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23–26 January 2007

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Executive summary

The Study Group on Baltic Sea Productivity (SGPROD) met in Gdynia, Poland, from January 23–26 2007 and in a coastal subgroup meeting in Riga, from 1– 2 February2007. The meeting was attended by 22 participants from seven countries.

Evolving from the Study Group on Baltic Sea Productivity Issues in Support of the BSRP (SGPROD), with the current meeting the group started to take over tasks not specifically related to the Baltic Sea Regional Project (BSRP). In particular, the group updated and presented hydrographic, nutrient, phytoplankton and zooplankton indicator time series for the use of the ICES/HELCOM Working Group on Integrated Assessments of the Baltic (WGIAB), as well as for the Baltic Fisheries Assessment Working Group (WKBFAS).

The group continued to refine the design of Baltic Sea productivity indicators. Particular interest was raised by the discussion of suitable primary productivity indicators. SGPROD concluded that the current primary productivity data coverage is very low. In addition the group pointed out, that primary productivity in the Baltic Sea consists to a large part of regenerated production, which mostly cannot be transferred to higher trophic levels. On the other hand, the group discussed evidences of the influence of regenerated production on pelagic fish stock production. SGPROD recommends that further efforts should be made to clarify the significance of new, regenerated and total primary production for the Baltic ecosystem in order to design ecologically meaningful Baltic primary productivity indicators.

Refinement of zooplankton indicators suggested, that statistical methods have difficulties discerning controlling factors of Baltic Sea zooplankton dynamics. In the test areas, Eastern Gotland Basin, Gulf of Riga, and Gulf of Finland, zooplankton seems to be controlled by a mix of bottom-up (predominantly hydrography) and top-down factors (planktivorous fish), which partially counteract each other.

SGPROD also gave advice for a potential second phase of the BSRP. The group proposed a work programme for a potential Lead Laboratory for phytoplankton and primary productivity and discussed approaches to integrate productivity information into integrated coastal zone management.

1 Opening of the meeting

The local host, Pjotr Margonski, welcomed the participants on behalf of the Sea Fisheries Institute. Group chair Bärbel Müller-Karulis emphasized that after its period of Study Group on Baltic Sea Productivity Issues in Support of the BSRP, SGPROD has now grown into a "regular" ICES Study Group. She thanked the participants for their continued support and interest and opened the meeting.

2 Adoption of the agenda

The draft agenda (Annex 2) was briefly discussed. There was large interest within the group on the discussion of productivity indicators, in particular primary productivity and its role for assessing Baltic Sea productivity. Therefore the group decided not to split into subgroups dealing with individual ToRs, but rather to base the meeting on extended plenary discussion and presentations. Updating of lower trophic level indicator time series (ToR b) was done in a small group with Philip Axe and Bärbel Müller-Karulis taking the lead. Unfortunately it was not possible for the key players of the BSRP coastal activities to join the meeting in Gdynia, therefore the group agreed that ToR c, initiate a BSRP case study to integrate productivity information into integrated coastal zone management will be discussed at a coastal subgroup meeting 1–2 February in Riga.

3 Discussion of the terms of References

3.1 Refinement of Baltic Sea productivity indicators

SGPROD summarized the experiences and lessons learned for the use of productivity indicators based on a) the suite of productivity indicators used in Large Marine Ecosystem mangagement worldwide, b) experiences with indicator based assessment during the ICES/HELCOM/BSRP Workshop on Developing a Framework for Integrated Assessment for the Baltic Sea (WKIAB), c) phytoplankton indicator development within the HELCOM Phytoplankton expert network, d) expert experience with use of primary productivity indicators presented at the meeting, e) zooplankton indicator testing within the BSRP Lead Laboratory on zooplankton and ichthyoplankton. Unfortunately, due to the lack of expertise within the group, it was not possible to initiate the analysis of macrozoobenthos as a potential productivity indicator.

3.1.1 Experiences from Large Marine Ecosystem management

Mark Berman pointed out that productivity indicators should also be regarded in the wider framework of ecosystem based management of Large Marine Ecosystems (LME) and presented the suite of indicators that has been generally successful in LME management. He pointed out that Large Marine Ecosystems throughout the world are employing the same five module approach to management of their resources. In any LME, the Productivity Module is based on the typical makeup of the marine food web. Although each LME has unique characteristics which may require specific productivity indices, the basic productivity indicators will be common to all LME's. He proposed a s a minimum set of indicators:

Hydrographic indicators of oceanic variability: temperature and salinity profiles.

Measures of phytoplankton abundance and productivity: chlorophyll concentration and primary production.

Characterization of the zooplankton community: biomass, biodiversity, and taxonomic make up of the zooplankton.

Characterization of the Ichthyoplankton: concentration and biodiversity.

Other environmental variables: nutrient concentration, dissolved oxygen.

Mark Berman emphasized that the Baltic Sea has existing sampling programs that already measure most of these indicators (see also the updated lower trophic indicator time series in Annex 9). He pointed out that primary productivity is one indicator not currently being surveyed in the Baltic and emphasized that it is important in describing the amount of organic material available to plankton and fish communities, and that changes in the productivity of an LME can indicate a change in the state of the ecosystem. Since traditional techniques for its measurement are cumbersome, involving incubations, often with ^{14}C, newer techniques including variable fluorescence (e.g. Fast Repetition Rate Flourometry) and ocean color sensing satellite data should be considered carefully. Mark Berman also drew attention that another basic indicator currently only sparsely surveyed in the Baltic is the ichthyoplankton community. Sampling can be done by plankton net as part of standard zooplankton assessment cruises. Ichthyoplankton data can be a key link between Productivity and Fish/Fisheries Modules.

3.1.2 Lessons learned from the ICES/HELCOM/BSRP Workshop on Integrated Assessment in the Baltic

The results of the ICES/HELCOM/BSRP Workshop on Integrated Assessment in the Baltic were summarized by Bärbel Müller-Karulis.

