the spatial and temporal variability in benthic invertebrate assemblages and relate this to the anthropogenic impact. The programme, which has been carried out regularly since 1993, covers the major bays and deeps around Estonian coastal waters. Three bays are investigated more frequently (fortnightly, monthly) since 1997. Additional data exist on hydrography, phytoplankton, and zooplankton. Within the phytobenthos monitoring programme, macrozoobenthos have been studied since 1995. Six transects around Estonian coastal sea are investigated. Most prevalent phytobenthic communities are sampled in each vegetation zone (e.g., *Cladophora*, *Fucus*, *Furcellaria*). Other programmes related to productivity and involving macrozoobenthos studies include: (1) human induced introductions and their possible impact on the productivity, (2) water quality status in terms of benthic invertebrates, (3) process and ecosystem studies (*Estonian Governmental Programme*). Further information about these activities can be found at http://www.sea.ee.

Arturas Razinkovas reported on trophic network analysis to evaluate the ecosystem role of introduced Ponto-Caspian crustaceans in the Curonian lagoon ecosystem. Ponto-Caspian mysids and gammarids intentionally introduced into Lithuanian waters in the early 1960s formed a number of assemblages in lakes finally reaching rivers the Curonian lagoon of the Baltic sea via passive transport downstream.

Their ecosystem role was still unclear due to the lack of trophology data as well as their position in the foodweb. Based on *in situ* studies, foodwebs of littoral and pelagic parts were quantified using the ECOPATH model. Three trophic levels were available in the littoral zone. Phytoplankton and macrophytes represented the autotrophs, while six other compartments formed second trophic level and the fish larvae represented the third level. As strong diurnal variation in the diet of introduced species was found, transition of mysids to higher trophic level was accounted. As in the pelagic zone, zooplankton is the most important consumer of primary production (up to 28%), introduced crustaceans play an important role of energy transformation in the littoral zone (up to 12%). However, the impact of introduced crustaceans is stronger in the littoral zone, where their biomass is the highest.

An attempt was made to reconstruct the pre-introduction of the Curonian lagoon foodweb based on the historical data. The comparison of two models pointed mostly to a qualitative shift in food chain predatory fish -> juveniles -> zooplankton -> phytoplankton towards predatory fish -> mysids -> detritus pathway.

Georg Martin presented productivity-related phytobenthos studies in Estonian coastal waters. Phytobenthos investigations have a long history in Estonian coastal waters. The first literature records about phytobenthos from Estonian coastal waters date back already to 18th century. Most of the studies conducted before the middle of the 20th century were mostly floristic studies. The first quantitative investigations started in the late 1950s. The most recent period in phytobenthic investigations started in the beginning of 1990s when the presently active group, the Department of Biology of the Estonian Marine Institute, started with its work.

Phytobenthos investigations could be divided into the following categories:

1) Phytobenthos mapping studies (species, biomass, coverage);
2) Physiological studies (primary production, growth rate);
3) Ecological studies (grazing, habitat preference, environmantal forcing, etc.);
4) Monitoring.

1 Phytobenthos mapping studies cover all coastal waters of Estonia. Extensive mapping activities took place in 1995–1996 in the waters of the Gulf of Riga and West-Estonian Archipelago. Later several small-scale phytobenthos mapping studies were carried out in waters of national parks and nature conservation areas located on the seashore. A short summary of published mapping results is given in Table 1.

Table 1. Phytobenthos mapping studies in Estonian coastal waters.

Area	Type of investigation	Reference
Pärnu Bay, 1991	Phytobenthos mapping	Kukk and Martin 1992; Martin, 1999
Kunda Bay, 1993, 1994	Phytobenthos mapping	Murumets *et al*., 1997
Tallinn Bay, 1993–1997	Phytobenthos mapping, bioindication	Martin and Kukk, 1997
Gulf of Riga 1995–1996	Phytobenthos mapping	Kautsky *et al.*, 1999
Naisaar island 1995	Phytobenthos mapping	Kukk *et al.*, 1997
Estonian coastline 1998	Fucus community mapping	Reitalu *et al.*, 2002
West Estonian Archipelago Sea 1995–1998	Phytobenthos mapping	Martin, 2000
South coast of Vormsi island	Phytobenthos mapping	Martin, 1994
Eastern coastline	Distribution of Aglaothamnion roseum	Torn and Orav, 2002
West Estonian Archipelago Sea 1998–1999	Phytobenthos community mapping	Martin *et al*., 2000; Martin and Torn, 2003
West Estonian coastal sea 1995–1999	Quantitative mapping	Martin, 2000
Lahemaa National Park 2000	Benthic mapping	Kotta *et al*., 2003
Bays of W Estonia	Charophytes mapping	Torn and Martin, 2003
Estonian coastline 2001–2002	Mapping of charophytes	Torn *et al*., 2003

2 Physiological studies

The following examples are physiologically related studies carried out in Estonian coastal waters during the last decade, with relevant references:

Different macroalgal species common in Estonian coastal waters (e.g., *Pilayella littoralis*, *Fucus vesiculosus*, *Furcellaria lumbricalis*, *Enteromorpha intestinalis*, *Cladophora glomerata)*; incubation depth 0.5 meter; diurnal and seasonal changes in primary production were followed (in relation to light condition, nutrients and water temperature).

Paalme, T. 1997. Primary production of different species of algae measured in situ in Tallinn and Muuga bays. EMI Report Series, 1997, 8: 19–31.

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P. littoralis and *C. glomerata* forming free floating algal mats; Comparison of net primary production rates of attached algae and algae forming the free-floating mats were carried out during the formation, development and decomposition of algal mats.

Paalme, T., Kukk, H., Kotta, J., Orav, H. 2002. "*In vitro*" and "*in situ*" decomposition of nuisance macroalgae Cladophora glomerata and Pilayella littoralis. Hydrobiologia, 475/476: 469–476.

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Paalme, T., Kukk, H., Kotta, J., Orav, H. 2002. "*In vitro*" and "*in situ*" decomposition of nuisance macroalgae Cladophora glomerata and Pilayella littoralis. Hydrobiologia, 475/476: 469–476.
Kotta, J., Orav, H., Paalme, T.,and Kukk, H. 2001. "*In situ*" evidence on the role of benthic invertebrates on the decomposition of drifting algal mats in the NE Baltic Sea. Abstracts 36th European Marine Biology Symposium, 17–22 September, Mao, Spain.

3. Ecological studies involve experimental work connected to primary productivity, grazing impact, impact of changes in trophic conditions as well as changes of community structure. *4. Monitoring studies.* The Estonian national phytobenthos monitoring programme has been running since 1995 and includes six areas. Methodology is based on the one used in Scandinavian countries and comply with the Phytobenhos Monitoring Guidelines developed for HELCOM COMBINE programme. Results of the monitoring programme are published annually in the State of The Environment Report and several scientific publications have been generated from this material. **Anda Ikauniece** reported on existing data quality requirements for the plankton monitoring in the HELCOM COMBINE program. The purpose of data collection in the COMBINE was described and general approach of the HELCOM QA system characterized. The main emphasis of the presentation was on the sampling requirements of the parameters and the treatment of samples as these procedures are the essential source of errors in data. Sampling features of phytoplankton, chlorophyll *a* and mesozooplankton were reflected, and counting issues of planktonic organisms were covered.

3.3 Data and information for modelling and assessment

Magdalena Wielgat described an application of a dynamic box model to simulate main processes of the nutrient (nitrogen and phosphorus) cycling as an example or case study for the Szczecin (Oder) Lagoon. As a first step of work, the model was used to analyse processes influencing nitrogen and phosphorus cycling in the Szczecin Lagoon during the period 1980–99 and to calculate a nutrient budget. It allowed to estimate nutrient retention in the estuary and the possible pathways of this retention. As the second step of work, changes in nutrient loads discharged by the Oder River over the period of the last 50 years were analysed. Based on the reconstructed riverine loads the model was run to simulate the development of eutrophication, and its consequences, in the Szczecin Lagoon over the last five decades. Next, the model was run to simulate predicitive sceanarios, to see how the reduction of nutrient emission from the Oder drainage basin would influence the trophic state of the Szczecin Lagoon. Application of the same modelling tool for retrospective simulation and scenarios allowed to compare the expected results of improvement of the Szczecin Lagoon water quality as compared to the situation in the past.

Bärbel Müller-Karulis reported on attempts to model nutrients and phytoplankton based on monitoring data. The use of monitoring data for modelling was recently investigated in the NMR financed STAMP project (STAMP – statistical analysis and modelling of phytoplankton dynamics). Data interpolation methods (general linear model, optimum analysis, LOESS smoothing) proved useful for filling gaps in monitored time-series, when simultaneous observations are available at different locations. Monitoring data supported both empirical (Carstensen *et al.,* 2003) as well as mechanistic (Toompuu *et al.,* 2003) modelling approaches. Using an empirical modelling approach, primary production in the Kattegat was split into regenerated and new production. The latter clearly correlated with land and atmospheric N loading (Carstensen *et al.,* 2003), while a mechanistic model showed, that in summer new production is based entirely on external inputs (Toompuu *et al.,* 2003).

A box model (Savchuk, 2002) was used to model long-term nutrient and phytoplankton trends in the Gulf of Riga (Müller-Karulis, in preparation). Differences in the response of N and P pools to nutrient load reductions were linked to the dynamics of nutrient sinks in the Gulf. While N was efficiently removed by denitrification, slow export to the Baltic Proper and sediment burial were the dominant P sinks.

Generally monitoring data is suited for mathematical modelling. However, model resolution has to be adapted to spatial and temporal scales of data. For mechanistic models that include nutrient regeneration, primary production should be available as a measure of total biomass turnover. Due to the high natural variability in land-based nutrient loads, hindcast models can provide a first indication of ecosystem response to different load scenarios.

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4 ANY OTHER BUSINESS

4.1 Conference participation

4.1.1 Baltic Sea Ecosystem structure and dynamics – consequences of physical and anthropogenic forcing?

Theme Session at the 2004 ICES Annual Science Conference in Vigo, Spain.

Christian Möllmann summarized the goals of the Theme Session. The Study Group agreed that the theme session would provide a good opportunity to present preliminary results on trophic networks in the Baltic Sea if work has progressed sufficiently by 2004.

4.1.2 Theme Session on Regional Integrated Assessments

Brian MacKenzie introduced the proposal made by the Regional Ecosystem Study Group for the North Sea (REGNS) for a Theme Session at the 2006 ICES Annual Science Conference. REGNS approaches the assessment of the North Sea Ecosystem by forming writing panels that address specific components of the ecosystem. The proposed Theme Session will present the results of the writing panels. REGNS also invites contributions from other ecosystems. Brian MacKenzie emphasized that writing panels set up for the assessment of other ecosystems will not have to parallel the structure followed by REGNS, but should address components in the Baltic Sea ecosystem that are considered important with respect to understanding and describing major changes.

The Group agreed that the Theme Session provides an opportunity to present results from the work of SGPROD. The subgroups formed during the meeting could serve as a basis for writing panels.

4.1.3 Material and energy flows in trophic networks of the Baltic Sea ecosystem

Theme Session proposal for the 2005 ICES Annual Science Conference (Annex 2).

To provide an opportunity for SGPROD to present their results, Bärbel Müller-Karulis had submitted a proposal for a Theme Session to the Baltic Committee at the 2003 ICES Annual Science Conference, and the proposal had been included in the list of potential theme sessions for the 2005 Annual Science Conference. The Study Group welcomed the proposal as a good opportunity to present results on the analysis of trophic networks. The Group agreed that the scientific justification of the proposal as well as the links to the ICES strategic plan should be elaborated until summer 2004. Bärbel Müller-Karulis was suggested as convener of the Theme Session, a second convener will have to be found before summer 2004. The proposal will then be finalized and resubmitted to the Baltic Committee to be discussed at the 2004 Annual Science Conference.

5 DISCUSSION OF THE TERMS OF REFERENCE

5.1 TOR a – Commence a summary of the evidence for links between land-based nutrient inputs and long-term changes of both productivity and biodiversity in eutrophied areas of the Baltic Sea

Eutrophication of the Baltic Sea first came to attention in the late 1960s, when Fonselius (1969, cited in Elmgren, 2001) reported extensive oxygen depletion in the Baltic Deep Basins. Fonselius’ work triggered a scientific debate whether natural variations in hydrographic conditions or increased productivity and sedimentation of organic matter had caused the decreased oxygen (Elmgren, 2001). Already in the first HELCOM assessment of the Baltic Sea ecosystem in 1981 (Melvasalo *et al.,* 1981) it became clear, that changes in coastal areas, like decreased Secchi depth or hypoxia, could easily be linked to local and, at that time, excessive sewage inputs. On the other hand, it was not possible to decide whether changes in the open sea, for example increasing phosphate concentrations in the Gotland Basin, were linked to natural fluctuations or anthropogenic loadings.

Generally, there is a lack of quantitative information on both nutrient loads to the Baltic Sea prior to the mid-1970s as well as to the state of the ecosystem itself. Systematic observations of riverine nutrient concentrations started in the 1970s in most riparian countries (Stalnacke *et al.,* 1999). Only for some European rivers outside the Baltic Sea drainage basin like the Rhine (Germany/Netherlands) or the Tisza (Hungary) time-series reach back as far as the 1950s (Grimvall *et al.,* 2000), indicating that riverine nutrient loads had started to rise already during the 1950s. Monitoring of the nutrient concentrations and biological variables in the Baltic Sea began in the early 1970s. National cooperation among the coastal states intensified with the establishment of the 1974 Helsinki Convention (Convention on the Protection of the Marine Environment of the Baltic Sea Area) and the formation of the Helsinki Commission (Baltic Marine Environment Protection Commission, HELCOM). Still, while observations of salinity, temperature and oxygen conditions date back to the early 1900s (Melvasalo *et al.,* 1981), the longest time-series of phosphate concentrations in the Baltic Sea starts in 1958, observations for nitrate in 1969 (Nehring *et al.,* 1984). Therefore, attempts to reconstruct early states of the Baltic Sea ecosystem based on direct observations have been restricted to few parameters like Secchi depth and fucus coverage (for example, Jansson and Dahlberg, 1999). Indirect approaches, which rely on paleolimnological techniques to reconstruct nutrient concentrations, are currently under development (www.helsinki.fi/science/ ecru/MOLTEN.html). Simulation modelling as a tool to link external loading of the Baltic Sea to changes in nutrient concentrations and biological variables was introduced during the late 1980s (for example, Savchuk and Wulff, 1996; Savchuk and Wulff, 1999; Neumann *et al.*, 2002). However, models have been almost exclusively used either to describe the current state of the Baltic Sea ecosystem or to forecast the response to nutrient load reductions. An exception is a simple biogeochemical model that describes a fast increase of pelagic nutrient concentrations paralleling rising nutrient loads to the Baltic Sea between 1950–1980 (Wulff and Stigebrand, 1989). Thus, while the symptoms of eutrophication are well monitored there is still a lack of quantitative understanding how these symptoms are linked to external nutrient loads (Savchuk and Wulff, 1999). It also has to be taken in mind, that most of our quantitative knowledge of the Baltic Sea ecosystem and its external loading is based on data covering the time-period mid 1970s to present, when the system had most likely already been subject to increased riverine nutrient loads, while the pristine state of the Baltic Sea ecosystem is poorly described.

After a continuing increase in nutrient concentrations in the Baltic Sea, the Ministers of the Environment of the Baltic Sea countries reached a political consensus to reduce nutrient loads to the Baltic Sea by 50% in 1988, despite the lack of "undisputed scientific proof", adopting a precautionary approach (1988 Ministerial Declaration):

> "BEING CONVINCED that the damage to the marine environment can be irreversible or remediable only in a long-term perspective and at considerable expense and that, therefore, Contracting Parties to the Convention must adopt a precautionary approach and not wait for full undisputed scientific proof of harmful events before taking action to prevent and abate pollution," (Declaration on the protection of the marine environment of the Baltic Sea, 1988 Ministerial Declaration)

The search for scientific proofs of links between nutrient loading to the Baltic Sea and impacts on the ecosystem is complicated further by high spatial variability of eutrophication effects on the Baltic Sea ecosystem. Major effects are (Elmgren and Larsson, 2001, and references cited):

- Reduced water transparency, affecting submerged vegetation
- Increase of toxic or noxious algal blooms
- Increased areas of oxygen-deficient bottom waters
- Both positive and negative effects on fish stocks

Rönnberg (2001) adapted a conceptual model (Bernes 1988; Bonsdorff *et al.,* 1997) to systematize eutrophication effects in nine Baltic Sea Subareas (Figure 6). However, the pathways along which increased nutrient inputs altered the ecosystem and the compartments most strongly affected differed between subareas. Also the HELCOM periodic assessments of the Baltic Sea ecosystem give a complex picture of eutrophication effects in the Baltic Sea, which is further complicated by interannual variations in hydrographic conditions and nutrient loadings.

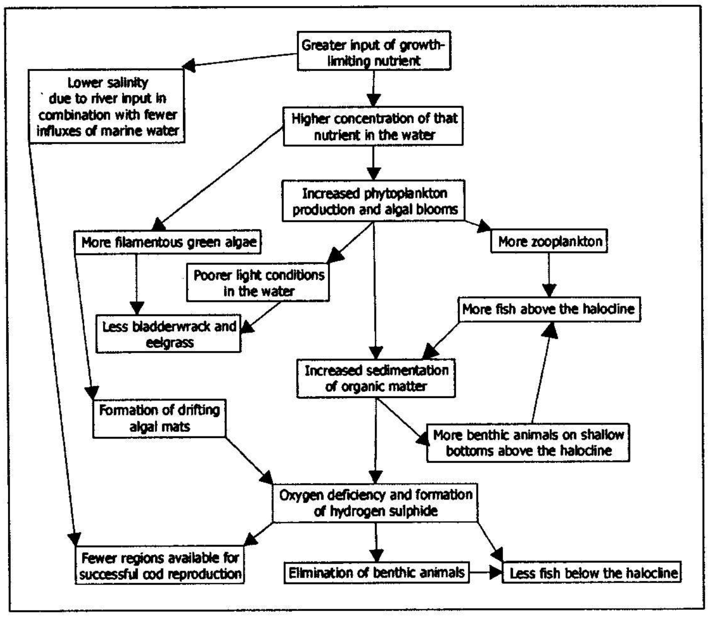

Figure 6: Conceptual flow-model of the eutrophication process (Rönnberg (2001) after Bernes (1988), Bonsdorff *et al.* (1997)).

HELCOM Baltic Monitoring Programme data (HELCOM 1990, HELCOM 1996, HELCOM 2002, HELCOM 2003) have proved that long-term trends of phosphate (1958–1993) and nitrates (1969–1993) in the Baltic Sea have been positive because of a considerable increase of concentrations between 1969–1978 and 1969–1983, respectively. However, the reflection of increased nutrient loading in the biological components of the pelagic ecosystem had not been so obvious. Only in some parts of the Baltic Sea with high human activity – e.g., in Kattegat and the Western Gulf of Finland – some proofs were found in 1980–1993. In Kattegat, the anthropogenic loading together with highly variable hydrography had caused a pronounced variability in the phytoplankton dominating species composition while in the rest of the Baltic the bulk of algal biomass was formed by the same three to five dominating species. In the Western Gulf of Finland an increase in the peak phytoplankton biomass during spring blooms was observed for 1968–1988. An increase has been recorded also for zooplankton abundance in the Archipelago and Åland Seas till 1993.

The benthic communities have shown more distinct responses to eutrophication, especially the macroalgae. The major features have been the decrease of coverage and depth distribution of eelgrass (*Zostera marina*) and other perennial macroalgae at the southern parts of Baltic and the same for bladder wrack (*Fucus vesiculosus*) in the north-western areas in 1984–1993.

Since the end of the 1980s the waterborne phosphorus load decreased considerably and the same was true also for the 1990s. In contrast, the waterborne nitrogen load has not decreased since the end of 1980s. Thus the N:P ratios have increased in the Kattegat and in the Baltic Proper since 1994. There also the biomass of most phytoplankton groups has decreased. In other Baltic Sea areas the dominance of diatoms during spring bloom has been switched to dinoflagellates, and biomass has been decreasing or increasing. In general, phytoplankton biomass and chlorophyll *a* concentration exhibited large variability with no directed changes in many parts of the Baltic Sea. In the Gulf of Riga the chlorophyll *a* values have been lower since 1994, coinciding with the decline in winter nitrogen concentrations observed since the early 1990s. Also mesozooplankton abundance and biomass tended to decrease in the Gulf of Riga and the southern part of the Baltic Sea, but no changes were observed for the other marine areas. Extensive summer phytoplankton blooms, often formed by potentially toxic algae and cyanobacteria have become more common since 1995.

During mid- and late 1990s the perennial benthic vegetation has decreased in the northern part of the Gulf of Riga and in many Danish fjords. At the same time, recovery of the bladder wrack population has been recorded for the Gulf of Finland and the southern Gulf of Riga.

In general, pathways and time-scales of ecosystem recovery after extensive nutrient loading are known mainly from coastal areas. For example, nitrogen removal in a sewage treatment plant, the main polluter of the Himmerfjärden area, led to a decrease in chlorophyll *a* already after two years (Elmgren and Larsson, 2001). Macrozoobenthos communities on the other hand had not recovered fully after five years (Savage *et al.*, 2002). Immediate response to two years with low runoff and consequently low nutrient loading was also observed in the coastal waters around the island of Funen, where Secchi depth, eelgrass coverage and bottom water oxygen concentration had increased, while phytoplankton biomass and production declined (Rask *et al.*, 1999). In the southern part of the Gulf of Riga (Saulkrasti area) the phytobenthic communities were extremely poor in 1995. Only two species of green algae were observed in the area. In 1999 the phytobenthos of the same area was more diverse – 10 species and the depth limit had increased from 2 to 8 metres (Institute of Aquatic Ecology, University of Latvia, 1999 Marine monitoring report).

Modelling studies had mainly focused on the Baltic Proper or large Bays like the Gulf of Finland and the Gulf of Riga. Model results suggest that in the Baltic Proper increased nitrogen fixation by cyanobacteria might compensate nitrogen load reductions (Savchuk and Wulff, 1999). Times scales for ecosystem recovery after a 50% load reduction are predicted to be on the order of decades for the Baltic Proper (Savchuk and Wulff, 1999; Neumann *et al.*, 2002), but nutrient inventories in coastal systems have been modeled to decline at the same rate fast than the load reductions (Neumann *et al.*, 2002). Similarly, also the primary production in the Gulf of Finland is indicated to respond fast to nutrient load reductions (Savchuk and Wulff, 1999), but for the Gulf of Riga, a 50% nitrogen and phosphorus load reduction was predicted to reduce primary production by only 20% after 12 years, but winter pools of nitrate and phosphate were simulated to drop by approximately 30% and 15%, respectively (Savchuk, 2002, cited from Figure 8). However, winter nitrate in the Gulf of Riga correlated strongly with riverine runoff over the period 1981–1998 (HELCOM, 2002), suggesting a faster response of the Gulf of Riga pelagic nutrient pools to changes in nutrient loads. High correlations of new production and sedimentation to riverine and atmospheric nutrient inputs were also observed in the Kattegat, where a 50% reduction of nitrogen loading was predicted to immediately decrease net primary production by 20 to 47% (Carstensen *et al.* 2003). Thus, there is considerable uncertainty about the time-scale and course of ecosystem recovery under reduced nutrient loading.

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5.2 TOR b – Commence development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea that are important to ecosystem-based management taking into account the work already undertaken by ACE and the EEA

The goal of the group with respect to TOR b) was to plan and initiate the future work to develop a system of ecological indicators characterizing productivity at different trophic levels (and maybe also in different subareas) in the Baltic. As a first step the Group made an effort to update their knowledge with respect to the present use of indicators, especially considering the work conducted by ACE and EEA.

5.2.1 Indicators and Ecological Quality Objectives

Numerous definitions exist for environmental and ecological indicators. Most are based on the concept of identifying values representative of more complex phenomena. The European Commission defines an indicator as

> "Observed value representative of a phenomenon to study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesised. In short, indicators simplify information that can help to reveal complex phenomena." (http://europa.eu.int/comm/dg06/publi/landscape/gloss.htm)

In the context of ecosystem assessment and monitoring, indicators can be used to "represent key information about ecosystem structure, functioning and composition" (Dale and Beyeler, 2001). Similarly, the US Environmental Protection Agency (EPA) definition regards indicators as tools to characterize ecosystems, but at the same time highlights their usefulness in tracking temporal changes and predicting future ecosystem states.

> "An indicator is a sign or signal that relays a complex message, potentially from numerous sources, in a simplified and useful manner. An ecological indicator is defined here as a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components. An indicator may reflect biological, chemical or physical attributes of ecological condition. The primary uses of an indicator are to characterize current status and to track or predict significant change. With a foundation of diagnostic research, an ecological indicator may also be used to identify major ecosystem stress." (Jackson *et al*., 2000)

Indicators are not only used to assess the state of an ecosystem, but are frequently applied to design and evaluate environmental policies. For this purpose, indicators should be relevant to address environmental policy issues. The US EPA uses indicators in a pressure-state-response framework to describe pressures on the environment, the state of the environment, and the response of society to environmental changes. Similarly, the European Environment Agency (EEA) has adopted a DPSIR framework, where indicators describe the **driving forces** for environmental processes, **pressures** on the environment, the **state** of the environment, the resulting **impact** on human beings, ecosystems and materials, and the societal **responses** to changes in the environment (Nixon *et al*., 2003). Accordingly, the EEA defines indicators as follows:

“A parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action” (http://glossary.eea.eu.int/EEAGlossary/E/environmental_indicator)

Also the European Marine Strategy advocates the use of indicators and plans to “initiate in 2002 the development of an ecosystem-based approach based on ecosystem indicators and benchmarks” (Commission of the European Communities, 2002).

While indicators are parameters characterizing environmental states or processes, ecological quality objectives (EcoQOs) are a “tool for setting clear operational environmental objectives directed towards specific management and serving as indicators for the ecosystem health” (Bergen Declaration 2002). EcoQOs are a quantitative instrument stating both the “desired level of ecological quality and baselines against which progress can be measured” (Bergen Declaration 2002). ICES is actively involved in developing EcoQOs for the North Sea (ICES, 2002)

Ecological Quality (EcoQ) is defined as “An overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities.

Ecological Quality Elements: are the individual aspects of overall Ecological Quality.

An Ecological Quality Objective (EcoQO) is the desired level of an ecological quality (EcoQ). Such a level may be set in relation to a reference level.” (Annex 3 of the Bergen Declaration)

HELCOM adopted the use of EcoQO with appropriate eutrophication indicators in the 2003 ministerial declaration “with the view to facilitate the development and implementation of the most effective set of measures to combat eutrophication, to develop and apply … ecological quality objectives with appropriate indicators of the eutrophication status which express “good quality status” as stipulated in the Water Framework Directive, but covering the whole Baltic Sea Area” (HELCOM Bremen Declaration). So far HELCOM has conducted a pilot study drafting a system of Ecological Quality Elements and Ecological Quality Objectives (Poutanen *et al*., 2003).

Quality elements are also a central issue in the European Water Framework Directive, the legal basis for the management of coastal (1 nautical mile from the coast) and transitional waters of the Baltic Sea, with the exception of Russia. The Water Framework Directive lists a mandatory set of quality elements to be used in monitoring and assessment (Annex V of the Water Framework Directive). The existing HELCOM monitoring and assessment programmes and the indicator reports by HELCOM and the EEA *de facto* comprise a system of indicators currently used in the management of the Baltic Sea (Table 2).

Table 2. Indicators currently used for monitoring and assessment in the Baltic Sea (adapted from HELCOM MONAS 6, 2003), toxic substances not included.

Variable/Substance	**HELCOM COMBINE**	**EU Water Framework Directive**	**HELCOM 4th periodic assessment**	**HELCOM Indicator reports**	**EEA indicator report[1]**
Hydromorphological					
Substrate quantity and structure		1			
Hydrography					
Temperature	1	1	*	*	
Salinity	1	1	*	*	
Oxygenation conditions	1	Oxygenation conditions	*	*	Oxygen in bottom layer
H_2S	1	Oxygenation conditions	*	*	
pH	2				
Alkalinity	2				
Transparency	1	1			

Variable/Substance	HELCOM COMBINE	EU Water Framework Directive	HELCOM 4th periodic assessment	HELCOM Indicator reports	EEA indicator report[1]
Nutrients					
$NO_3 + NO_2$	1	Nutrient conditions	*	*	*
NH_4	1	Nutrient conditions	*	*	
Tot-N	1	Nutrient conditions	*	*	
PO_4	1	Nutrient conditions	*	*	*
Tot-P	1	Nutrient conditions	*	*	
SiO_4	1			*	
Biology					
Phytoplankton	Abundance, composition, biomass	Abundance, composition, biomass	*	*	Harmful species
Chlorophyll *a*	1		*	*	*
Primary production	2				
Zooplankton	2		*		
Macrozoobenthos	Abundance, composition, biomass	Composition and abundance of benthic invertebrate fauna	*		
Phytobenthos	2	Composition and abundance of other aquatic flora	*		
Fish	2	Transitional waters	*		not used in Baltic Sea
Non-indigenous species					*

Legend: 1 = mandatory, 2 = voluntary.
[1] Nixon *et al*., 2003.

5.2.2 Indicator development

Most of the indicators in Table 2 refer to the standing stock of a biological component of the Baltic Sea ecosystem, or reflect the hydrographical and chemical conditions supporting the biological component. Primary production is the only flux measurement in the current system of indicators.

In general, indicators of productivity serve several purposes:

- Assess eutrophication (e.g., oxygen conditions, chlorophyll *a*);
- Monitor potentially toxic or nuisance species (related to ecosystem health);
- Measure trophic transfers (e.g., primary production);
- Describe ecosystem structure and trophic interactions.

Indicators that describe ecosystem structure and trophic interactions can be grouped according to Rice (2000, 2003):

i) Indicator species (including abundance, biomass etc);
ii) Diversity indices (e.g., H´);
iii) Ordination methods (e.g., MDS, PCA);
iv) Metrics emerging from ecosystem models (e.g., ECOPATH, size-spectra models).

The Group agreed that their future goal and challenge will be to identify the indicators or suite of indicators best suited for the purpose of assessing productivity in the Baltic. Along the line of Dale and Beyeler (2001) indicators should be chosen according to different criteria which include that they:

i) are easy to measure;
ii) are sensitive to stress on the system;
iii) respond to stress in a predictable manner;
iv) are anticipatory (signify an impending change in the ecological system);
v) predict changes that can be averted by management actions;
vi) are integrative (a full suite of indicators provides a measure of coverage of the key gradients across the ecological systems);
vii) have a known response to natural disturbances, anthropogenic stresses, and changes over time;
viii) have low variability in response..

Based on the Group's discussions on the issue, a first (and very preliminary list) of indicators probably useful for assessing the productivity in Baltic coastal zone as well as open-sea areas was established (Table 3). The Study Group on Fish and Fisheries Issues in the BSRP (SGBFFI) refined the indicators addressing fish at their meeting in Riga, 3–5 February 2004.

Table 3. Preliminary list of ecological indicators potentially useful for assessing Baltic productivity.

<table>
<tr><th>Coastal Zone</th><th>Open Sea</th></tr>
<tr><td>Salinity/O2, SST</td><td>Salinity/O2 in the halocline, SST</td></tr>
<tr><td>Nutrients (DIN, DIP, Dsi…)</td><td>Nutrients (DIN, DIP, Dsi…)</td></tr>
<tr><td>Chlorophyll a</td><td>Chlorophyll a</td></tr>
<tr><td>Primary production</td><td>Primary production</td></tr>
<tr><td>Phytoplankton (key species, functional groups)</td><td>Phytoplankton (key species, functional groups)</td></tr>
<tr><td>Zooplankton (displacement vol., total biomass, species, invertebrate predators)</td><td>Zooplankton (displacement vol., total biomass, species, invertebrate predators)</td></tr>
<tr><td>Phytobenthos (key species, functional groups)</td><td rowspan="2">Fish (key species, recruitment, SSB, fishing mortality, body condition factor, stomach contents, fish diseases)</td></tr>
<tr><td>Fish (Community composition, abundance index, recruitment, stomach contents, fish diseases)</td></tr>
</table>

Another issue discussed by the Group was the future use of automated methods to generate ecological indicators. The use of Continuous Plankton Recorders (CPR) to survey zooplankton abundance, biomass and species composition as well as an index for phytoplankton was discussed. Generally, it was agreed that establishing CPRs on Ships-of-Opportunities (SOOP) is useful as it provides highly temporally and spatially resolved data. However, it was noted that due to the distribution of key zooplankton species in the halocline of the deep basins (e.g., *Pseudocalanus* sp., *Oithona similis*), an important component will not be sampled by CPR. Consequently, these species have to be covered by conventional net sampling, e.g., on regular fish or research surveys.

It was suggested that as a first step it might be necessary or possible to upgrade CTD-equipment of different institutes with a fluorometer to provide fast measurements of chlorophyll *a*. Using these on, e.g., the May hydroacoustic survey, might be a first step in using chlorophyll *a* as a spatio-temporally highly resolved indicator. Additionally, it was suggested to complement these measurements with easily accessible color sensing satellite data.

For the future it was recommended to discuss the use of FRRP (Fast Repetition Rate Fluorometer) which allows easy measurements of primary production.

Considering the first recommendations to the BRSP with respect to cruise, sampling and measurement programmes, the group strongly favoured to initiate enhanced sampling on May hydroacoustic surveys in 2004. This should include CTD-measurements including the chlorophyll *a*-fluorometer measurements discussed above, and mesozooplankton sampling in deep areas of the Baltic using WP-2 nets. The Chair of the Group was asked to coordinate this together with the Study Group on Fish and Fishery Issues in the BSRP (SGBFFI). Furthermore, technical procedures as, e.g., where to analyse samples have to be further discussed.

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5.3 TOR c – Establish an inventory of available productivity data and characterize their use

In the Baltic Sea, productivity and supporting data (Table 4) are collected by a variety of organizations and the data is stored in several databases. Hydrographic, hydrochemical, and biological data collected within HELCOM COMBINE are stored in ICES databases. ICES also holds the database for the Baltic International Bottom Trawl Sruveys (BITS). However, data are often published with substantial time lags. For example, biological data reported within COMBINE for the year 2002 was still not available in the ICES database in the beginning of 2004.

Recent attempts to operationalize the data exchange are web publications, for example within the Alg@line system (www.itameriportaali.fi, www2.fimr.fi), and the ftp-box network established within the BOOS/PAPA projects (http://www.boos.org/).

Table 4. Baltic Sea productivity data inventory.