On a Baltic Sea scale, the ICES/HELCOM/BSRP Workshop on Developing a Framework for Integrated Assessment for the Baltic Sea (WKIAB, 1–4 March 2006, ICES 2006) was a first trial to produce an indicator based assessment of all components of the Baltic Sea ecosystem, spanning oceanographic conditions, nutrients, state of the lower trophic levels (phytoplankton, zooplankton) as well as planktivorous and piscivorous fish. The workshop triggered discussions on optimizing the work and information flow within the ICES working and study groups involved in Baltic Sea research and assessment. In this context, WKIAB proposed that SGPROD should be responsible for aggregating “lower trophic” indicators, i.e. oceanographic information, nutrient state, phytoplankton and zooplankton, both for the use of an integrated assessment working group (WGIAB) that is now developing from the experiences of WKIAB, as well as for the use of Baltic fisheries assessment groups.

WKIAB used a multivariate statistical approach (principal component analysis) to assess the ecosystem state of two trial areas, the Central Baltic Sea and the Gulf of Riga. The Central Baltic Sea represents the deep basins of the Baltic, i.e. the Bornholm Basin, Gdansk Basin and the Eastern Gotland Basin, which are permanently stratified with a deep, more saline bottom layer dependent on the influx of North Sea water. The deep basins are at the same time the spawning area of Eastern Baltic cod. In contrast, the Gulf of Riga is a semi-enclosed, relatively shallow brackish basin without permanent salinity stratification. It has high riverine nutrient input and is affected by eutrophication. Pelagic food web structure in the Gulf of Riga is simpler than in the Central Baltic Sea, because cod and sprat are absent from the basin during most years and its herring stock is mostly isolated from the Central Baltic Sea.

WKIAB based its trial assessments on time series covering 1973–2004, characterizing a) climate and physics (temperature and salinity in different water layers, ice cover, inflow index, oxygen), b) nutrients (surface winter DIN and DIP, concentrations in diffent water layers, nutrient loads), c) phytoplankton (chlorophyll *a*, biomass of species groups, Secchi depth), d) zooplankton (species biomass in different seasons), and e) fish stock indexes and fishing mortality (sprat, herring, cod, flounder, salmon).

The principal component analysis found consistent temporal changes in many indicator time series, so that chronological clustering of the PCA scores (Figure 1) resulted in three groups of years in each basin with similar ecosystem properties. In particular, the major pattern of ecosystem change captured by the first principal component showed that the Central Baltic Sea had shifted from a cod and herring dominated system to high sprat stocks, with a simultaneous decrease in salinity and increase in temperature. Spring zooplankton above the halocline benefited from the temperature increase, whereas *Pseudocalanus acuspes* declined due to the lower salinity in the halocline region. The second principal component mainly summarized bottom water processes and depicted the accumulation of nutrients and the depletion of oxygen during the long Baltic stagnation period.

In the Gulf of Riga, the climatic pattern with decline in salinity and increase in temperature was also extracted with the first principal component. In contrast to the Baltic Proper, eutrophication related signals – increase in winter DIP and summer chlorophyll *a* – are part of the major ecosystem pattern and correlated to the first principal component.

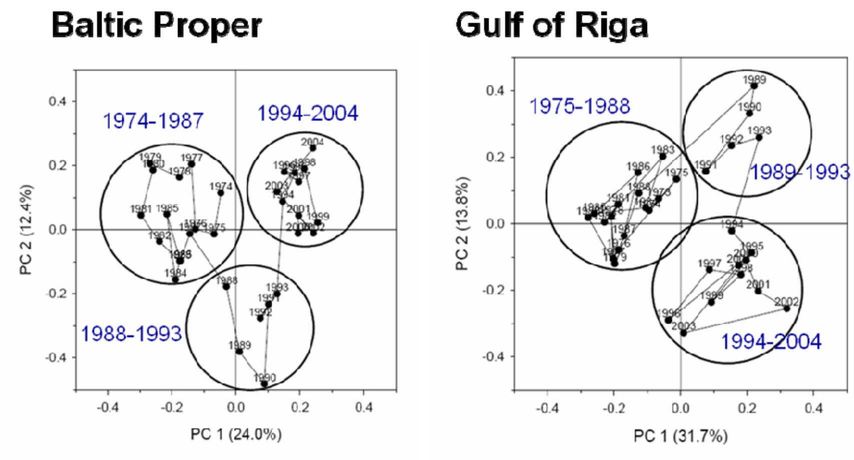

Figure 1. Years with similar ecosystem properties in Central Baltic Sea and Gulf of Riga as shown by principal component analysis scores (ICES, 2006).

The WKIAB analysis showed that long-term ecosystem changes in the Central Baltic Sea and the Gulf of Riga affected all ecosystem components. The statistical analysis also allowed to identify major drivers – climate shifts, inflow regime, fishery, and in the Gulf of Riga also eutrophication.

Experiences during WKIAB revealed also several problems with data availability and aggregation into meaningful indicators. The analysis found only very weak links between phytoplankton and the other ecosystem components in the Central Baltic. The chlorophyll *a* and phytoplankton time series were significantly shorter than all other indicator series, starting only in 1979/1980, and showed high interannual variation, which might have masked statistical relationships. There was also little experience in the group in choosing meaningful hydrographic and nutrient indicators. In particular, WKIAB showed that it is important to limit the number of hydrographic indicators, as they tend to intercorrelate, to water layers that can be expected to influence biological communities, either being a habitat layer for a particular species, or by providing a nutrient reservoir that is at least partially accessible during the productive season. Problems were encountered also with the data flow between data collectors – mainly institutes involved in marine and fisheries monitoring – and WKIAB. For biological data – phytoplankton and zooplankton – centralized databases are currently not functioning. Further, the group felt, that for most indicators there is a high degree of expert involvement needed to extract meaningful indicators out of raw data and that involvement of specialists to process raw data into spatially and temporally aggregated indicator time series is key to the success of indicator based assessments.

References

ICES. 2006. Report of the ICES/BSRP/HELCOM Workshop on Developing a Framework for Integrated Assessment for the Baltic Sea (WKIAB), 1–4 March 2006, Tvärminne, Finland. ICES CM 2006/BCC:09. 57 pp.