		Indicator for		Coverage for Baltic Sea			Useable for		
Biota	Parameter	Water Quality	Trohpic links	High	Low	Very low	Trend detection	Flux	Research
Phytoplankton	Chlorophyll *a*	*	*	*			*		
	Species composition	*		*			*		
	Semi-quantitative composition (pigment composition)	*		*			*		
	Biomass	*	*	*			*		
	Vertical profile fluorescence	*		*			*		
	Primary production	*	*		*			*	
	Limiting factor (bioassay)	*				*			
	Harmful (toxic) species	*		*					
	Harmful (non toxic) species (Phaeocystis)	*				*			
	Plankton community respiration	*				*			
	Flow cytometry					*			*
	Fast repetition rate fluorometry					*		*	*
	Nitrogen fixation					*		*	*
Macrophytobenthos	Biomass or biomass of dominating sp.	*	*		*		*		
	Species composition	*			*		*		
	Coverage of species	*			*		*		
	Spatial distribution	*			*		*		
	Depth distibution	*			*		*		
	Max. depth of indicator species	*			*		*		
	Epiphytes	*			*		*		
	Primary production		*			*		*	
	Distribution of drifting species	*				*	*		
Periphyton	Chlorophyll *a*	*							
	biomass	*							
Bacteria	Density	*	*			*	*		
	Biomass	*				*	*		
	Production	*	*			*		*	
	BOD	*		*			*		
	E. Coli			*			*		
Microzooplankton	Species composition					*			*
	Abundance					*			*
	Biomass					*			*
Mesozooplankton	Species composition	*		*			*		
	Abundance	*		*			*		
	Biomass	*	*	*			*		
	Secondary production		*			*		*	
Macrozoobenthos	Species composition	*		*			*		
	Abundance	*		*			*		
	Biomass	*	*	*			*		
	Spatial distribution	*		*			*		
	Species composition	*		*			*		
	Presence of indicator species	*		*			*		
	Mussell coverage	*							
Nectobenthos	Species composition		*		*				
	Abundance		*		*				
	Biomass		*		*				
Fish									
target species in commercial fishery or indicator species in the coastal fish monitoring	Total stock biomass								
	Spawning stock biomass		*	*			*		
	Abundance		*	*			*		
	Recruitment/juvenile abundance		*	*			*		
	Spatial distribution		*	*			*		
	Mortality rates		*	*			*		
	Size/age structure		*	*			*		
	Condition		*	*			*		
	Maturity		*	*			*		
all or selected species	Species composition/diversity		*	*			*		
	Diseases				*				*
	Contaminants				*				*

Marine monitoring programmes coordinated under HELCOM COMBINE collect the majority of information on lower trophic levels, i.e. phytoplankton, mesozooplankton, phyto- and zoobenthos. Most parameters assess biomass and species composition. Fluxes –for example primary production – are only rarely measured directly (see also ICES Working Group on Phytoplankton Ecology, 2003). Marine monitoring programs also provide information on supporting parameters like nutrient concentrations and hydrographic variables (salinity, temperature). Currently, marine monitoring data are mainly used to detect temporal trends in Baltic Sea ecosystem. Hydrographic data are also collected by meteorological and maritime government institutes (former Western countries) or research organizations (former Eastern countries).

While the scope of marine monitoring programmes mainly ends at the trophic level of mesozooplankton and macrozoobenthos, information on fish is gathered by national fisheries research institutes. ICES coordinates the monitoring and assessment of fish stocks and fishing activities in two workgroups. The Baltic International Fish Survey Working Group (WGBIFS) coordinates common fish surveys, and the Baltic Fisheries Assessment Working Group (WGBFA) produces fish stock assessment and medium- and long-term prognosis. Fisheries research institutes commonly also collect data on fish prey items like mesozooplankton and nectobenthos, as well as hydrographic variables important to fish (temperature, salinity, oxygen).

Several attempts have been made to collect metadata on marine information, for example the EU projects EDIOS (http://www.edios-project.de/) and SEA-SEARCH (http://www.sea-search.net/). The measurement network in the Baltic Sea was analysed also in the PAPA project (http://www.boos.org/papa/papa.html) and maps of the station network show (Figure 7), that the observation density decreases in the order hydrographic parameters/nutrients > phytoplankton > other biological parameters (mesozooplankton, macrozoobenthos).

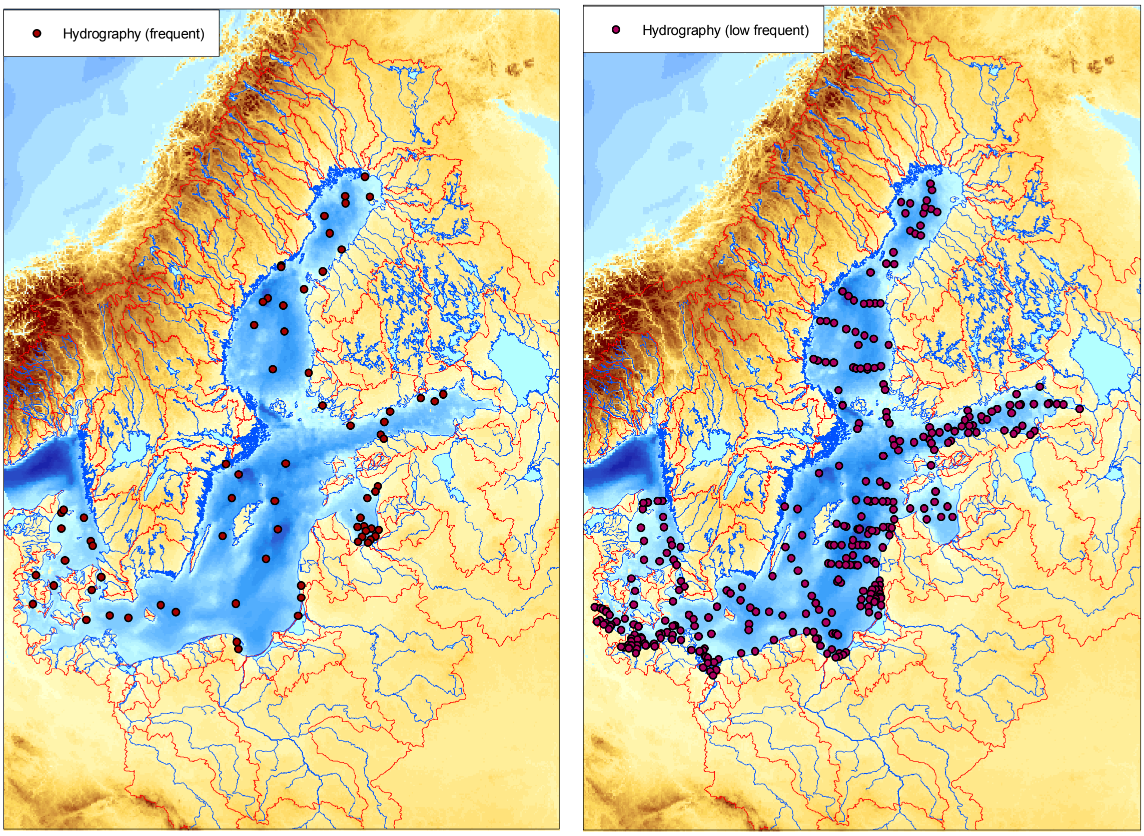

Figure 7. Baltic Sea observation network (Gorring and Håkansson, 2003).

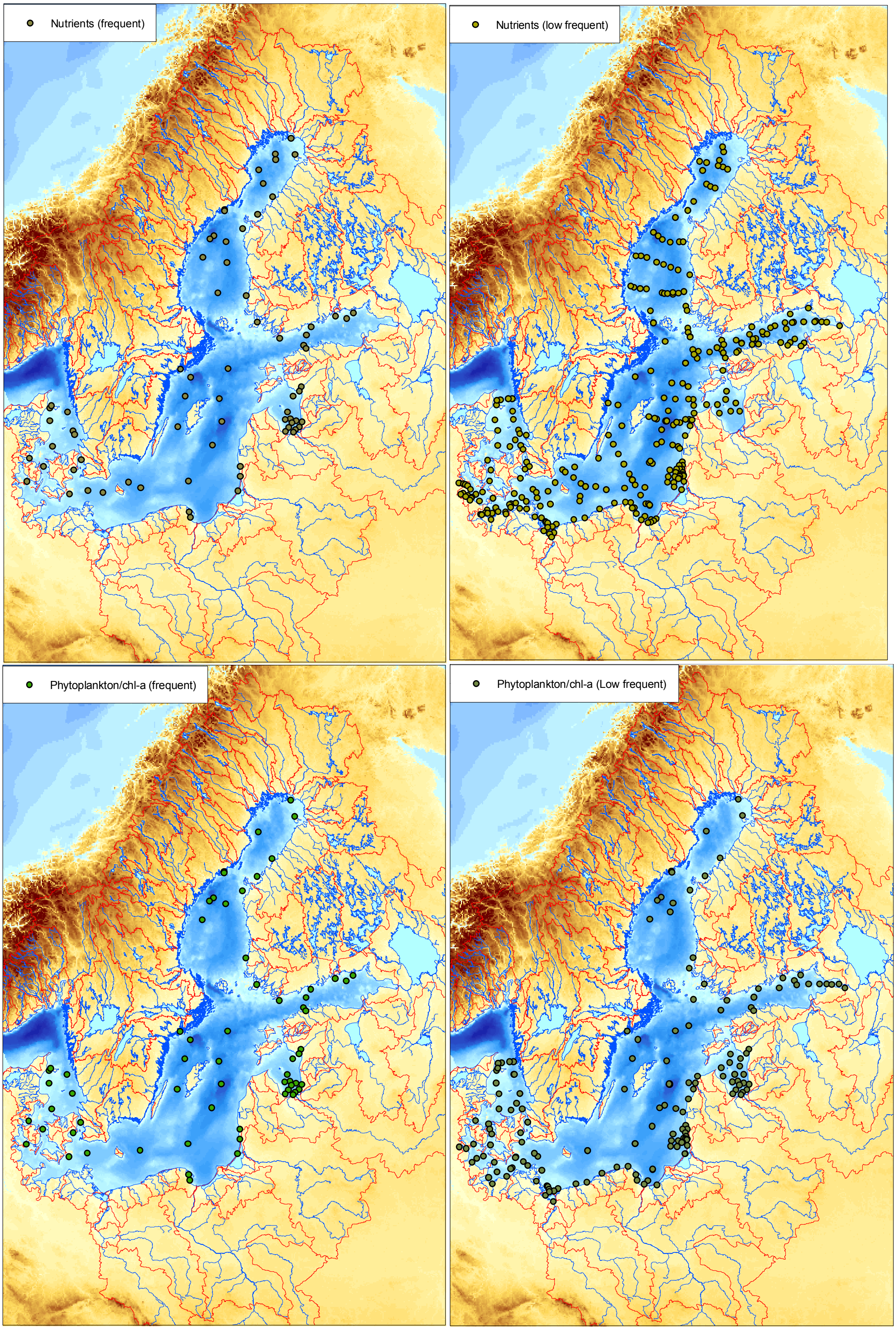

Figure 7. Continued.

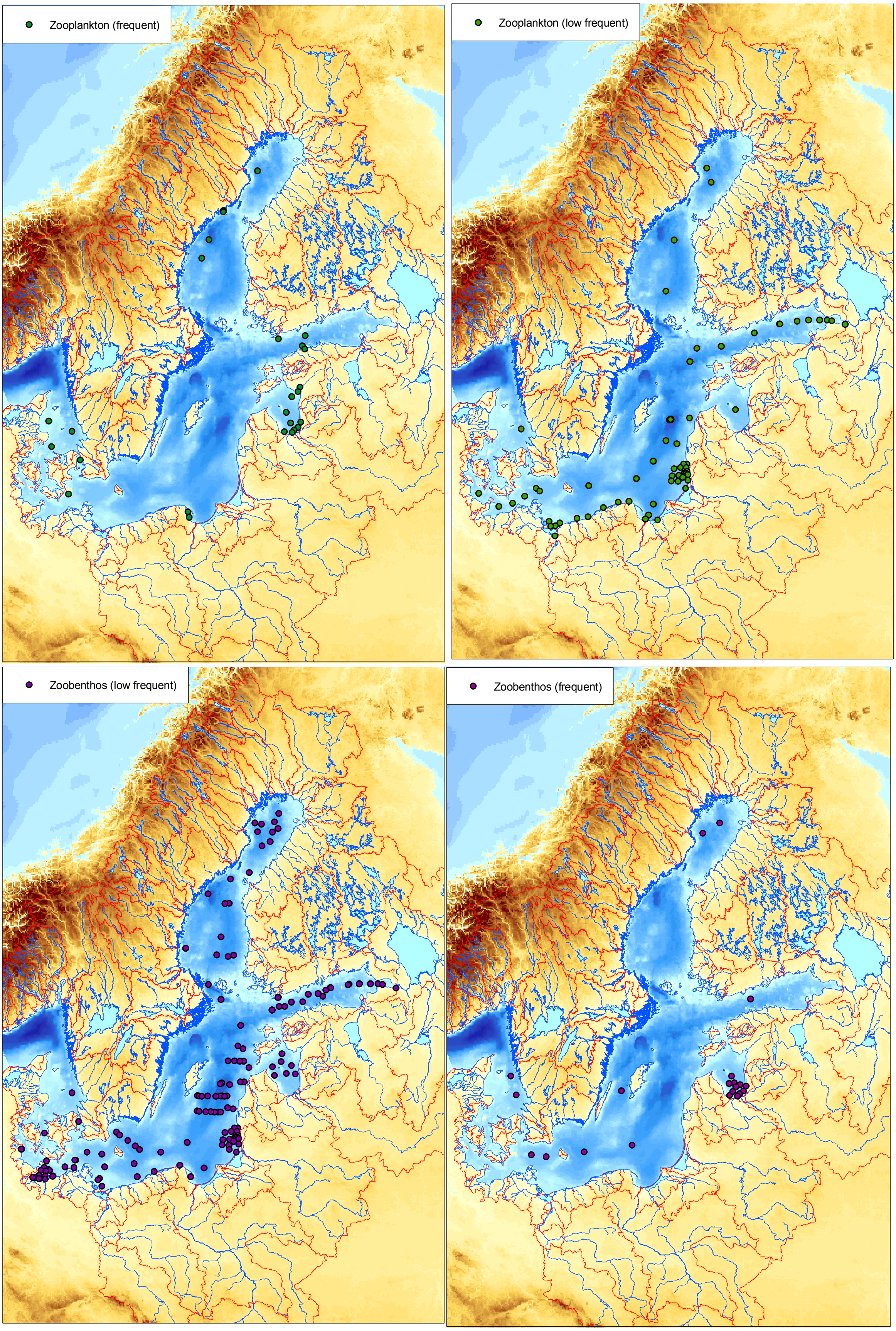

Figure 7. Continued.

Baltic Sea productivity data and supporting information are mainly collected during cruises on board research vessels. A ferrybox system—Alg@line (Figure 8)—has operated since 1992, gathering *in situ* fluorescence, temperature and salinity data, as well as water samples to be analyzed for nutrient concentrations and phytoplankton biomass and species composition. In 2004, a modified plankton recorder will be added to determine zooplankton distributions. So far, Alg@line information has mainly been used to detect and monitor harmful algal blooms. A detailed description of the Alg@line system is included in Annex 3.

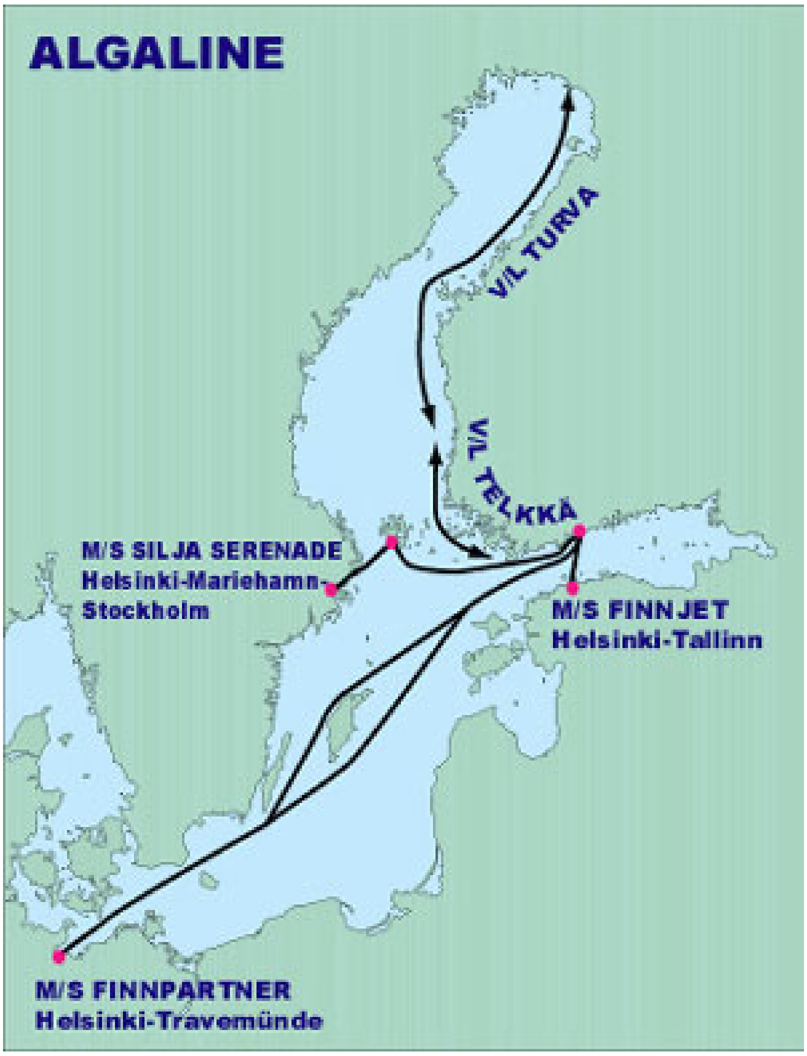

Figure 8. Transects sampled within Alg@line (www2.fimr.fi/en/itamerikanta/bsds/812.html).

Unattended measurements from buoys, bridges, or lighthouses in the Baltic Sea (Figure 9) are currently mostly limited to temperature, salinity, and in some cases dissolved oxygen and current speed. Only in the Fehmern Belt the German Federal Maritime and Hydrographic Agency operates a station that collects also nutrient data. Most automated stations are located in the western part of the Baltic Sea (Gorringe and Håkansson, 2003). In 2003, automated station data enabled scientists for the first time to follow a saltwater intrusion in the Baltic Sea "online". The early information over the BOOS network made follow-up cruises possible that traced the oxygen-rich water in the Baltic Sea. The high temporal resolution of automated station measurements together with current speed data has also been used for detailed calculations of oxygen exchange (Badewien, 2002).

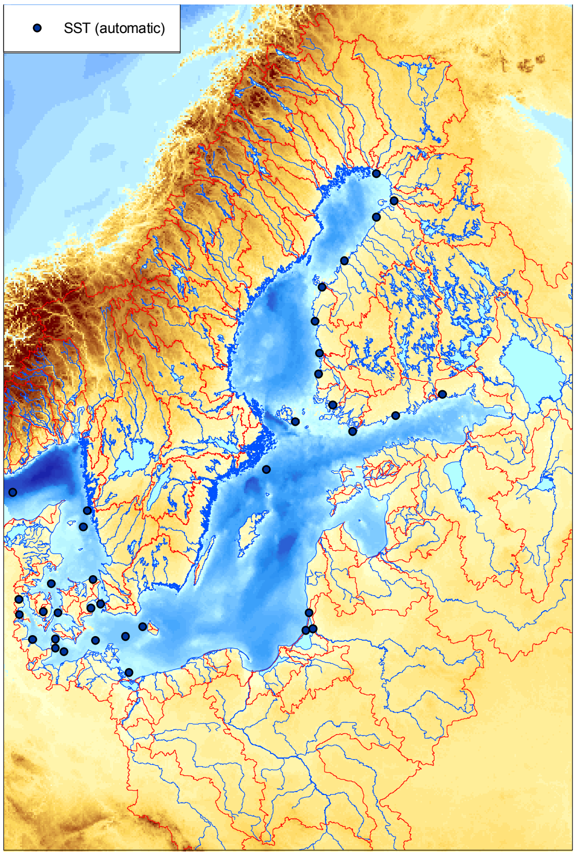

Figure 9. Automated stations in the Baltic Sea (Gorringe and Håkansson, 2003).

Satellite data is currently used for temperature measurements, sea-ice monitoring and algal bloom detection. Only seven institutes in the Baltic Sea have satellite receivers and the data exchange of already processed maps is not coordinated well. For a description of the type of satellites used, see ToR e.

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5.4 TOR d – Identify information gaps along important trophic transfers in the Baltic Sea ecosystem

The brackish Baltic Sea has been seen as particularly suitable for studies of foodwebs. Compared to fully marine ecosystems, it has low species diversity, which means fewer trophic linkages to analyze. The Baltic Sea is also one of the best-studied areas of the world, suggesting that most data requirements for foodweb models should be fulfilled. Nevertheless, the influence of physical and biological factors on trophic interactions and biogeochemical patterns varies spatially in the Baltic Sea, adding considerable complexity to foodweb studies. Foodweb structure and processes can be described and compared quantitatively between areas by estimating the flow of matter or energy through the organisms. Most such models have been based on carbon, though studies of complementary flows of other elements limiting production, such as nitrogen and phosphorus would be desirable (Sandberg, J., Elmgren, R., and Wulff, F., 2000).

At present, several trophic transfer networks for the Baltic Sea are build:

1) Sandberg, J., Elmgren, R., and Wulff, F. (2000). Carbon flows in Baltic Sea food webs – a re-evaluation using a mass balance approach. Journal of Marine Systems, 25:249–60
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However, most of them are related to geographically quite large regions of the Baltic or even regard the Baltic Sea as a whole. That introduces a significant limitation to use these networks as predictive tools due to heterogeneity of climatic, salinity and biotope conditions. That is particularly true for enclosed and semi-enclosed regions in the Baltic. Based on that information we propose the following activities:

1. Identify important trophic transfers in the Baltic Sea, especially with respect to ecosystem-based assessment and management.

   We recognize that retention of nutrients is of high importance to explain both the eutrophication effects and the pathway from PP to fish (defining the structure of the foodweb at similar loadings).

   That could be approached by linking the nutrient loadings to the retention and recycling in different areas of the Baltic Sea. The open stratified areas should treated differently than shallow and non-stratified ones.

2. Quantify trophic transfers in the Baltic Sea

   Data regarding the trophodynamic parameters as P/B (production/biomass), P/R (production/respiration), EE (ecotrophic efficiency), etc., are quite scarce even regarding the key (important) species. It is necessary to collect a database of those parameters by data mining.

3. To use data assimilation software to summarize the foodweb structure in different areas of the Baltic Sea and test ecosystem sensitivity with respect to individual trophic links. Sensitive trophic links should be prime candidates for use as productivity indicators.

   We have suggested the following areas as test cases for this approach, because they represent typical subsystems of the Baltic Sea and have high data/information coverage:

   - Curonian lagoon
   - Pärnu Bay
   - Askö area
   - Pommeranian Bight
   - Gulf of Riga

   Other proposals for activities

4. To identify test areas where PP could be related to the fish production.

   - To make an inventory of existing attempts to quantify foodwebs in the Baltic Sea.

5.5 TOR e – study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms etc.), in collaboration with BOOS

At the Study Group meeting, Mark Berman gave an overview on the use of automated measurement techniques for productivity monitoring in the US (see also Study Group presentations). Additional information became available from cooperation with BOOS and Alg@line.

Sigfried Krüger (IOW Warnemünde), who has designed the autonomous buoy system operated in the German part of the Baltic Sea, has agreed to take part in SGPROD, but was not able to attend the October meeting. A preliminary overview on automated measurement methods was based Mark Berman's presentation at the Study Group meeting and the work of the PAPA network implementing BOOS, where Bärbel Müller-Karulis participated in several work packages.

Unattended productivity measurements in the Baltic Sea are further implemented by the Alg@line ship of opportunity network. Seppo Kaitala of Alg@line is a member of SGPROD. Because Seppo Kaitala could not attend the Study Group meeting, a short meeting was organized at the Finnish Institute of Marine Research attended by Bärbel Müller-Karulis (SGPROD), Petri Maunula, Eija Rantajärvi, Mika Raateeoja, Riita Olsonen, and Seppo Kaitala (all FIMR/Alg@line).

Generally, the following automated methods are currently available for productivity data collection:

- Satellite imagery;
- Unattended fixed stations (buoy systems, light-vessels, etc.);
- Ship of opportunity/ferrybox systems;
- Continuous plankton recorders;
- Undulating towed vehicles.

5.5.1 Satellite imagery

In the Baltic Sea, satellite imagery is used from a variety of sensors (Table 5). Generally, satellite sensors can only provide information about the sea surface layer. With respect to productivity, remotely sensed data can be used to map the extent of algal blooms, but in order to quantify the amount of phytoplankton biomass, calibrated algorithms are necessary to convert the ocean color into chlorophyll *a*. Remotely sensed sea surface temperature can be used as a supporting parameter to characterize the physical environment. Fish recruitment for example is sensitive to temperature.

With the exception of NOAA ad RADARSAT, most satellite data in the Baltic Sea region is used in delayed mode, due to the cost of operational data (Gorringe and Håkansson, 2003).

Table 5. Use of satellite data in the Baltic Sea (Gorringe and Håkansson, 2003).

Satellite	Sensor	Sea Surface Temp	Sea Surface Height	Algal blooms	Suspended matter	Ice	Oil spill
ENVISAT	MERIS			√	√		
	AATSR	√					
	RA-2		√				
	ASAR					√	
AQUA	MODIS	√		√	√		
	AMSR					√	
TERRA	MODIS	√		√	√		
Orbview-2	SeaWiFS			√	√		
NOAA	AVHRR	√					
RADARSAT	SAR					√	√

5.5.2 Unattended fixed stations (buoy systems, light-vessels, etc.)

A network of unattended buoys and moorings is established mainly in the western part of the Baltic Sea (Figure. 9, see also ToR c). The use of unattended fixed stations is limited by the availability of sensors with low drift. Currently, in the Baltic Sea most unattended stations record temperature, salinity, oxygen, and current speed. Only in the Fehmern Belt the German Federal Maritime and Hydrographic Agency operates a station that collects also nutrient data. Cost of data transmission and servicing of unattended stations are substantial. Biological fouling of sensors is likely to degrade data quality and mandate accelerated maintenance schedules, especially in the summer.

By using statistical analysis (including synergy among satellite, buoy, floating profiler, ferry and XBT sections) the EU funded research project ODON aims to improve the design of salinity and temperature measurement in the Baltic and North Sea. We are not aware of similar projects concerning nutrients or biological variables.

5.5.3 Ships of opportunity/ferrybox systems

Ships of opportunity provide a cost-efficient method of marine data collection. Sensors and water samplers are installed on-board commercial ferries or merchant ships. Water is pumped through an intake in the ship's hull. Therefore samples are generally limited to the surface layer. Sensors are operational for water temperature, conductivity/salinity, fluorescence, and dissolved oxygen. In addition, water samples can be taken and analyzed at a laboratory after the ship has reached a port. This expands the range of parameters to nutrients and phytoplankton (biomass/species composition, chlorophyll *a*). Fast repetition rate fluorometry, a technique to measure primary production, is currently under development. In the Baltic Sea, the Alg@line consortium has established a ship of opportunity network. A description of the routes, range of parameters investigated, as well as cost estimates for operating the network, is given in Annex 3.

5.5.4 Continuous Plankton Recorders (CPR)

The Continuous Plankton Recorder was developed by Sir Alister Hardy in the mid 1920s. A steel case is towed behind a ship and plankton organisms are filtered out of the water through a moving filter band of silk. In the original design, the towing momentum drives an impeller, which unwinds the filter band. Recent technical improvements using a motor to drive the filter gear make the device more reliable.

Continuous Plankton Recorders have been routinely towed from merchant ships since World War II (with some earlier routes starting form 1931). Zooplankton is monitored in monthly intervals on various routes in the North Sea and in the Atlantic (Figure 10). In 2004, the Alg@line consortium plans to start routine CPR measurements on a transect from Lübeck to Hamina in the eastern Gulf of Finland. For use in the Baltic Sea, where zooplankton is smaller than in the North Sea and the Atlantic, the CPR will be equipped with a filter band made from standard WP2 net material with 100 µm mesh size. In experimental runs, results have been comparable to standard WP2 net samples. Annex 4 describes the adaptations of the CPR for use in the Baltic Sea in detail.

A drawback of the CPR system for use in the Baltic Sea is the limitation to approximately 10 m sampling depth, because some zooplankton species, for example *Pseudocalanus*, which are an important food supply to fish larvae, do not ascent into the surface layer. Also the cost of analyzing the zooplankton samples collected by CPRs can be substantial.

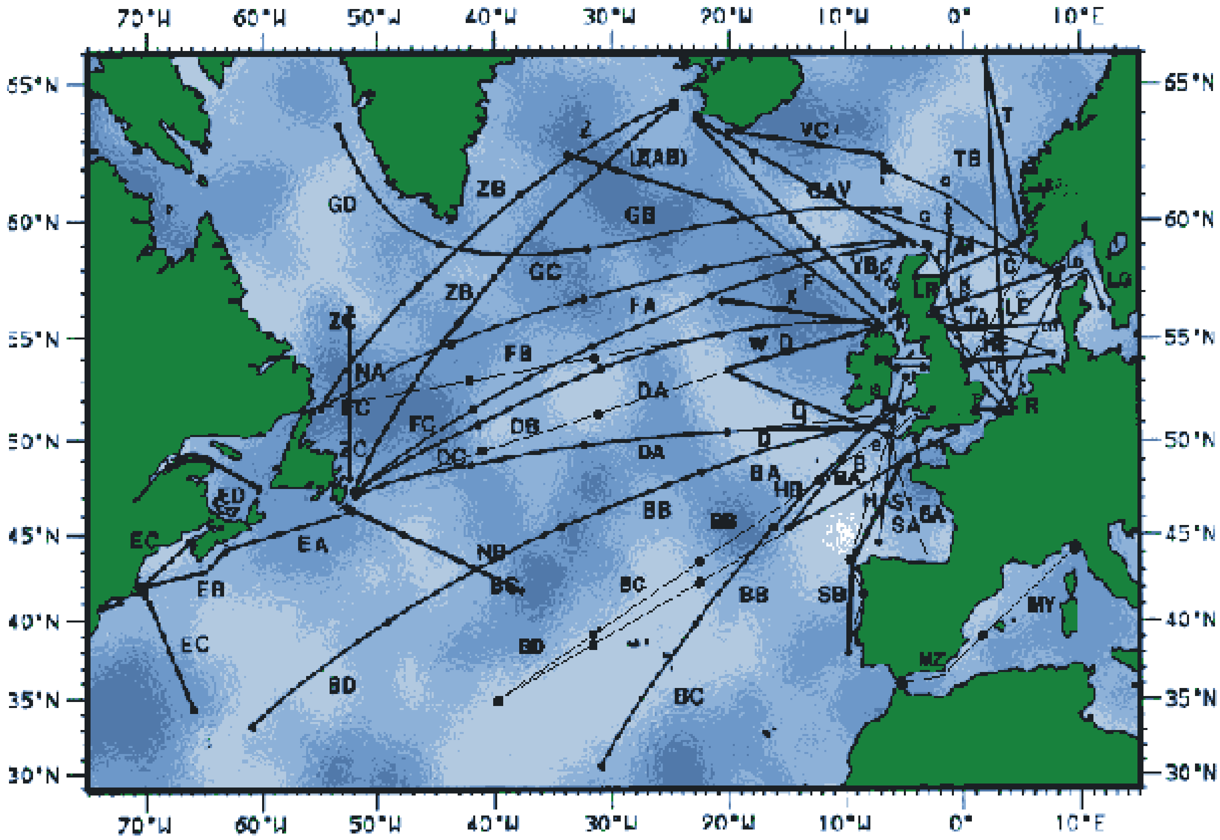


Figure 10. CPR routes in the North Sea and Atlantic (www.sahfos.org).

5.5.5 Undulating towed vehicles

A variety of undulating towed vehicles, which can be equipped with optical and electronical sensors as well as zooplankton samplers are commercially available. Operating depths of up to 500 m are possible. However, undulating samplers in many cases still require a scientist to operate the tow and can mostly not be used from ships of opportunity. These platforms are the only ones currently being assessed which can sample the distribution of physical, chemical, and biological parameters throughout the entire water column. The data they collect can be essential in understanding how the surface conditions measured by the SOOP, Alg@line, and satellite programmes relate to the 3-D ecology of the Baltic. Therefore, occasional (perhaps monthly) research vessel surveys with an undulating towed sensor should be given serious consideration as part of the BLME monitoring plan.

5.6 TOR f – recommend measures to adapt the existing measurement programmes to improve the assessment of Baltic Sea productivity within the framework of ecosystem-based marine management

HELCOM and OSPAR have defined the ecosystem approach as "the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity" (Annex 5 to the HELCOM/OSPAR Bremen declaration).

The inventory of available productivity data constructed under ToR c shows, that most of the productivity parameters currently used in Baltic Sea ecosystem assessments are applied to detect temporal trends in five compartments of the ecosystem: nutrients, phytoplankton, phytobenthos, zooplankton, and zoobenthos. This method is not sufficient to fulfil the requirements of the ecosystem approach, which demands management advice to be based on scientific knowledge of the ecosystem **and its dynamics**. Therefore, the assessment strategy should not only address the state of isolated compartments, but also has to include the interactions between them. The variety of ecosystem responses to eutrophication, as well as to nutrient load reductions found under ToR a, implies that these interactions modify the response of ecosystem compartments to management actions. Further, interactions between ecosystem compartments appear to be site-specific. Therefore, management advice has to be based on knowledge of site-specific ecosystem dynamics.

Under the ecosystem approach, top-down control of the lower part of the foodweb by fish, or vice versa bottom-up control of planktivorous fish should be strengthened in assessments and communication between fisheries and productivity experts should be improved. The Baltic Sea Regional Project has already brought together both groups within its ICES Working Groups.

The current indicator system used in Baltic Sea ecosystem assessments described under ToR b will have to be adapted to the quantitative approach demanded by HELCOM with the intention to establish ecological quality objectives (EcoQO). Reference conditions will have to be constructed to define the desired ecological status and the indicator system will have to be able to distinguish, whether these goals are met.

SGPROD also identified approaches to improve the efficiency of data collection. First, synergy effects between fishery data and productivity data collection should be exploited. Especially, the hydroaccoustic surveys for herring and sprat provide a good spatial coverage of the Baltic Sea (except Bothnian Sea and Bothnian Bay). It is technically feasible to collect nutrient and chlorophyll data during these cruises and also some plankton hauls can be integrated. This could reduce the ship cost for the productivity data collection and at the same time additional environmental data would be available for fishery assessments. SGPROD recommended the BSRP to test simultaneous productivity data collection at the May hydroaccoustic survey. Reduction of ship-time and higher temporal coverage of productivity data can also be achieved by expanding the ship of opportunity network in the Baltic. Especially the Eastern coast of the Baltic Proper is not covered by SOOP measurements and SGPROD advised the BSRP to establish an additional route in this area. Also the use of continuous plankton recorders should be further tested.