3.1.3 Nutrients and hydrography

Philip Axe and Bärbel Müller-Karulis reviewed the nutrient and hydrographic indicators used during WKIAB and refined the indicator time series (see Annex 9). During WKIAB, it became clear that many hydrographic time series are intercorrelated. In order not to dilute statistically significant relationships, only those indicators should be used that provide independent, ecologically meaningful information. Generally, summer time series had better spatial and temporal coverage and for deep water layers without pronounced seasonal dynamics they therefore provided more reliable signals. However, in order to provide a first characteristic of the current year conditions for the use of fisheries assessment groups, winter hydrographic conditions were used also for deeper water layers in this report. The water layers proposed to characterize the hydrographic conditions in the Eastern Gotland Basin and the Bornholm Basin are listed in Table 1. For nutrient conditions, winter surface nutrient concentrations should be used in combination with summer nutrient conditions in the bottom layer of Eastern Gotland and Bornholm basin to capture the influence of the Baltic bottom water dynamics on Baltic Proper nutrient concentrations.

Table 1. Water layers used to characterize hydrographic conditions in the Eastern Gotland and Bornholm Basin.

	Eastern Gotland Basin	Bornholm Basin
Surface	0 – 10 m	0 – 10 m
Winter water	40 – 60 m	-
Halocline region	80 – 100 m	Not meaningful, high fluctuation
Bottom layer	200 – 220 m	70 – 90 m

3.1.4 Phytoplankton

Lars Edler summarized the phytoplankton indicator development within the HLEOCM Phytoplankton Expert Group. This network has worked with aspects of quality assurance of the phytoplankton analysis since the beginning of the 1990s. This has been done by an annual meeting of the persons involved with the actual microscopical analysis of phytoplankton. At the annual meetings there have been lectures on different groups of phytoplankton by taxonomic experts and identification training on samples brought by the participants. For a ten year period PEG has also worked with the compilation of a list with biovolumes of Baltic phytoplankton and its grouping into different size classes. Only recently PEG has started to deal with indicator development. In 2006 PEG reported to HELCOM on "unusual events" in the Baltic Sea. This report contained e.g. the presence of saline phytoplankton species in the Baltic Proper and observations of the seldom occurring bioluminescence in the Baltic Proper. In its last meeting PEG decided on future indicators to be reported annually. These comprise "spring bloom index" and a "Phytoplankton bloom index". As these indicators are highly quality controlled, they are prime candidates for integration into the work of SGPROD and WGIAB.

Experience during WKIAB showed, that extending the chlorophyll *a* and phytoplankton time series to 1974 would be desirable. Therefore SGPROD, in cooperation with PEG, distributed a questionnaire to the monitoring and research institutes around the Baltic Sea to construct an inventory for chlorophyll *a*, phytoplankton and primary productivity data. Unfortunately, the inventory (Annex 6) resulted in no additional data for the period 1974 – 1979/1980. Not all institutes responded to the questionnaire, but for the Southern part of the Baltic Proper it provides a good overview of the available information.

3.1.5 Primary Productivity

Lars Edler (Sweden) made an introduction about the history and present state of phytoplankton primary productivity measurements in the Baltic Sea area. Together with Franciscus Colijn, Lars Edler has compiled the HELCOM COMBINE Manual for Phytoplankton Primary Productivity (http://sea.helcom.fi/Monas/CombineManual2/PartC/anxc5.html). According to the manual, primary production should be measured with the P/E method, which is based on incubations at different irradiance levels. Daily production is then estimated from the P/E curves by mimicking the daily irradiance profile in the water column ("simulated in-situ method"). Procedures applied at different Baltic Sea laboratories are mostly variations of the HELCOM COMBINE method. For example, a procedure applied at the Polish Sea Fisheries Institute uses 2-hour incubations with phytoplankton collected at 2.5 m depth. Different light levels are generated by a system of filters and mirrors and photosynthectic rates are measured with the C-14 isotopic method. Daily primary production is estimated according to Renk and Ochocki (1999) based on light curve parameters combined with daily irradiance and water transparency.

Presently, very few laboratories in the Baltic Sea area conduct routine primary production measurements, as shown by a questionnaire sent about five years ago to 30 laboratories dealing with PP measurements (20 questionnaire returns). Also the phytoplankton inventory (Annex 6) showed that PP measurements are only sporadically available and are mainly used for research purposes. Besides few remaining Danish measurements, currently, only Sweden conducts phytoplankton PP measurements as part of their national marine monitoring programme, with monthly measurements in the Bornholm Basin and the Kattegat area. The main reasons for the decline in PP monitoring are the time-consuming measurements, the need to use radioactive substances, and little application of PP data in the recent Baltic environmental assessments. *In situ* measurements, as a potential "easier" alternative to incubation at different light levels, have to be deployed around noon with a recommended time of 4 hours and are therefore limited to experimental studies, as ship time is costly. Studies with fast repetition rate fluorometer (FRF) in the Baltic have been conducted mainly at the Finnish Institute of Marine Research, and showed that the relationship between FRF measurements and C^{14} based primary productivity rates is non-linear and in addition depends on the properties of the phytoplankton community, so that calibration of FRF measurements by C^{14} incubations is required. This means that FRF measurements have the potential to expand the temporal and spatial coverage of primary productivity data, but do not eliminate the need for C^{14} measurements (Raateoja, 2006).

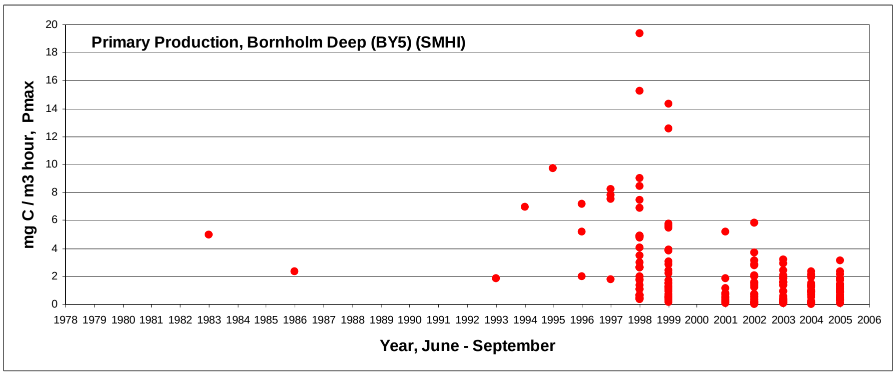

Figure 2. An example of Baltic primary production rates measured in the Swedish monitoring programme (Data from SMHI).