Secondly, a variety of automated methods described under ToR e are available to improve productivity data collection. These include upgrading existing CTD systems with fluorometers to reduce the number of laboratory analyses for chlorophyll *a*, as well as the use of automated buoy stations for hydrographic and potentially also hydrochemical parameters. The use of satellite data to assess surface temperature and chlorophyll distributions should be further expanded. A shortcoming of satellite and SOOP data, which provide information only from the surface layer, could be overcome by undulating towed samplers. Their use should be further tested in the Baltic, especially in connection with CPR cassettes, that can provide high spatial resolution of zooplankton data.

A discussion of the Terms of Reference also revealed that improving the exchange of data and data products between individual laboratories and assessment groups could strengthen the ecosystem-based management of the Baltic. Modern web-based data and information exchange tools should be created that reduce the time lag between measurement and data publication.

5.7 TOR g – prepare a workplan, including a schedule for deliverables, in cooperation with other BSRP Groups; including considerations of potential contributions to 2006 Theme Session on Regional Integrated Assessments

The Group proposed to meet on 4–6 November 2004 in Nidda (Lithuania) addressing the following Terms of Reference:

a) describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;
b) continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;
c) continue to study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms etc.), in collaboration with BOOS;
d) review the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators.

Discussion of the Terms of Reference will be prepared intersessionally.

ToR a)

Trophic networks will be described for typical subsystems of the Baltic Sea. Trophic networks will be used to analyze the sensitivity of the system to disturbances and to identify suitable productivity indicators. Results will contribute to the indicator system applied in the BSRP. Furthermore, it is planned to present the analysis of the trophic networks at the proposed theme session on “Material and energy flows in trophic networks of the Baltic Sea ecosystem” at the 2005 ICES Annual Science Conference and to publish the results as a scientific paper.

The following test cases were suggested for constructing trophic networks:

- Curonian lagoon
- Pärnu Bay
- Askö area
- Pommeranian Bight
- Gulf of Riga

Experts on the foodwebs of each of these systems will be contacted by March 2004, and invited to contribute. Data should be prepared by October 2004 and the analysis of trophic networks will be started at the November Study Group meeting.

ToR b)

The Study Group will contribute to the development of productivity indicators in the Baltic Sea. During the first half of 2004, the Chair of the Group will intensify contacts to other groups working on indicator development in the Baltic, especially with HELCOM and with the ICES Study Group on Baltic Ecosystem Health Issues in support of the BSRP [SGEH]. The coastal zone management demonstration sites of the BSRP will serve as test cases for indicator development and the Study Group will participate in indicator development and testing. By July 2004, the Chair of the Group will distribute a description of current indicator initiatives in the Baltic Sea as well as background information about the BSRP demonstration sites, available data, and preliminary suggestions for indicator variables, based on the indicator set laid out in this report. By October 2004, the Chair of the group will update the information on the proposed indicators. At the 2004 Study Group meeting, the Study Group will review the indicator set for the demonstration sites.

ToR c)

Feasibility and efficiency of automated productivity data collection methods will be discussed intersessionally among SGPROD members with relevant expertise. So far members of the group have expertise with unattended stations and ships of opportunities and the group has established links with BOOS and Alg@line. During 2004, the Group will establish contacts to users of satellite data for productivity monitoring in the Baltic. Intersession consultations will provide the BSRP with the necessary expertise to design the technical upgrading of the productivity monitoring system in the Eastern Baltic. The Chair of SGPROD will distribute a report of the intersession activities to all members in July 2004 and October 2004. Activities will be presented and reviewed at the November 2004 Study Group meeting.

ToR d)

The Chair of the Study Group will distribute a description of the productivity data collection strategy in the BSRP by July 2004, with an update in October 2004, and invite the Study Group members for their comments and suggestions. The data collection strategy will be discussed and reviewed at the November 2004 Study Group meeting.

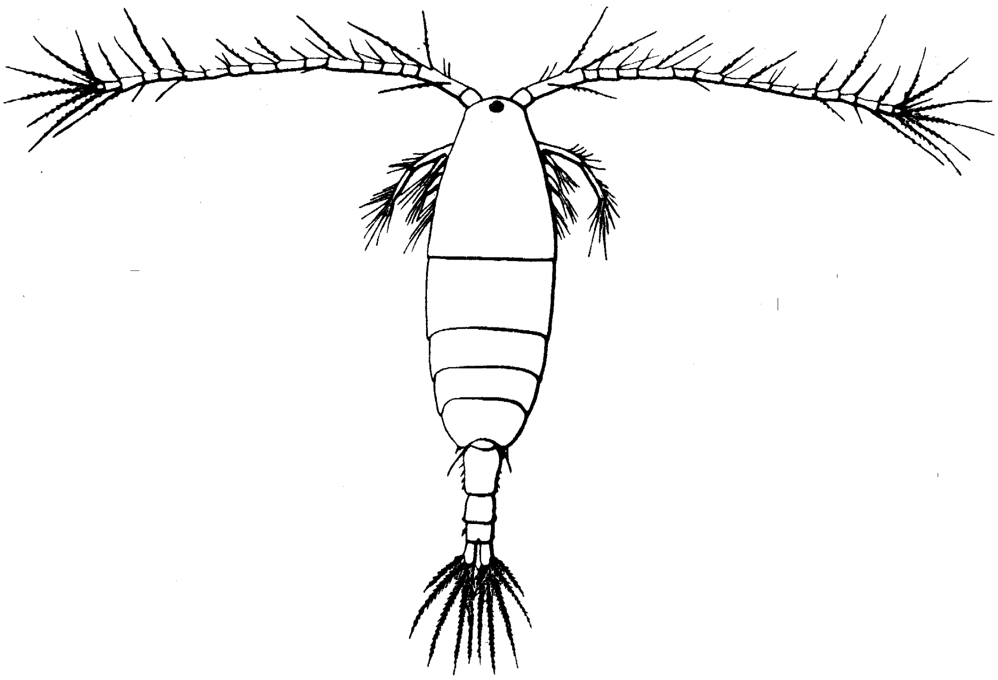
Potential contributions to the 2006 Theme Session on Integrated Regional Assessment

Potential contributions will be discussed during the Study Group meeting to be held in November 2004.

	March 2004	**July 2004**	**October 2004**	**Study group meeting November 4–6, 2004**
Trophic networks (ToR a)	Expert contacts on selected Baltic Sea trophic networks		Data preparation for trophic network analysis	Analysis of trophic networks
Indicator development (ToR b)	Improved cooperation with other Baltic indicator development groups	Background information on BSRP demonstration sites Draft of indicators in BSRP	Updated draft of planned indicators in BSRP	BSRP indicator system review
Automated productivity monitoring methods (ToR c)	Contacts to Baltic satellite monitoring groups	Report on technical consultations and planned upgrades in the BSRP	Report on technical consultations and planned upgrades in the BSRP	Review of planned technical upgrades in the BSRP
BSRP data collection strategy (ToR d)		Description of BSRP productivity data collection strategy	Updated description of BSRP productivity data collection strategy	BSRP productivity data collection strategy review
Theme session proposal on trophic networks in the Baltic Sea		Invite co-convener Elaborate scientific justification for proposal		Discuss further strategy

6 ANNEXES

Annex 1 Copepods – role in the transfer of primary production to pelagic fish Nutrient load, trophical structure and productivity



Michael Olesen
Marine Biological Laboratory
University of Copenhagen

This presentation consists of four parts:

1) Copepods – sink or link in a laboratory experiment?

2) Primary production and eutrophication

3) Role of copepods – Sink or link in natural systems

4) Trophical interaction between phytoplankton-copepod-fish interaction

1) Copepods – sink or link? A laboratory experiment

Whether copepods act as a link or sink in the pelagic foodweb have been frequently questioned over the past few years (see review of J.T. Turner, 2002, Aquat Microb Ecol, 27: 57-102). Copepods have previously been considered as the main contributors of autochthonous matter in the vertical flux of stratified neritic waters. Copepods like many other pelagic crustaceans produce compact fecal pellets (surrounded by a peritrophic membrane) known to have much higher sinking rates than phytoplankton cells. The general relative low contributions of recognizable fecal pellets in sediment traps deployed around the world, however, suggest that fecal material from copepods is mostly degraded within the mixed layer.

In order to elucidate this question, I recently made a lab experiment in collaboration with Solvita Strake and Andris Andrushaitis from Institute of Aquatic Ecology, University of Latvia

Experimental set up and results:

Part 1. Enclosure experiment which purpose was to achieve a combined idea of production rate, degradation rate and sinking rate of copepod fecal pellets. Two different food items were used: a chain forming diatom and a small cryptophyte.

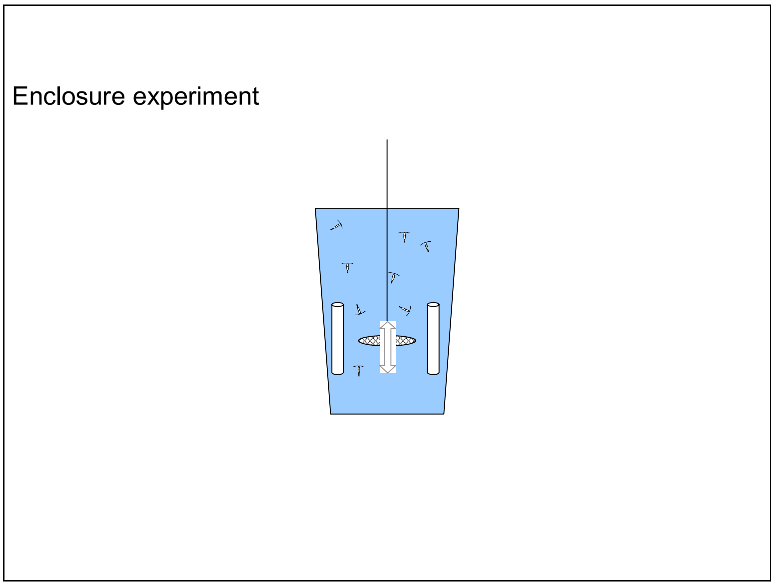


Figure 1.

The set-up was large 100 l containers with permanent mixing to assure that food and fecal pellets was continuously held in suspension during the week-long experiment. Copepod of app. 50/l and algae was transferred and the development of eggs and fecal pellets was followed. Sediment traps were frequently deployed in the enclosures for a couple of hours.

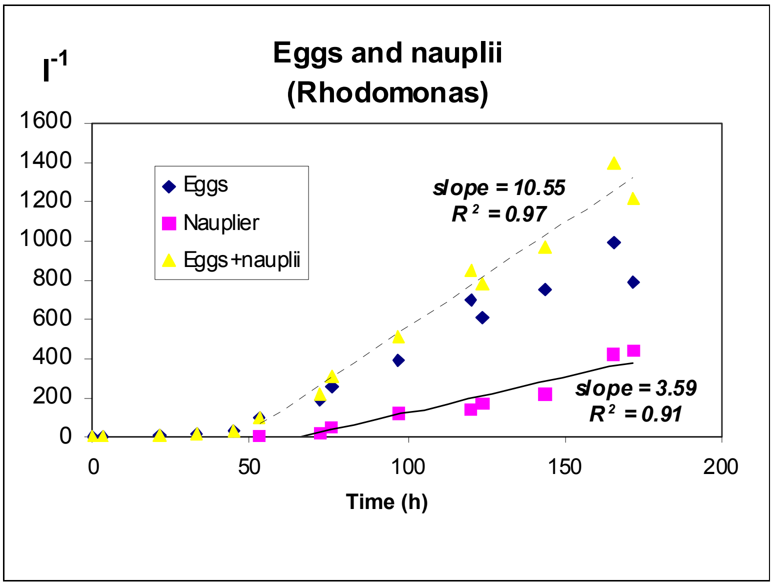


Figure 2.

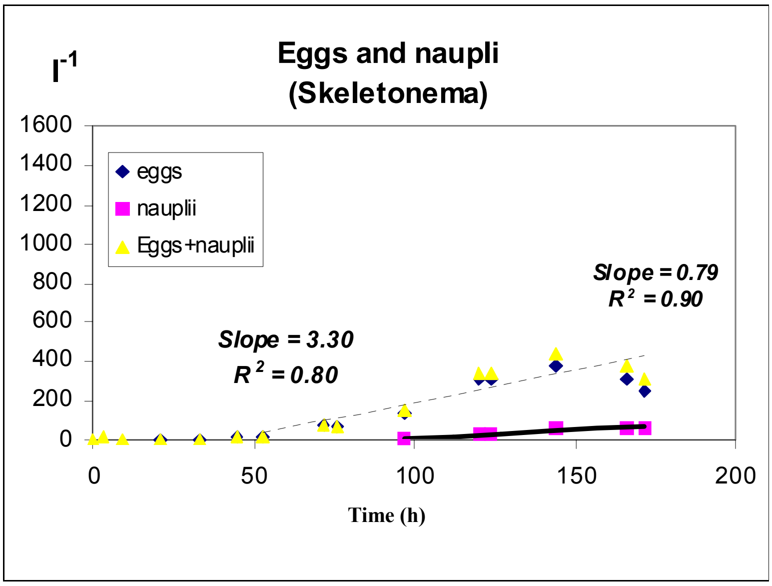


Figure 3.

The egg production was 0.25 eggs pr female pr hour for the *Skeletonema* diet and 0.56 when *Rhodomonas* was used as food item. The ratio between the linear recruitment of nauplii with time and the estimated egg production rates, which express the hatching success, is found to be 34% for the Rhodomonas fed copepods and 25% for the Skeletonema diet.

Because adult copepods exhibit almost no somatic growth, it is expected that egg production will budget the assimilated energy for growth.

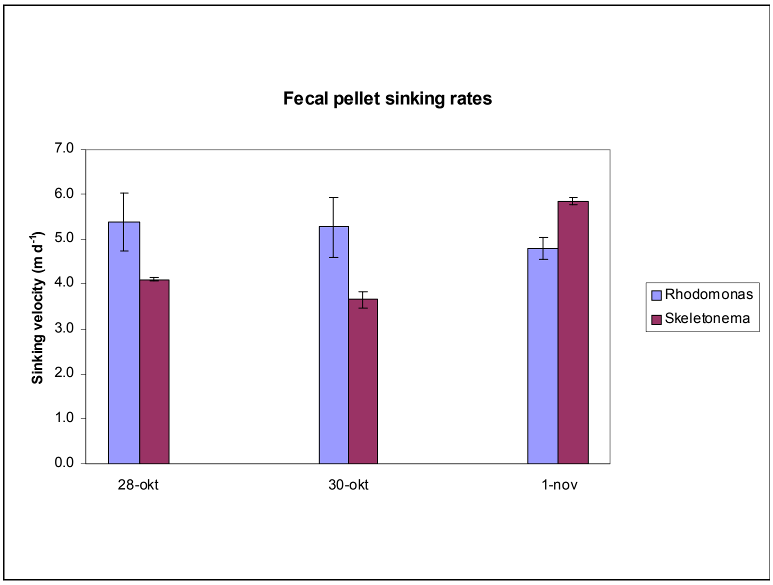


Figure 4.

Sinking rate. In spite of the difference in size, sinking rate of the two types of fecal pellets was quite similar with average sinking velocities of 4.5 and 5.1 m d^{-1} for pellets based on the *Skeletonema* diet and the *Rhodomonas* diet, respectively.

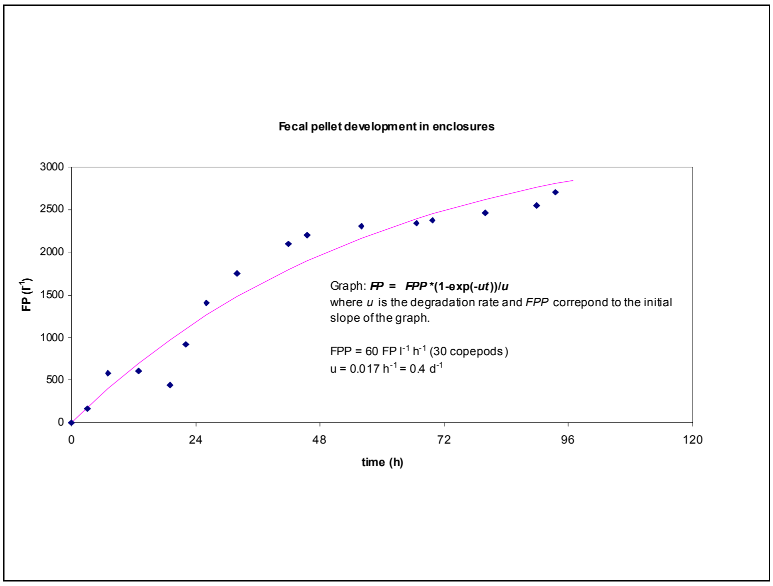


Figure 5.

Fecal pellet production. Copepods fed on diatoms produced in average 3.4 fecal pellets pr hour but only 1.0 pr hour when fed on the flagellate. Furthermore, the size of the *Skeletonema* based fecal pellets was almost 50% larger in volume than the fecal pellets produced on the *Rhodomonas* diet, which further amplifies the difference. The degradation rate of fecal pellets can be calculated from the fitted curve as shown on Figure 5. The result from this part of the experiment is summarized in Table 1.

Table 1

Production and fate of fecal material

Diet	*Rhodomonas*	*Skeletonema*
Egg productio/Ingestion	43%	15 %
Egestion/Ingestion	18 %	31 %
Sloppy feeding/Ingestion	26 %	106 %
Fecal pellets/Egestion	32 %	28 %
Amorphous defecation/Egestion	68 %	72 %
Degradation rate of fecal pellet; no copepods	0.65 d^{-1}	0.38 d^{-1}
Degradation rate of fecal pellet; + copepods	0.86 d^{-1}	0.55 d^{-1}
Sinking rate of fecal pellets	5.1 m d^{-1}	4.5 m d^{-1}

Part 2. Tracer experiment.

The second part of the experiment was conducted as a tracer experiment. The purpose was to evaluate the energetic of the copepods, especially with respect to egestion. Microscopic observation of living copepods has drawn our attention on alternative pathways of fecal production than in the shape of fecal pellets.

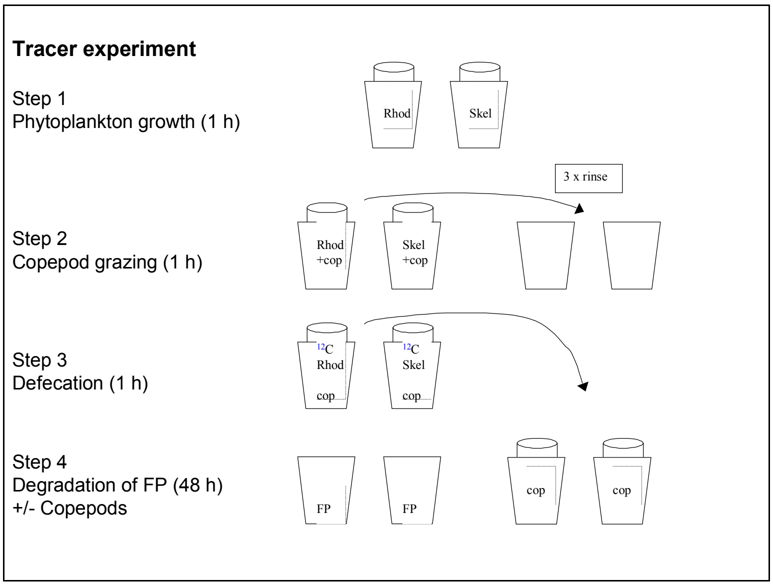


Figure 6.

Step 1. Phytoplankton growth. The development of the labeled algae was followed for one hour without zooplankton

Step 2. Zooplankton grazing. The empty cylinders were replaced with the fecatrons containing copepods. The copepods were allowed to feed on the labeled phytoplankton for 1–2 hours

Step 3. Defecation. The copepods were then removed and carefully rinsed in two beakers with clean water before the cylinders was placed in a new beaker with unlabeled phytoplankton. After one hour, the cylinders with copepods were removed leaving the labeled excreted matter in the beaker.

Step 4A. Fecal matter production and degradation. The fecal matter was gently resuspended in the same water and evenly distributed in 12 bottles of 300 ml, and 10–12 copepods were added to half of them.

Two of the bottles were measured immediately for labeled carbon in the fractions > and < 10 µm (T= 0). The fraction >10 µm was gently sieved through a 15x15 µm circular Nytex mesh net (dia. 25 mm) mounted in a filter holder by passive filtration. The fraction < 10 µm consisted of the filtrate retained on a GF/C filter. 8 ml of the GF/C filtrate was collected in a vial for measuring the radioactivity of matter below this fraction (colloids and DOC). The 2x5 other bottles were placed on a rotating plankton wheel (1 rpm) for later measuring of the same three fractions (T = 3, 6, 18, 24, 36, and 48 hours).

Step 4B. Assimilation. The copepod used in the tracer experiment was allowed to stay another 30 min in clean water before they were counted for living and dead animals. The dead were removed and the living collected on a 240 µm circular filter for determination of the incorporated ^{14}C as proxy for assimilation.

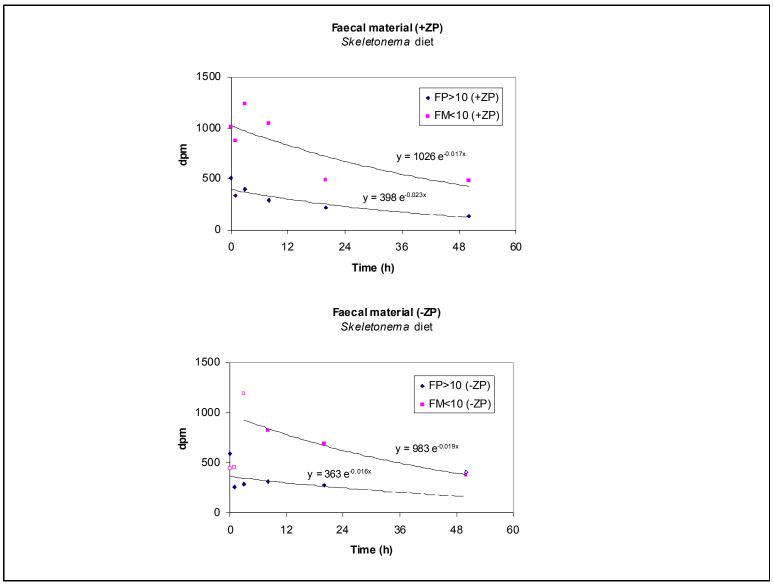


Figure 7.

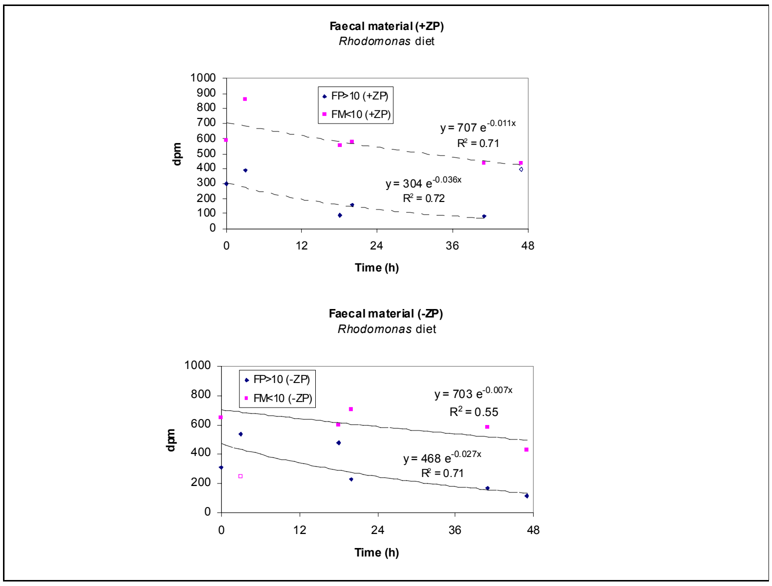


Figure 8.

From the production of labeled fecal material we calculated the egestion. Surprisingly we found that the major part belonged to the fraction below 10 um.

We examined if this fraction could possibly result from a subsequent break up of pellets due to the mechanical handling of the egested material, but did not find any difference in the number of intact pellets before and after a filtration. Also direct microscopic examination of particles released during a 30 min. period by *Rhodomonas* fed copepods in Petri dishes with clean GF/C filtrated water, clearly demonstrated that a substantial part of the defecation consisted of small dispersed particles. Finally the good accordance between the fecal pellets estimates form the two independent methods suggest that these small particles are egested separately as such. To our knowledge there has not yet been any firmly description of fecal material egested from copepods in the shape of small particles not surrounded by a peritrophic membrane.

Conclusions

Ecological implications

Considering a mixed layer of 15 m, then a sinking velocity of 5 m d^{-1} will correspond to a loss of fecal pellets across the pycnocline of one-third per day. Assuming that a degradation rate of 2/3 pr day and a sinking rate of 5 m d^{-1} applies for an open stratified coastal system with a mixing depths of 15 m, then only 33% of the produced fecal pellets will be lost to the bottom layer while the major part (66%) will bee degraded within the mixed layer

When also the production of the non pellet fecal material in taken into account an even larger part of the egested material is expected to degrade before it sinks out of the euphotic zone because these small particles presumably only sinks very slowly. If this material comprise 2/3 of the total egestion ca. 90% of the fecal material will be retained and decomposed in the mixed layer.

2) Primary production and eutrophication

One of the purposes (Terms of References) of our work is to give recommendations on how to implement productivity measurements in monitoring eutrophication. Primary production is, however, not a very suitable measurement for eutrophication.

System productivity or total primary production is only very weakly linked to eutrophication, understood as the nutrient load or discharge.

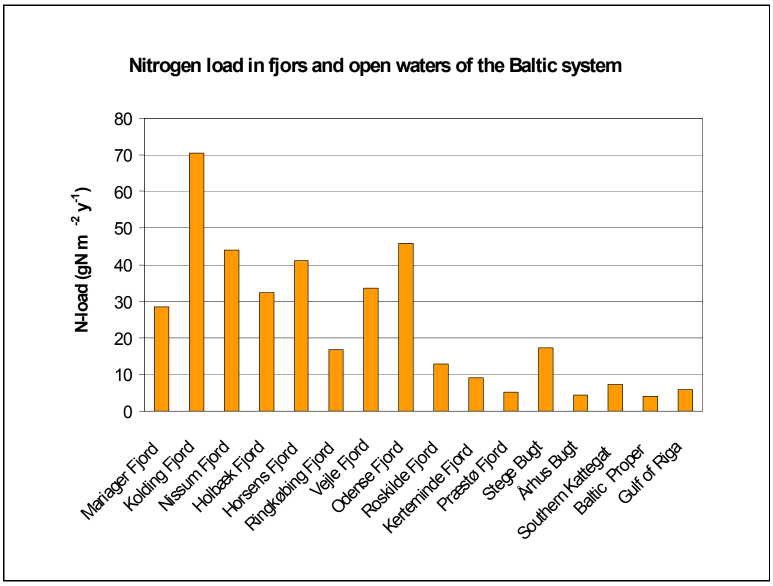


Figure 9.

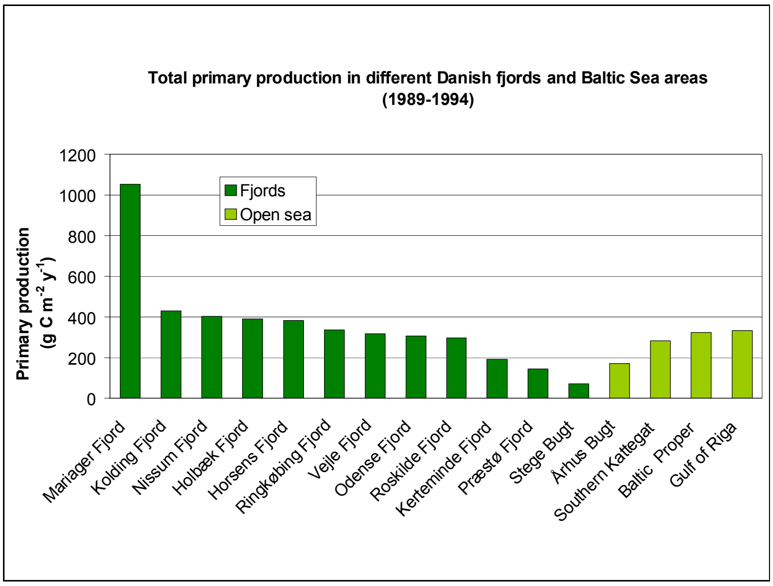


Figure 10

Why?

The reason for the weak link is that most of the primary production is based on nutrient recycling (regenerated production) and not on the external nutrient load (new production). And that the recycling efficiency varies unpredictably from one system to another within the Baltic Sea and adjacent seas

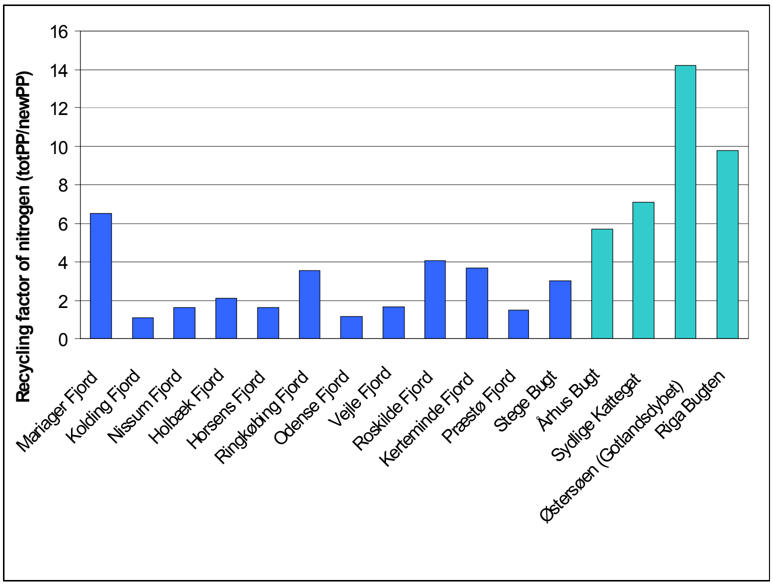


Figure 11.

When it comes to the relation between fish and PP the relationship seems even weaker. For example, we do not even know whether nutrient load stimulates fish production or not. The suspicion that the last decades' heavy nutrient load to the Baltic Sea does actually hamper the fish stocks is quite speculative and are more a matter of faith than of knowledge.

PP is therefore not a suitable tool for assessing eutrophication.

Conclusions

There are, however, some other good reasons for measuring PP. In my opinion the most important reason for measuring PP is that it provides you with knowledge of the productivity of the particulate ecosystem. Knowledge of PP is necessary if you want to understand how the system behaves with respect to the interaction between loading, trophical structure and fish production. The problem is that to evaluate the efficiency of the system in managing the nutrients it is necessary to accomplish the PP measurements with measurement on sedimentation, system metabolism and preferably also nutrient input. This can hardly been done on a routine basis and is therefore difficult to implement in an ordinary monitoring programme.

3) Role of copepods – Sink or link in natural systems.

If we accept that the major part of primary production is based on regenerated production, what is then the role of copepods in this nutrient recycling? This can bee evaluated by comparing estimates of ZP activity and vertical flux of organic matter in real systems.

Table 2.

Vertical flux of fecal pellet (FPC-sed) relative to total flux (POC-sed) and to fecal pellet production (FPC-prod) in different boreal regions.

Location	FPCsed/POCsed		FPCsed/FPCprod		Dominant copepods	Source
Gulf of Finland	*Max 10 %*	4-17 %	*Max 10 %*	< 1 %	Limnocalanus, Eurytemora, Acartia	Viitasalo et al 1999
Gulf of Riga		0-25 % (avg. 8 %)		1-7 %	Eurytemora, Acartia	Lundsgaard et al 1999
Baltic Proper		5-10 %		< 1 %	Eurytemora, Acartia	Olesen (not published)
Kattegat	*Max 2.5 %*	< 5 %	*Max 20 %*	10-15 %	Acartia, Temora, Centro-pages, Oithona, Pseudo-calanus, Paracalanus	Olesen & Lundsgaard 1996
Norwegian sea		5-35 %		2-100 %	Calanus	Wassmann et al 1999
Baffin Bay		22 % (avg.)		> 100 %	Calanus	Juul-Pedersen (submitted)
Norwegian Fjord		ND		0-100 %	Calanus/Oithona	Svensen 2001
California Bight		8-38 %		69-96 %	Calanus, Clausocalanus	Landry et al 1994

The table shows the fecal pellet to POC sedimentation (FPsed/POCsed) and FP sedimentation to FP production (FPsed/FPP) in different area of the Baltic Sea and adjacent seas. FPP is in most of the studies based on the biomass of copepods. The first column shows quite varying contribution of pellets to the overall sedimentation (from less than 5% to more than 1/3). There does not seem to be a clear pattern in these differences. The other column shows the fraction of pellets produced which sinks out of the mixed layer. It is remarkable how few of the pellets produced in the Baltic Sea that seem to leave the euphotic zone intact. When we move towards more oceanic conditions this ratio seems to increase dramatically. The presence of large species of *Calanus* in these more open systems is likely to be an obvious reason for the difference. Consequently, more than 90% of the fecal pellets seem to be degraded already in the upper mixed layer in the Baltic Sea.

Table 3

Copepods sink or link?

Assuming steady state, then new production (New PP) will equal sedimentation and regenerated production (Reg PP) will equal the degradation of the retarded matter.

	Baltic Sea	Kattegat
Copepod based system		
New PP to Total PP	**100/10 = 10 times**	**100/20 = 5 times**
Reg PP to New PP = recycling factor	**90/10 = 9 times**	**80/20 = 4 times**
Real system		
Reg PP/New PP = recycling factor	**5-8 times**	**3-5 times**
Copepods - Sink or link?	**link**	**both**

Measurements of primary production in the Baltic Sea and the Kattegat have shown that the *f*-ratio (i.e. new/total primary production) is around 1/6, leading to a recycling factor of 5 in both systems. According to these consideration copepods apparently will stimulate the recycling of nutrients in the Baltic Sea (link) while they will tend to increase sedimentation rates in the Kattegat and thereby act as a sink for nutrients.

To elucidate whether copepods may stimulate system production by increasing nutrient recycling or inhibit it by reducing the retention time of nutrients in the upper water column we can make a calculation for the Baltic Sea and the Kattegat based on the data in Table 2. See Table 3 for explanation.