Lars Edler presented primary production rates measured within the Swedish monitoring programme (Figure 2). Because often water column light profiles and information on daily irradiance were not available, the data were not recalculated to daily productivity. Scatter in the raw data is extremely large, so that evaluation of productivity trends would have to rely mainly on the adequacy of the procedure used for estimating daily production. In addition, intercalibration exercises within HELCOM laboratories showed high variation among the participants. Mariusz Zalewsky pointed out that primary productivity measurements made at SFI for research purposes showed good correlation between daily production estimated from incubations and light attenuation in the water column ("simulated *in situ*") with in-situ measurements at 4 hour incubation time, when the measurements were made around noon, but weaker relationships if the measurements were conducted in the early morning or late evening. The SFI comparative analysis then found water column integrated primary production estimated by the incubator method to be essentially equal to in-situ measurements (incubator based productivity = 0.993 * in-situ productivity, Renk and Ochocki, 1999). This implies that reliable estimates of daily production can be made based on incubations. SGRPOD therefore proposes that, if realistic total primary productivity estimates should be desired for monitoring purposes, efforts should be made to standardize the procedures used to estimate daily or monthly primary production form incubator measurements.

SGPROD concluded that the present data is currently insufficient to quantify trends in primary productivity for the Baltic Sea sub-basins on shorter than decadal time scales. However, there was agreement in the group that primary productivity has to be assessed by measurements and that this information cannot be replaced by any modelling approaches.

On the other hand, the group intensively discussed the significance of total primary production as a productivity indicator in the seasonally stratified Baltic Sea. During the summer stratified period, total primary productivity mainly consists of regenerated production. Already during the 1960s, Dugdale and Goering introduced the view that regenerated production cannot be harvested from aquatic ecosystems sustainably, i.e. without disturbing the equilibrium of the present plankton community, and that instead new production would better describe the rate at which organic carbon can be transferred to higher trophic levels (Dugdale and Goering, 1967). In the Baltic Sea, regenerated production dominates the total production especially during summer. Figure 3 gives a conceptual sketch of the relationship between annual primary production and regenerated production in the Kattegat, where regenerated production makes up approximately 80 % of total primary production. This implies that potentially 80 % of the measured total primary productivity signal does not relate to the transfer to higher trophic levels, but consists of "noise" generated by regenerated production. Further, the group discussed whether new production would be a better indicator for the trophic transfer within the foodweb. There was general agreement that new production, which can for example be estimated by the supply of new nitrogen to the euphotic zone or by the export of organic matter by sedimentation, is difficult to measure. SGPROD therefore suggests first to focus on the role of new, regenerated and total primary production for describing the ecological carrying capacity of the Baltic Sea ecosystem in terms of biomass production in higher trophic levels. During its 2008 meeting, SGPROD plans to start a comparative case study (see Annex 7) based on available literature information for the Baltic Sea subbasins, combined with conceptual foodweb modelling, to examine the a) physical and structural (biological) controls of organic matter transfer to higher trophic levels, b) sensitivity of different "primary" productivity indicators, i.e. total/new primary production, standing stock of phyto- and zooplantkon to the flux of organic matter channelled to higher trophic levels.

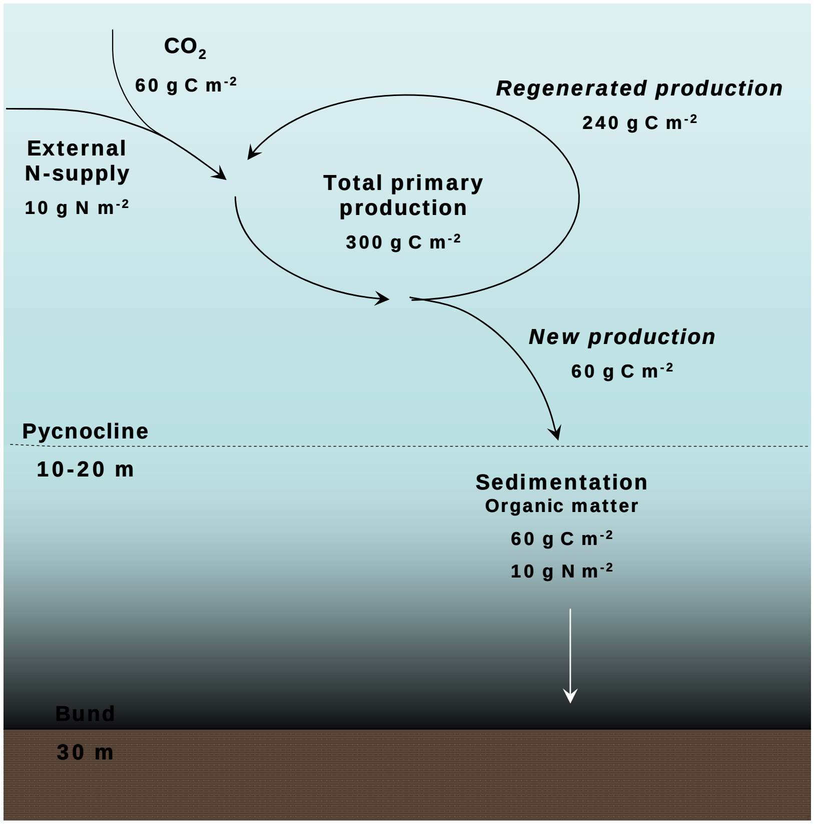

Figure 3: Diagram showing the tight quantitative relation between nutrient supply and export of organic matter, i.e. sedimentation. The example is from the seasonal outcome of primary production in the Kattegat (March–November). In stratified waters inorganic nutrients limiting primary production will fast be incorporated into organic matter. Some of these nutrients are remineralised within the mixed layer and will nourish an additional production. Primary production based on external nutrients is called new production whereas primary production based on local remineralized nutrients is called regenerated production.