Table 4

How important are copepods for productivity in the Baltic Sea and the Kattegat?

.

A way to assess the significance of copepods in the two system can be to compare the production of fecal pellets (FPCprod) with the total sedimentation (POCsed). A proxy for this can be achieved by dividing the figures of the two columns with each other:
[FPCsed/POCsed]/{FPCsed/FPCprod] = FPCprod/POCsed

Assuming steady state then FPCprod/POCsed = FPCprod/newPP.

	Baltic Sea	Kattegat
FPCprod/newPP	**10/10 = 1.000**	**2.5/20 = 0.125**
Real system Reg PP/New PP = recycling factor	**5-8 times**	**3-5 times**
FPCprod/RegPP	**1/8 - 1/5 = 15-20 %**	**0.125/5 - 0.125/3 = 2.5-5 %**

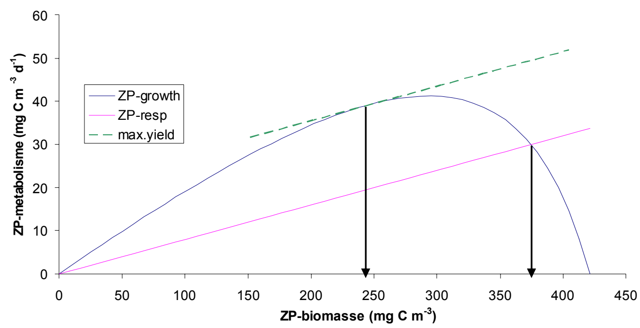
Also an idea of the actual role of the copepods can be achieved from Table 2. See Table 4 for explanation. Other measurements of copepod biomass in the Kattegat and the Baltic Sea support the impression of a 3–4 times copepod activity in the later.

Conclusion on the trophical role of copepods in the Baltic Sea

- Most (> 80 %) of the fecal matter from copepods is recycled within the mixed layer in the Baltic Sea.
- Copepod grazing enables nutrients to be recycled and exploited 4-9 times before leaving the euphotic zone.
- The copepod activity seems 3-4 times higher in the Baltic Sea than in the Kattegat.

4) Trophical interaction between copepods and fish

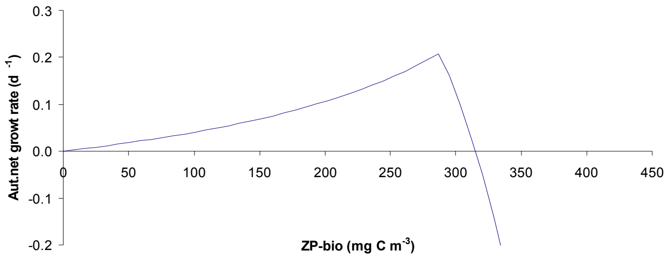
There might be several reasons for why we find more copepods in the Baltic Sea than for instance in the Kattegat, but we do not know with certainty. The next part offers one explanation for why copepods might be more abundant in the Baltic in comparison to the Kattegat. The annual copepod production in the Baltic Sea is maybe up to eight times higher than in the Kattegat. This could be a straightforward effect of the different composition of copepods in these two systems. In the Kattegat the general higher salinity allows a higher number of species than in the Baltic. This implies a higher tension of competition in the first preventing any specific copepods to be dominant.



- Gross growth and respiration of copepods relative to their density. The growth rate is almost linear at the beginning but starts rapidly decreasing when the biomass becomes larger than 300 mg C m^{-3}. The decrease growth rate is due to food limitation. Hence, the intercept of the x-axis reflects the carrying capacity of the system. The loss due to respiration is shown as the solid line. The crossing of the line with the growth curve indicates at which biomass level growth and loss is equal. On the left side of this point net growths rate is positive and on the right side negative. In such a system the copepod population will tend to stabilize around a copepod biomass of 350 to 400 mg C m^{-3}. The point where the tangent touch the growth curve indicates the copepod biomass at witch the highest net-production of copepods is obtained.

Figure 12

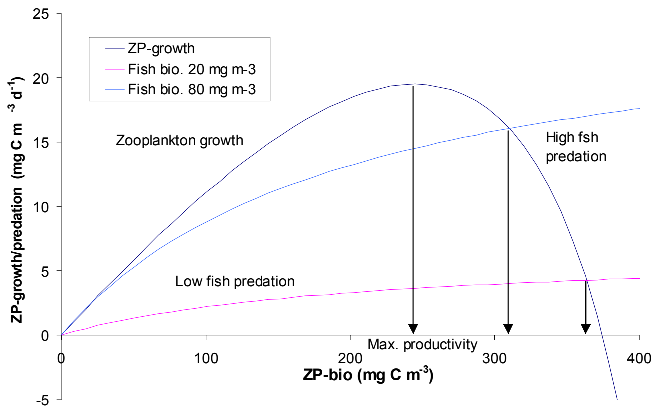
Another explanation could be more related to the trophic interaction. If predation on copepods is relatively low which seems to be the case in the Kattegat, then copepods will tend to overexploit net-phytoplankton (>10 µm) which inevitable will lead to a lower primary production within this fraction. Copepods will accordingly decrease to a low number for which survival is mainly based on the production of protist. The resulting relatively low population of copepods is, however, still capable to control the net plankton. By exerting a strong top-down control copepods, so to speak, become victims of a strong self-inflicted bottom-up control. They have ruined there own basis of subsistence. In some respects this is analogue to the "clear water phase" described for lakes. In the opposite end of the specter an absence of copepods may result in massive blooming of large phytoplankton forms turning the system into an "algal soup". Self shading and low remineralization leads to a decrease primary production in these kinds of systems. Beside of lakes, this phenomenon has been described for certain Fjords. In between these scenarios a production optimum exists capable to sustain a relative high copepod biomass and production. Even though that these "in-between systems" are probably more common than the two described extremities, marine systems are seldom understood and described in such a context.



- Net growths rate of autotrophs relative to zooplankton biomass. At a copepod biomass of ca. 300 mg C m-3 phytoplankton cells have obtained their maximum growths rate. At this biomass level copepods are still encountering net-growth (c.f. fig.1) and will therefore further increase their biomass. This will lead to a situation of "overgrazing" (grazing rate > autotrophic growth rate). In such a system copepod will not only starve but also turn the system into a low productive system

Figure 13.

The problem of maintaining a high productive system requires a delicate balance between biomass standing stocks and grazing. It also requires an efficient retention of the nutrients. There have to exist some mechanisms that prevent copepods to overgraze their food items. Fish larvae and regular planktivore species may represent such a mechanism. Differences in fish stocks between the Kattegat and the Baltic Sea may offer an explanation for the different trophic structure found in these two systems.



- In this system fish predation will regulate the copepod biomass to a level that prevents copepod to "overgraze" their food items. A high fish predation will not only prevent the system to collapse (cf. fig.2) but also ensure a high productive system close to its maximal ability

Figure 14.

A possible benefit of system productivity on fish

The amount of nutrients defines the potential carrying capacity of a system. These considerations are based on the following assumptions. A constant amount of nutrients means that when the ZP biomass increases phytoplankton biomass and thereby the resources of zooplankton will decrease accordingly.

Table 5

	Area km^2	New Production g C m^{-2} y^{-1}	Landings of planktivorous fish 1000 t/y (ww)	Ecological efficiency (%)
Kattegat/ Skagerak	80.000	42 (Stigebrant 1995)	113 (2001-03)	0.34
Baltic Sea	275.000	29 (Wassmund et al 2001)	546 (2001-03)	0.68
Gulf of Riga	35.000	40 (Olesen et al 1999)	90 (2001-03)	0.64
Peruvian upwelling system	220.000 (max 1997-99)	1200 (Nixon & Thomas 2001)	10.000 (max. 1961-72)	0.34

Anyhow, when comparing new production with fish landing of different systems, a quite remarkable relationship is found. Table 5 shows how large a part the landing of planktivore fish makes up of the new production. Apparently, a higher efficiency is obtained in the Baltic Sea than even in the upwelling system offshore Peru where the classical food chain prevails. This indicates that the transfer of biogenic material from primary producers to pelagic fish seems more efficient for regenerated system than for systems with short chained foodwebs.

Conclusion

Conclusion on trophical interaction between fish and copepods

If the stocks of planktivore fish as sprat and herring is not to low they can exert an efficient top-down control on copepod.

This might in turn prevent an over-grazing of net-fytoplankton (>10 µm).

This indicates the presences of a critical biomass of sprat and herring above which system productivity is high. Below this critical fish-biomass copepods will tend to over-exploit their resource, which lead to decrease productivity.

The transfer of energy from primary producers to fish seems more efficient in regenerated system like the Baltic Sea than in short chained systems where the classical food web prevails

Annex 2 Theme session proposal

Bärbel Müller-Karulis

Proposed Chair of SGPROD

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Proposal for a Theme Session at the 2005 ICES Annual Science Conference

Title: **Material and energy flows in trophic networks of the Baltic Sea ecosystem**

Conveners: Two members of SGPROD

Scientific justification:

In the Baltic Sea, the standing stocks of phytoplankton, zooplankton, zoobenthos and fish are intensely monitored, creating datasets of high spatial and temporal coverage. On the other hand, material and energy flows along trophic pathways in the Baltic Sea ecosystem are mainly investigated within academic research programmes. The knowledge about trophic transfers in the Baltic Sea ecosystem is scattered according to geographical regions and often highly segmented along parts of the foodweb.

The proposed session invites presentations about trophic transfers at all levels of the Baltic Sea ecosystem, from primary production to top predators, including the material and energy removal by fisheries. The session aims to summarize the existing quantitative knowledge on material and energy flows in the system. We especially invite presentations that address the natural variability and the stability of material and energy flows.

Annex 3 Alg@line – Joint Operational Unattended Phytoplankton Monitoring in the Baltic Sea

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Mika Raateoja (mika.raateoja@fimr.fi)
Seppo Kaitala (seppo.kaitala@fimr.fi), member of the ICES Study Group on Baltic Sea Productivity in Support of the GEF Baltic Sea Regional Project.

The Baltic Sea is a unique continental brackish water sea. Today, the Baltic Sea is eutrophied and the blooms of harmful planktonic algae are annual phenomena. The blooms are harmful to the marine ecosystem as well as to recreational and economic use of the marine resources. High-quality research gives reliable information on the state of the ecosystem and its changes. Adequate monitoring information is a prerequisite for sound protection measures and only research is able to reliably show the effects of the protection investments. Because the phytoplankton blooms are extremely patchy and temporally rapidly changing, they remain often unobserved using traditional sampling methods.

Alg@line has monitored and reported the events in the phytoplankton community and the state of the Baltic Sea for 10 years.

Alg@line is a forerunner in the field of monitoring research and is based on co-operation between several research institutes and shipping companies. In 1992, the Finnish Institute of Marine Research started systematic measurements onboard ferry Finnjet, crossing the Baltic Sea Proper, using unattended recording and sampling. Alg@line monitors the fluctuations in the Baltic Sea ecosystem in real-time using several approaches. It combines studies onboard research vessels with high-frequency automated sampling onboard several merchant ships (ships of opportunity), satellite imagery, buoy recordings and traditional sampling and observations in coastal waters. Ecosystem models are under development. Without the high-frequency observations with the shipofopportunity technique, the rapid fluctuations in the Baltic Sea ecosystem could not be monitored.

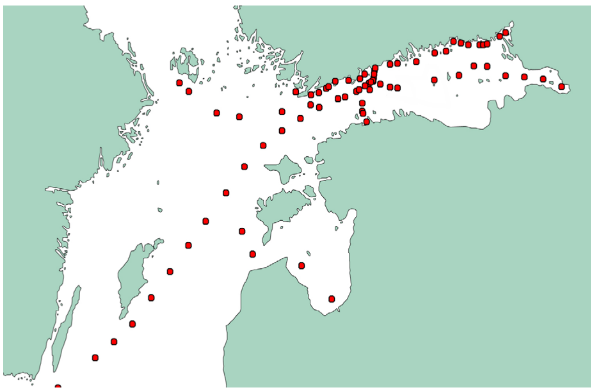
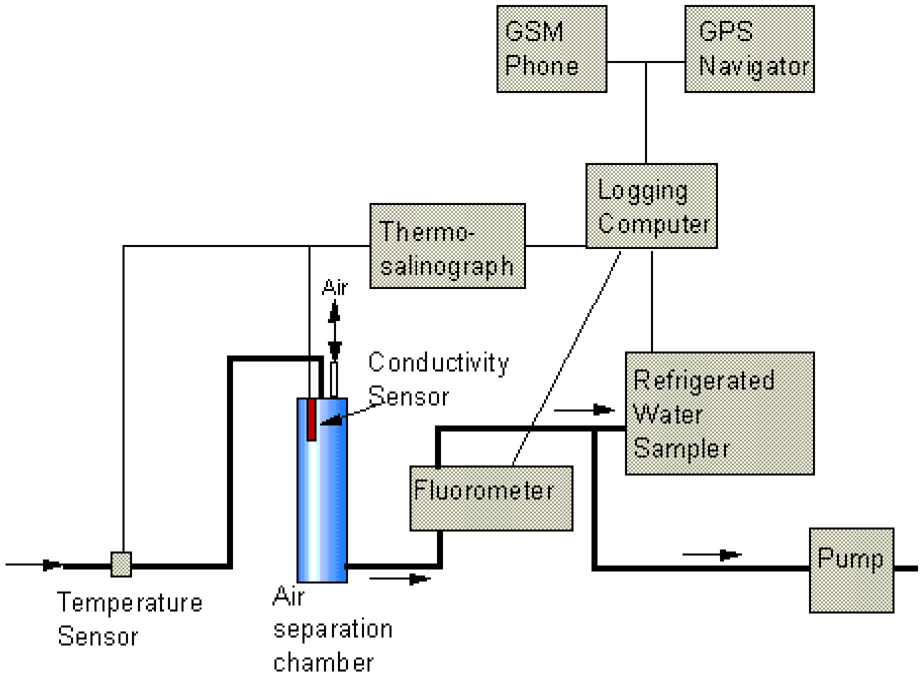


Figure 1. Water sampling locations along Alg@line routes.

Alg@line has analyzers and sample collectors on six merchant ships (Figure 1). Furthermore, three vessels of the Finnish frontier guard provide analyzer and CTD-data. Yearly 1.5 to 2 million flow through observations (*in vivo* chlorophyll *a*, salinity and temperature), 7 000 semiquantitative species observations and 1000 nutrients observations are gathered. Alg@line is the only research project in the Baltic Sea region, even in the whole world, which utilises the ship-of-opportunity technique in the monitoring of the state of the environment on this scale.

Alg@line method and equipment

Water is pumped constantly through the sensors from a fixed depth (ca. 5 m) while the ship is moving. The *in vivo* chlorophyll *a* fluorescence, temperature and salinity are recorded quasi-continuously with spatial resolution of 100–300 m while the ferries are moving. Concurrently, water samples are taken. The measurements and sampling are repeated ca. every 0.5–3 days in the same sea area depending on the schedule of the ferry.



EQUIPMENT ONBOARD THE SHIP:
Computer
GPS navigator
Flow-through fluorometer
Thermosalinograph
Refridgerated water sampler

MEASURED PARAMETERS:
latitude and longitude (spatially 100–200 m accuracy)
time (date and time)
S, T, chl a *in vivo* fluorescence
additionally, on-board Finnpartner: Continuous CO^2 partial pressure measurement system (collaboration of FIMR and IOW), phycocyanin fluorometer, FRR-fluorometer

ANALYTICAL DETERMINATIONS AT LABORATORY:
Parameters: phytoplankton species, chl *a*, PO_4, NO_3, NH_4, Si, Tot P, Tot N, partly turbidity

FURTHER DATA MANAGEMENT:
Data processing
Q/C
Information products
Sampling and analyses are quality-controlled using ISO GUIDE 25 and SFS-EN 45001, and laboratory methods are accredited. After the preliminary quality control, the data is used operationally to promptly produce graphs and statistics. The final quality check of the data is done monthly and data is used for annual monitoring reporting. Finally the data is stored in a database for further analysis and research.

Reporting

Online reports on phytoplankton blooms and general information on the Baltic Sea are published in the Baltic Sea Portal: www.itameriportaali.fi. Annual monitoring reports are published in partners' own publications and, e.g., within HELCOM.

Alg@line is co-operation – current partners

Estonian Marine Institute
Uusimaa Regional Environment Centre
City of Helsinki Environment Centre
Southwest Finland Regional Environment Centre
West Finland Regional Environment Centre
Southeast Finland Regional Environment Centre
Shipping companies (Silja Line, Transfennica)
Finnish Frontier Guard
Finnish Sea Scouts
Finnish Environment Institute

Co-operation also with HELCOM, ICES, EuroGOOS, BOOS, etc.

Projects which have used Alg@line-data:

EU projects at FIMR:
BOING (information system, not a scientific project, 2000–spring 2003)
HABES (2001–2003)
HABILE (2002–2004)
FerryBox (2003–2005)

Other projects and co-operation:
co-operation with EMI since 1997, funded by Finnish Ministry of the Environment
FEI, calibration of satellite images, started 2001
FEI, cyanobacterial bloom forecast model
GEF/BSRP SOOP-project, started 2003

Advantages;

The versatility and openness make possible to tailor the combination of sensors and analyzers according to the specific requirements of the user. The basic equipment is relatively inexpensive and the final costs are determined by the prices of the sensors. The environmental circumstances on ferries correspond almost to those in laboratories and therefore no special requirements for the analyzers and sensors are needed. The regular visits of the ships in the harbours make the maintenance of the system easy to carry out and enable rapid transport of the water samples to the laboratory for analysis.