To conclude the discussions of primary productivity measurements and primary productivity indicators, Mariusz Zalewski showed the lab facilities used for primary productivity measurements at SFI to the group. Sergey Aleksandrov added a presentation on the phytoplankton and primary productivity research at AtlantNIRO (Annex 10), including some very interesting preliminary results from the huge sampling campaign in the Baltic Sea ordered by Gazprom for environmental impact assessment of the Nordstream gas pipe line from Russia to Germany.

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3.1.6 Zooplankton

Intersessional work focused on the refinement of zooplankton indicators. Meaningful productivity indicators should either clearly respond to changes in bottom up forcing and/or should significantly impact the next higher trophic level (ICES 2005). Zooplankton plays an important role within the lower part of the Baltic foodweb because it transfers primary production into biomass useable for planktivorous fish. Additionally, all fish species are planktivorous during their early live stages and therefore zooplankton dynamics affect fish recruitment. However, zooplankton dynamics in the Baltic Sea are not only linked to primary producers and planktivores, but also affected by hydrographic conditions, especially temperature and salinity. Our aim in refining zooplankton indicators was to clarify, to which extend mesozooplankton biomass fluctuations are driven by bottom-up forcing by primary producers versus variations in physical conditions, and how strongly zooplankton dynamics affect the following trophic level, i.e. planktivorous fish and fish recruitment.

Analysis presented at the meeting focused on the long-term (1974 to present) dynamics of mesozooplankton in three subbasins of the Baltic Sea, the Gulf of Finland, Gulf of Riga and the Eastern Gotland Basin. Datasets were collected that describe potential physical influence factors (temperature, salinity), primary producers (winter nutrient conditions as proxy, phytoplankton biomass, chlorophyll *a*), and consumers (ICES assessment data for planktivorous fish, recruitment estimates for herring and sprat as well as catch and condition data).

The datasets were analysed by univariate and multivariate regression methods (see Annex 8 for details), with mostly single zooplankton species as target variable, as well as by ordination techniques to determine patterns in zooplankton abundance/species composition and their underlying driving factors. In the Gulf of Riga, analysis focused on the impact of zooplankton on herring recruitment. Herring recruitment could both be linked to spring biomass of *Acartia* and *Eurytemora*, as well as to climatic indices (Winter Baltic Climate Index WBIX). In the Gulf of Finland, both PCA as well as univariate regression showed correlations between the dynamics of planktivorous fish landings and their condition with mostly small zooplankton species. These correlations were not interpreted as causal relationships, but rather seem to indicate that both small zooplankton and planktivoures in the Gulf of Finland were affected by similar driving factors. In the Gulf of Finland dataset correlations with physical factors (salinity, temperature) and nutrient conditions (winter concentrations) were weak, with the exception of *Bosmina coregoni maritime* that responded to increased summer temperatures. Analysis in the Eastern Gotland Basin focused on the summer biomass of the three dominating species, *Acartia sp*., *Temora longicornis* and *Pseudocalanus acuspes*. Both multivariate regression models as well as general additive models (GAM) were constructed. Summer data were chosen because during the thermally stratified, nutrient deplete summer situation zooplankton grazing was expected to have the highest impact on phytoplankton of all seasons, while planktivorous fish (herring, sprat) are known to feed in the Eastern Gotland Basin during summer. Physical input variables were limited to the summer conditions in the preferred depth range of each species. GAM models found significant predation impact of herring, and sprat/sprat recruits on *Acartia* and *Temora*, while *Pseudocalanus* was more affected by physical conditions in the halocline region together with sprat predation. Significant negative correlation with chlorophyll *a* was found for *Temora*, suggesting grazing control on the summer phytoplankton community.

Analysis from all three subareas showed, that statistical methods have difficulties discerning controlling factors of zooplankton dynamics. This can be partially attributed to undersampling and sampling error in the zooplankton time series, but can be also thought to indicate that Baltic zooplankton is neither completely bottom up controlled (physical factors, primary producers) nor top-down dominated (planktivorous fish). Therefore their time-series are determined by both bottom-up and top-down control signals, which have the potential to counteract each other, so that the impact of single factors is masked in the statistical analysis.

Georg Kornilovs further demonstrated the application of zooplankton information for recruitment predictions (see Annex 8 for further details). A general problem with recruitment predictions for Baltic herring and sprat seems to be the large interannual recruitment fluctuation, where a single strong year class has the potential to destroy the statistical relationship between recruitment and zooplankton and/or climatic predictors. This has been observed for herring recruitment predictions in the Gulf of Riga, where May copepod abundance and May water temperatures are used as predictors in stock assessments, as well as for the dependency of sprat recruitment on winter climatic indexes (MacKenzie and Köster 2004).

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3.2 Updating lower trophic level indicator time series

Annex 9 summarizes the time series of hydrographic, nutrient, phytoplankton and zooplankton indicators for the Eastern Gotland Basin, Bornholm Basin, and the Gulf of Riga.

In all three basins, exceptionally warm autumn conditions in 2006 were noticeable. In the Gulf of Riga, the warm autumn, together with a salt water inflow from the Eastern Gotland Basin, prolonged the stratification of the water column and led to hypoxic conditions in the bottom waters.

In the Eastern Gotland Basin the bottom water (200–220 m) was relatively warm and saline, but oxygen conditions were poor (H_2S present in the bottom water, low oxygen concentrations in the halocline region). DIN concentrations continued to decrease in winter 2006/2007, while DIP concentrations remained on a high level. Therefore nutrient conditions in the Eastern Gotland Basin, but also in the Bornholm Basin, can be expected to be favourable for cyanobacteria blooms. In contrast to the Eastern Gotland Basin, oxygen conditions in the Bornholm Basin had slightly improved in winters 2005/2006 and 2006/2007. Alg@line information characterized timing and intensity of the 2006 phytoplankton spring bloom as "average" in the Central Baltic Sea. During summer 2006, intense cyanobacteria blooms were noted in the Bornholm Basin. Zooplankton information was only available for the Eastern Gotland Basin and the Gulf of Riga. In the Eastern Gotland Basin, *Pseudocalanus acuspes* biomass continued to increase in 2006, while *Acartia spp*. and *Temora longicornis* declined.

3.3 Initiate a BSRP case study to integrate productivity information into integrated coastal zone management

Andris Andrušaitis summarized briefly the current status of the BSRP project implementation. He emphasized that it was uncertain, whether the application for the second phase of the BSRP would receive World Bank support. Therefore he advised the group to discuss ideas on integrating productivity information into integrated coastal zone management with a Baltic Sea focus, but not targeted specifically to the BSRP. To support the group with background information on ongoing coastal zone research programmes in the Baltic Sea and the available data that was generated, Juris Aigars presented the progress of the BALANCE and LIFE projects.

In the following, several approaches to treat productivity information in coastal zone assessment were discussed. Henn Ojaveer summarized the role of the coastal zone as a fish habitat. Bärbel Müller-Karulis briefly reviewed the results of the ECOPATH food web modelling activities initiated within the BSRP and proposed to apply indicators based on foodweb modelling (flows at the basis of benthic and pelagic foodweb, Ecotrophic Efficiency, Mixed Trophic Impacts). The coastal subgroup however criticized, that the use of food web models widely depends on the representativity and completeness of the input data. Sergej Olenin proposed instead to use a more general framework, the functional traits of Baltic marine habitats/biotopes, as a decision support tool for integrated coastal zone management (see for example Olenin and Ducrotoy, 2006, for the functional aspects of biotopes in coastal marine ecology). The group felt, that a matrix of the functional role of Baltic coastal biotopes, in combination with maps (GIS layers) of their spatial distribution, would provide essential background information to Baltic decision makers, which should be integrated into a decision support system.

In case BSRP funding will not be available in the future, several funding sources for developing a case study were discussed (INTERREG, LIFE, FP 7, BONUS).

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Olenin, S., Ducrotoy, J. 2006. The concept of biotope in marine ecology and coastal management. Marine Pollution Bulletin 53, 20 – 29.

3.4 Primary productivity capacity building programme for a potential BSPR Lead Laboratory

To establish a Lead Laboratory for phytoplankton and primary productivity monitoring during the second phase of the BSRP was suggested by SGPROD at its 2006 meeting (ICES, 2006) and the group charged itself with the tasks of establishing its work programme and terms of references. According to BSRP component 1 assisstant coordinator Andris Andrušaitis, if funding for a second phase of the BSRP will be granted, a Lead Laboratory for phytoplankton and primary productivity monitoring will be established in one of the beneficiary countries (Estonia, Latvia, Lithuania, Russia, Poland). SGPROD emphasized, that a prime task for this Lead Laboratory will be to build a close cooperation and networking system between relevant experts in all countries surrounding the Baltic Sea, as spreading and shearing of knowledge will be very important to increase the efficiency of primary productivity monitoring. Since there are not many primary productivity experts in the laboratories of BSRP beneficiary countries, the selection of a hosting institute will actually also mean the selection of potential Lead Laboratory head. SGPROD therefore proposed to organize an open call to select a hosting institute and to base the selection among other factors on the interest, expertise and capacity of the applying institute, as well as on its potential sustaining the Lead Laboratory after the closure of the BSRP.

The following terms of references for the Lead Laboratory were proposed:

1) Identify scientists and labs measuring phytoplankton PP and interested in networking.
2) Initiate and supervise networking (e.g. by organizing collaboration and training workshops)
3) Develop inventories of methods used for primary productivity monitoring around the Baltic Sea.
4) Develop inventories of existing phytoplankton primary production time series and use those to develop approaches for temporal and spatial data integration.
5) Review the strengths and weaknesses of different measurement methods and protocols.
6) Develop approaches to split total primary production into new and regenerated production.
7) Propose realistic estimations on total primary production of different Baltic Sea sub basins. Use the outcome of task 5 to make suggestions how to assess their total primary production. Overcome data extrapolation problems and reduce the influence of short time fluctuations.
8) Develop and conduct regular observations in order to characterise phytoplankton primary production in one of the Baltic Sea sub regions.
9) Participate and support the HELCOM phytoplankton expert network, SGPROD, and WGIAB.
10) Propose a programme for long-term phytoplankton primary productivity assessment in the Baltic Sea that would fulfil the requirements of the EU Marine Strategy.

References

ICES. 2006. Report of the Study Group on Baltic Sea Productivity Issues in support of the BSRP (SGPROD), 6–7 April, 2006, Tallinn, Estonia. ICES CM 2006/BCC:04. 70 pp.

3.5 Arrangements for an undulating nutrient sensor demonstration

Mark Berman reported that there is little encouraging news about the use of in-situ nutrient samplers. After frustrating attempts to integrate the SubChemPak 4 channel nutrient sensor into the NMFS Mariner Shuttle (Chelsea NuShuttle), he is not yet able to recommend this technology to the SGPROD. Further, it became clear that a demonstration of it in the Baltic will remain prohibitively expensive.

Another option might be the ISUS sensor (http://www.satlantic.com/ default.asp?mn=1.15.25.34), which uses UV absorbance to measure nitrate concentration in real time with no wet chemistry. Its simplicity and ease of operation should make it attractive for use in LME studies mounted on undulating platforms or in FerryBox-like system. However, the usefulness of using a sensor limited to nitrate for Baltic work must be discussed, but the manufacturer may be willing to demonstrate this device in the Baltic during the spring of 2007. Currently there seem to be no commercially available phosphate sensor suitable for real time, in-situ applications. Ship-board determination of the nutrient concentration of collected water samples by AutoAnalyzer would remain a possible, although less than ideal, solution.

As at the time of the meeting it was clear that no BSRP funding would be available for field work activities during summer 2007, the group decided to delay arrangements for an undulating nutrient sensor demonstration until a funding decision has been made for the second phase of the project.

4 Other business

Michael Olesen was elected as a Co-Chair of SGPROD. He will be responsible for coordinating the productivity assessment case study.