Dense spatial sampling in combination with frequent voyages makes possible the reliable detection of patchy plankton blooms. The high-resolution sampling provides comprehensive data for long-term time-series and trend analysis. On the basis of fluorescence recordings, the water samples for the time consuming phytoplankton species determination can be preselected: only samples that coincide with high chlorophyll *a* values are analyzed. The number of samples analyzed can be reduced but the necessary information on the bloom forming species is still obtained.

Costs

The costs of this kind of SOOP project are divided into different levels as follows:

1. The ship-level

- Equipment 30–40k€
  (fluorometer 15 k€, thermosalinograph 5 k€, automated water sampler 7 k€,
  pump, 1k€, GPS 1k€, PC 2k€, software 5 k€), and its maintenance 2–4k€ per year

2. The laboratory-level

- No own laboratory
  - -analytical analyses by consultant 20–30k€ per year
  - -taxonomical analyses by consultant 50–100k€ per year

- Own laboratory
  - -material for analytical work 1–2 k€ per year
  - -tools for taxonomical work (microscope, etc.) 30–40k€

3. Data processing level
   - -raw data processing, Q/C, and processing to information products
     - -equipment and softwares 10–20 k€ and their maintenance 2–4k€ per year
   - -GUI-based database-system, insuring public assess to data via graphical user interface
     - -the construction of db 30–50 k€
     - -consulting services 10–20 k€

The initial investments for an institute having an own laboratory to get the system running: 60 k€, required for

- The ship-level equipment
- Data processing etc.

To complement the system: additional 70 k€ to cover

- Taxonomy (microscope and related equipment)
- Q/C-system
- Web-publishing, etc.

To finalize the system with a GUI-based database requires additional 70 k€

NOTE! No personnel salaries included.

Recommendations and potential interactions between BSRP and Alg@line

The SOOP-project of the BSRP aims at expanding the Baltic operational SOOP monitoring area towards the Eastern parts of the Baltic. Any reasonable SOOP-initiative starts by looking at the map over the current shiplines in the Baltic. Thus, the first requisite for a new SOOP-line is the already-existing, rather permanent merchant ship route – that is what SOOP-system is all about: the ship-of-opportunity. Of the Alg@line ships, Silja Opera sails from Helsinki to Riga in spring 2003 and to and St. Petersburg in summer 2004. Finnjet sails from Rostock to St. Petersburg from June 2004 on.

Ship routes exist in the Eastern parts of the Baltic (we assume these areas to be the Gulf of Finland, and the Eastern side of the Baltic Proper) that have not been utilized as a SOOP-route yet. However, their inclusion would be worthwhile. Our Polish colleagues mentioned the route Helsinki–Gdansk. Also, the establishment of SOOP routes across the Baltic Proper is regarded as important.

In this light, Alg@line would recommend BSRP to establish collaboration with the Algaline cooperation project. The main emphasis should be on the development of new operational monitoring systems, either as separate from the Alg@line or, preferably, as part of Alg@line, as we already have the necessary infrastructure and knowhow.

In case of a separate system, Alg@line knowhow can be dispensed to the new responsible party (training). The advantage of the SOOP-system lies in its online capability. The obtained SOOP results should be managed in a time schedule enabling the web-publishing of the results within a week. Furthermore, as Q/C purposes, cross-references of the results are recommended to be carried out with the Alg@line/Baltic Sea Portal.

This is an outline for the further communications and if the BSRP finds the collaboration worth of pursuing, Alg@line is open for further development of the cooperation.

Annex 4 Utilization of CPR for zooplankton monitoring of the Baltic Sea

Utilization of CPR for zooplankton monitoring of the Baltic Sea
Juha Flinkman
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Finland

Introduction

Traditional plankton monitoring with vertical nets from research vessels that may visit each sampling station, even as rarely as once a year, has been quite justly criticized for poor temporal and spatial coverage. In order to overcome this, even in the 1920s, Sir Alister Hardy developed the Continuous Plankton Recorder (CPR), that has successfully been towed on World Ocean by ships-of-opportunity ever since. In the 1980–1990s, research revealed the interdependence between salinity changes, zooplankton community structures and growth of economically important fish stocks in the Baltic. Development of Algaline operational monitoring system emphasized the need to develop zooplankton monitoring up to similar efficiency.

Experiences of using CPR in the Baltic

Experimental CPR tows across the Baltic Proper between Lübeck and Hanko were undertaken in 1998–99 as co-operation between Sir Alister Hardy Foundation for Ocean Science (SAHFOS), Finnish Institute of Marine Research (FIMR) and shipping company Transfennica Ltd. The data of altogether 10 tows showed that the traditional CPR could well follow the annual succession of zooplankton, and even reveal the distribution of invasive species, but that the abundances were 1–2 orders of magnitude less than in WP-2 Samples.

Standard CPR uses 280µm silk mesh, whereas HELCOM Baltic Monitoring Programme, and subsequent MONAS use 100 µm mwesh as standard in WP-2 nets. In order to find out how much the mesh size contributes to abundance decline observed in CPR samples, a comparison study was organised onboard r/v Aranda in summer 2001. Scientists from SAHFOS and FIMR towed a standard CPR and U-tow (Undulating towed vehicle) equipped with plankton sampling mechanism using 200 µm mesh. The difference in aperture is almost double with an increase from 200 to 280 µm (In preparation). Already, this decrease in mesh aperture brought the abundances to almost the same level with 100 µm WP-2 nets. Recent research in Antarctic waters show that plankton sampled simultaneously with vertical nets and CPR using same mesh corresponds very well (Hunt and Hosie, 2003). As the standard CPR is designed for oceanic use, the mesh size that has been found to be appropriate there (Batten *et al.* 2003) is not suitable for considerably smaller zooplankton of the Baltic Sea.

It was therefore concluded that the CPR utilized in the Baltic should be capable of using 100 µm mesh. This could only be achieved by using Automatic Plankton Sampling Mechanism (APSM) manufactured by Chelsea Technologies Group Ltd that can be fitted into a standard CPR body. APSM differs from original CPR filter mechanism, which is mechanically driven by a propeller 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 previous 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.

Current situation of Baltic CPR survey

FIMR received the new unit in spring 2003, and tested it onboard r/v Aranda I summer 2003. The samples are currently being analysed, and subsequently a comparison study between these samples and simultaneous WP-2 samples will be carried out.

An operational survey is planned to start in spring 2004. The unit will be towed monthly (all ice-free months) by a Transfennica containership from Lübeck to Hamina in eastern Gulf of Finland. The route covers Western Baltic, Bornholm Basin, Baltic Proper and Gulf of Finland. It is hard to imagine a single non-stop route with a better coverage of the area. The CPR tows will cover the whole passage in 10 nautical mile sections, which start and end at locations precisely known. From these samples an adequate proportion – if enough funding available, every second sample – will be analyzed.

The survey is ready to start, we have the CPR, and the shipping company is willing to do the tows. As the CPR survey is intended as an integral part of HELCOM/EU monitoring programmes, all data will be freely available to members. But before the data can be made available, the samples need to be analysed. However, there is still a bottleneck in the survey, namely the sample analysis. Each monthly tow produces ca. 50 samples, half of which should be analysed. It is practically a full-time job for a plankton analyst to achieve this, and currently there is only temporary and inadequate funding for the analysis. FIMR is trying to find out ways to ensure continuing analysis, but this is yet unsure.

Equipment and operating costs

The CPR equipment for the Baltic use is slightly more expensive than standard CPR operation. The APSM mechanism costs almost double in comparison to standard. Altogether acquisition of CPR body and APSM combine to roughly 28.000€, and annual operation costs mount to about 5000€. This provided that the shipping company does not charge for the tows. To this should be added the sample analysis and data processing costs.

Development of new routes

The planned CPR route covers the Baltic well. One can of course argue that Eastern Baltic and Bothnian Gulf are not covered, but it is well worth remembering that the problem of analysis of samples from even the first route remains to be solved. Once the trans-Baltic route is well established, should one look into incorporating additional routes into the survey.

References

Batten, S.D., Clark, R.A., Flinkman, J., Hays, G.C., John, E.H., John, A.W.G., Jonas, T.J., Lindley, J.A., Stevens, D.P., and Walne, A.W. 2003. CPR-sampling – The technical background, materials and methods, and issues of consistency and comparability. Progress in Oceanography, 58: 193–215.

Annex 5 Agenda

Wednesday, 29 October

13:30–14:00 Registration

14:00 Introduction, greetings

Andris Andrushaitis
GEF Baltic Sea Regional Project

Bärbel Müller-Karulis
Goals of the Productivity Module and SGPROD

Brian MacKenzie
ICES Baltic Committee Structure

Mark Berman
Assessing the Productivity of LME's

16:00 Coffee break

16:30 Trophic transfers

Andris Andrushaitis
Primary productivity of the Baltic Sea

Christian Möllmann
Long-term trends in Central Baltic mesozooplankton and their importance for fish stocks

Michael Olesen
Copepods role in the transfer of matter from phytoplankton to pelagic fish
Does copepod stimulate or inhibit regenerated production? What is the possible effect of the *f*-ratio on fish production?

Michael Olesen
Fish and productivity
Primary production in the Baltic Sea is extensively based on regenerated production. The microbial food chain thus plays a mayor role for the transfer of energy to fish. Can primary production under these conditions sustain the *de facto* fish production?

19:30 Dinner at "Sals un Pipars"

Thursday, 30 October

9:00 Trophic transfers II

Guntars Strods
Nektobenthos (*Mysidacea*) – an important element of the food chain in the Baltic Sea

Georgs Kornilovs
Research and data collection at the Latvian Fisheries Research Insitute

Maris Pliksh
Fish and fishery issues in the BSRP

10:15 Coffee break

10:30 Monitoring

Juris Aigars
Monitoring strategies
Jonne Kotta
Estonian coastal monitoring
Arturas Razinkovas
Monitoring efforts and quantification of foodwebs of the Curonian lagoon and the Lithuanian coastal zone

12:00 Lunch

13:00 Monitoring II

Georg Martin
Phytobenthic productivity studies in Estonia
Anda Ikauniece
Existing data quality requirements for the plankton monitoring in the HELCOM COMBINE program

14:00 Coffee break

14:30 Data And Information For Modelling And Assessment

Magdalena Wielgat
Modelling of the phosphorus and nitrogen cycle in the estuary of the Polish Baltic Sea coastal zone
Bärbel Müller-Karulis
Modelling nutrients and phytoplankton based on monitoring data

16:00 Coffee break

16:30 ToR c) establish an **inventory of available productivity data and characterize their use**;

17:00 Working groups

ToR a) commence a summary of the **evidence for links between land-based nutrient inputs and long-term changes of both productivity and biodiversity** in eutrophied areas of the Baltic Sea;

ToR b) commence development of a **system of indicators that characterize productivity at different trophic levels in the Baltic Sea** that are important to ecosystem-based management taking into account the work already undertaken by ACE and the EEA;

ToR d) identify information gaps along important trophic transfers in the Baltic Sea ecosystem;

Friday, 31 October

9:00 Working group results

10:00 Coffee break

10:30 Discussion of working group results

11:30 Any other business

Theme session for ICES annual science meeting 2005
Potential contributions to 2006 Theme session on Regional Integrated Assessments
Workplan for the Study Group

13:00 Close of the meeting, refreshments

Annex 6 Working groups

a) Commence a summary of the **evidence for links between land-based nutrient inputs and long-term changes of both productivity and biodiversity** in eutrophied areas of the Baltic Sea; • Examples where links between land-based nutrient inputs and long-term changes in the Baltic Sea ecosystem have been identified (open sea/coastal zone) • Mechanisms, by which nutrient input lead to changes in the ecosystem • Parameters, that are most sensitive to nutrient inputs • Examples for ecosystem recovery • Which parameters can be used to monitor ecosystem recovery, especially in coastal areas • Can automated methods (e.g., satellite imagery, ships of opportunity, profiling instrument platforms) contribute to linking nutrient inputs to ecosystem changes? • Recommendation for the BSRP: monitoring the effects of nutrient input reductions in the coastal zone for ecosystem-based marine management	Anda Ikauniece Magdalena Wielgat Georg Martin
b) Commence development of a **system of indicators that characterize productivity at different trophic levels in the Baltic Sea** that are important to ecosystem-based management taking into account the work already undertaken by ACE and the EEA; • Existing definitions of "indicator" • Approach of ACE, EEA • Desired properties of productivity indicators in the Baltic Sea • Productivity indicator candidates for the Baltic Sea (open sea/coastal zone) • Should productivity indicators provide quantitative information on trophic transfers in the Baltic Sea? • Can automated methods (e.g., satellite imagery, ships of opportunity, profiling instrument platforms) contribute to generate indicator data? • Recommendations to the BSRP with respect to cruise, sampling and measurement programs (coastal zone, open sea) for ecosystem-based marine management	Christian Möllmann Bärbel Müller-Karulis Mark Bermann
d) **Identify information gaps along important trophic transfers** in the Baltic Sea ecosystem; • Identify important trophic transfers in the Baltic Sea, especially with respect to ecosystem-base assessment and management • Quantify trophic transfers in the Baltic Sea • Identify gaps in our knowledge/information • Is it necessary to quantify trophic transfers in the Baltic Sea vs. using an indicator approach to identify changes? • Can automated methods (e.g., satellite imagery, ships of opportunity, profiling instrument platforms) contribute to assess trophic transfers in the Baltic Sea ecosystem? • Recommendations to the BSRP with respect to cruise, sampling and measurement programs (coastal zone, open sea) for ecosystem-based marine management	Michael Olesen Arturas Razinkovas Andris Andrušaitis Jonne Kotta

Annex 7 List of participants

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Annex 8 Draft resolutions

The Study Group on Baltic Sea Productivity Issues in Support of the BSRP [SGPROD] (Chair: Bärbel Müller-Karulis, Latvia) will meet in Nidda, Lithuania, from 4–6 November 2004 to:

a) describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;
b) continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;
c) continue to study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms, etc.), in collaboration with BOOS;
d) review the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators.

Supporting Information

Priority:	ICES is managing component 1 of the BSRP, Baltic Sea Large Marine Ecosystem Activities. SGPROD provides scientific advice to the productivity module of BSRP component 1. The current activities of the group will address important parts of the BSRP project implementation plan (productivity indicator development, institutional and technological capacity building). Supporting the BSRP, the work of the group also contributes to implementing the ecosystem approach to the management of marine resources and should therefore have a high priority.
Scientific Justification and relation to Action Plan:	a) – 1.2.1 b) – 2.2 c,d) – 1.10 all) - 5.6, 8.1 a) Trophic networks will be described for typical subsystems of the Baltic Sea. Trophic networks will be used to analyze the sensitivity of the system to disturbances and to identify suitable productivity indicators. Results will contribute to the indicator system applied in the BSRP. Furthermore, it is planned to present the analysis of the trophic networks at the proposed theme session on "Material and energy flows in trophic networks of the Baltic Sea ecosystem" at the 2005 ICES Annual Science Conference and to publish the results as a scientific paper. The following test cases were suggested for constructing trophic networks: • Curonian lagoon • Pärnu Bay • Askö area • Pommeranian Bight • Gulf of Riga Experts on the foodwebs of each of these systems will be contacted by March 2004, and invited to contribute. Data should be prepared by October 2004 and the analysis of trophic networks will be started at the November Study Group meeting. b) The Study Group will contribute to the development of productivity indicators in the Baltic Sea. During the first half of 2004, the Chair of the Group will intensify contacts to other groups working on indicator development in the Baltic, especially with HELCOM and with the ICES Study Group on Baltic Ecosystem Health Issues in support of the BSRP [SGEH]. The coastal zone management demonstration sites of the BSRP will serve as test cases for indicator development and the Study Group will participate in indicator development and testing. By July 2004, the Chair of the Group will distribute a description of current indicator initiatives in the Baltic Sea as well as background

	information about the BSRP demonstration sites, available data, and preliminary suggestions for indicator variables, based on the indicator set laid out in this report. By October 2004, the Chair of the group will update the information on the proposed indicators. At this meeting, the Study Group will review the indicator set for the demonstration sites. c) Feasibility and efficiency of automated productivity data collection methods will be discussed intersessionally among SGPROD members with relevant expertise. So far members of the group have expertise with unattended stations and ships of opportunities and the group has established links with BOOS and Alg@line. During 2004, the Group will establish contacts to users of satellite data for productivity monitoring in the Baltic. Intersession consultations will provide the BSRP with the necessary expertise to design the technical upgrading of the productivity monitoring system in the Eastern Baltic. The Chair of SGPROD will distribute a report of the intersession activities to all members in July 2004 and October 2004. Activities will be presented and reviewed at this meeting. d) The Chair will distribute a description of the productivity data collection strategy in the BSRP by July 2004, with an update in October 2004, and invite the Study Group members for their comments and suggestions. The data collection strategy will be discussed and reviewed at this meeting.
Resource Requirements:	None
Participants:	The group was attended by 14 participants in 2003. It is planned to expand the group by inviting scientists involved with foodweb analysis in the Baltic Proper and the Swedish archipelago.
Secretariat Facilities:	None
Financial:	Costs are met by BSRP
Linkages To Advisory Committees:	ACE, ACME. In the consideration of indicator issues, the group will closely follow the guidelines prepared by ACE.
Linkages To other Committees or Groups:	There are close working relationships to the other groups established in support of the BSRP (SGBFF, SGEH, SGBEM). Contacts have been also established to WGPE.
Linkages to other Organisations:	HELCOM
Secretariat Marginal Cost Share:	BSRP 100%