Annex 1: List of participants

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Annex 2: Agenda

January 23

12:00 Lunch

13:00 Opening of the meeting

13:30 Adoption of draft agenda

14:00 ToR a) refine Baltic Sea productivity indicators, especially with respect to zooplankton, review available phytoplankton productivity indicators and their data sources and initiate analysis of macrozoobenthos as a potential productivity indicator

Presentations:

- Zooplankton indicator analysis (Bärbel Müller-Karulis, Pjotr Margonski, Solvita Strāķe, Arno Polummae)
- Phytoplankton expert group indicators (Lars Edler)

15:30 Coffee break

- Design of a productivity indicator suite (Mark Berman, audio link)

Discussion

January 24

9:00 ToR b) update lower trophic level (hydrography, nutrient, phyto- and zooplankton) indicator time series for the use of WGIAB and fisheries assessment groups

Presentations:

- WKIAB results (Bärbel Müller-Karulis)
- Lower trophic level indicators useful for fisheries assessment groups (Georgs Kornilovs)

10:30 coffee break

Discussion: Refinement of productivity indicators

12:30 lunch break

Discussion: Refinement of productivity indicators
Updating of nutrient and hydrography indicator time series

15:00 coffee break

Discussion: Refinement of productivity indicators
Updating of nutrient and hydrography indicator time series

January 25

9:00 Plenary: Case study approach to refine productivity indicators

10:30 Coffee break

ToR d) prepare a training and technical capacity building programme to establish a suitable institute in the BSRP beneficiary countries as a local centre for primary productivity monitoring

Presentations:

- Primary productivity monitoring methods and phytoplankton training needs (Lars Edler)
- AtlantNIRO phytoplankton research (Sergey Alexandrov)

12:30 lunch break

13:30 Plenary: Discussion of a training and technical capacity building programme for primary productivity monitoring

Presentations:

- Apparent effect of temperature on regenerated production in the Baltic Proper (Michael Olesen)
- Zooplankton ring test

Visit to Sea Fisheries Institute Primary productivity laboratory (Mariusz Zalewski)

15:30 Coffee break

ToR e) prepare a BSRP trial demonstration of an undulating nutrient sensor in the Baltic Sea (Mark Berman, audio link)

17:00 Plenary, discussion of report inputs, SGPROD Terms of References 2008

January 26

Report drafting
Update of nutrient and hydrography indicator time series

10:30 coffee break

13:00 closing of the meeting

SGRPOD 2007 coastal subgroup meeting Riga

Feb 1

13:00 Opening of the meeting, adoption of draft agenda

Case study setting - Presentations:

Andris Andrušaitis: BSRP Phase II plans and timeframe

Sergej Olenin: Functional role of benthic biotopes

15:00 Coffee break

Henn Ojaveer: Food and habitat requirements of fish in the coastal zone

Bärbel Müller-Karulis: Coastal foodweb modeling

Juris Aigars: Coastal habitat information available from LIFE and BALANCE projects

Feb 2

9:00 Case study design – discussion and reporting

11:00 Coffee break

13:00 Closing of the meeting

Annex 3: SGPROD terms of reference for the next meeting

The **Study Group on Baltic Sea Productivity** [SGPROD] (Chairs: B. Müller-Karulis, Latvia, M. Olesen, Denmark) will meet in Jūrmala, Latvia, from 22–25 January 2008 to:

a) Update lower trophic level (hydrography, nutrient, phyto- and zooplankton) indicator time series for the use of WGIAB and fisheries assessment groups;

b) Summarize the zooplankton indicators developed during the Baltic Sea Regional Project;

c) Present preliminary results from Baltic zooplankton data collected by CPR in comparison to WP-2 nets;

d) Initiate a case study to test approaches to assess Baltic marine primary productivity.

SGPROD will report by DATE to the attention of the Baltic Committee.

Supporting Information

PRIORITY:	SGPROD was founded as Study Group on Baltic Sea Productivity Issues in Support of the BSRP. Within the new Baltic related study and working group structure proposed by WKIAB it should continue its work, strengthening productivity indicator development and supplying lower trophic level information for both fishery management and integrated assessment purposes. Work of the group should therefore be given high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	a) Trial integrated assessments for the Central Baltic and Gulf of Riga at WKIAB showed that raw data time-series have to be integrated into basin and process specific indicators by scientific experts. SGPROD will prepare and describe the hydrographic, nutrient, phytoplankton and zooplankton indicator time-series required by the Baltic integrated assessment processes and make the relevant indicator time-series available to fisheries related groups, as an important step to organize the information flow for Baltic Sea integrated assessments. b) Discussions at the 2006 SGPROD meeting showed a very active group of experts involved in zooplanktion indicator testing within the BSRP. Indicator testing results are expected to be finalized in summer 2007 with the closure of phase I of the BSRP. SGPROD will take the opportunity to discuss and review the results. c) Continuos plankton recorders (CPR) have been successfully and cost-efficiently applied in asessing zooplankton in the world oceans. In the Baltic Sea the applicability of CPR has been questioned because of the small zooplankton in relation to the standard CPR mesh-size. SGPROD will discuss the results of intercomparisons of modified CPRs with WP-2 nets and the potential for their application in the Baltic Sea, based on recent CPR trials in the Baltic Sea. d) SGPROD has also previously pointed out that in order to assess Baltic primary productivity, not only improved coverage of primary productivity data is needed, but that also that the applicability and ecological significance of different primary productivity indicators (e.g. total, new and regnerated production) should be reviewed. In order to refine Baltic primary productivity indicators, SGPROD will initiate a case study based on published literature and conceptual modeling in several Baltic sub-basins to a) investigate the role of new/tergenerated production for the ecological transfer efficiency to higher trophic levels, b) test the sensitivity of productivity indicators proposed earlier, c) propose measurement methods for new and regenerated production in the Baltic.
RESOURCE REQUIREMENTS:	None
PARTICIPANTS:	The group was attended by 22 participants from seven countries in 2007.
SECRETARIAT FACILITIES:	None
FINANCIAL:	
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	There are close working relationships to SGEH, to Baltic Integrated Assessment activities (WGIAB), to the HELCOM/ICES zooplankton expert network as well as to

COMMITTEES OR GROUPS:	ongoing HELCOM assessment activities (HELCOM EUTRO-PRO). Contacts are also established to the HELCOM phytoplankton expert network.
LINKAGES TO OTHER ORGANIZATIONS:	HELCOM

Annex 4: Recommendations

RECOMMENDATION	ACTION
1. Provide feedback on the usefulness of lower trophic level indicator information provided and input into the further refinement of indicators as supporting information for Baltic fisheries assessment groups	WGBFAS
2. Improve the accessability of Baltic Sea phytoplankton and zooplantkon data	ICES data center

Annex 5: SGRPOD Terms of references for the current meeting

2006/2/BCC02 The **Study Group on Baltic Sea Productivity** [SGPROD] (Chair: B. Müller-Karulis) will meet in Gdynia, Poland, from 23–26 January 2007 to:

a) refine Baltic Sea productivity indicators, especially with respect to zooplankton, review available phytoplankton productivity indicators and their data sources and initiate analysis of macrozoobenthos as a potential productivity indicator;

b) update lower trophic level (hydrography, nutrient, phyto- and zooplankton) indicator time-series for the use of WGIAB and fisheries assessment groups;

c) initiate a BSRP case study to integrate productivity information into integrated coastal zone management;

d) prepare a training and technical capacity building programme to establish a suitable institute in the BSRP beneficiary countries as a local centre for primary productivity monitoring;

e) prepare a BSRP trial demonstration of an undulating nutrient sensor in the Baltic Sea.

SGPROD will report by 15 February 2007 to the attention of the Baltic Committee.

Supporting Information

PRIORITY:	SGPROD was founded as Study Group on Baltic Sea Productivity Issues in Support of the BSRP. Within the new Baltic related study and working group structure proposed by WKIAB it should continue its work, strengthening productivity indicator development and supplying lower trophic level information for both fishery management and integrated assessment purposes. Work of the group should therefore be given high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	a) 1.12, 2.2; b) 1.12, 2.2; c) – 3.3, 4.14; d) – 1.2, 1.10; e) 1.10; f) 1.10 a) Data on lower trophic level components in the Baltic Sea are collected within fisheries monitoring (zooplankton, nectobenthos) and environmental monitoring programs (phytoplankton, macrozoobenthos). For use in integrated assessment and ecosystem based management, indicators must be developed that characterize the productivity of these components. SGPROD has so far successfully summarized the theoretical background for a system of lower trophic level indicators, as well as suggested and tested zooplankton indicators. Future work should refine the developed zooplankton indicators and initiate work on using phytoplankton and macrozoobenthos as productivity indicators. b) Trial integrated assessments for the Central Baltic and Gulf of Riga at WGIAB showed that raw data time-series have to be integrated into basin and process specific indicators by scientific experts. SGPROD will prepare and describe the hydrographic, nutrient, phytoplankton and zooplankton indicator time-series required by the Baltic integrated assessment processes and make the relevant indicator time-series available to fisheries related groups, as an important step to organize the information flow for Baltic Sea integrated assessments. c) Monitoring and assessment of the state of coastal waters in the Baltic Sea is currently driven by the requirements of the EU Water Framework Directive, and to a lesser degree by the EU Habitats Directive and the HELCOM network of Baltic Marine Protected Areas, as well as coastal fish monitoring. The BSRP/SGPROD has previously studied ecosystem functioning for five case study areas by foodweb modeling. In order to strengthen the functional aspects of coastal habitats the BSRP and SGPROD will cooperate to develop strategies to incorporate productivity information into integrated coastal zone management in a case study area.

SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	d) Though describing the basis of pelagic foodwebs, primary productivity measurements have been removed from most Baltic Sea monitoring programs, especially in the Eastern Baltic countries. The BSRP aims, with advice from SGPROD and through cooperation with its US partner organization, to provide training opportunities in primary productivity measurement methods and at the same time to improve the data coverage for the Eastern Baltic Sea. e) The use of modern technology – undulating sensors that provide fast 3D profiling of marine survey areas – is currently hampered by the lack of suitable nutrient sensors. Recently, flow injection analyzers have become available for use on towed bodies. To test this technology for the Baltic Sea, a trial will be arranged within the BSRP project.
RESOURCE REQUIREMENTS:	None
PARTICIPANTS:	The group was attended by 17 participants from seven countries in 2006.
SECRETARIAT FACILITIES:	None
FINANCIAL:	BSRP covers participation costs of two members/eastern Baltic country.
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 SGBFFD, SGEH, to Baltic Integrated Assessment activities WGIAB, to the HELCOM/ICES zooplankton expert network as well as to ongoing HELCOM assessment activities (HELCOM EUTRO-PRO). Contacts are also established to the HELCOM phytoplankton expert network.
LINKAGES TO OTHER ORGANIZATIONS:	HELCOM

Annex 6: Phytoplankton data inventory

Station	Area	Chlorophyll *a*		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
BMP N3, BMP N1, BMP M2, BMP M1, BMP K8, BMP K4, BMP K5, BMP K2, BMP K1, BMP J1	Belt Sea Mecklenburg Bight Arkona Sea Bornholm Sea Gotland Basin	1979 or 1980 until present	Lorenzen	1979 or 1980 until present	Utermöhl, acid Lugol	1980–1995(1997)	*in situ* and incubator method (14-C)	IOW (Norbert Wasmund)
Anholt E	Kattegat	1979–present	Acetone now ethanol fluor	1979–present	Lugol	1979–present	C14-incubator	SMHI (Lars Edler)
Hallands Väderö (Laholm Bay)	Kattegat	1989–1996	Ethanol fluor	1989–1996	Lugol	1989–1996	C14-incubator	SMHI (Lars Edler)
BY5	Bornholm Sea	1979–present	Acetone now ethanol fluor	See Univ Stockholm		1989–1996	C14-incubator	SMHI (Lars Edler)
W Landskrona	Øresund	1979–present	Acetone now ethanol fluor	No		No		SMHI (Lars Edler)
Øresund Several stations	Øresund	1985–present	Acetone now ethanol fluor	1985–present	Lugol	1985–present	C14-incubator	SMHI (Lars Edler)

Station	Area	Chlorophyll a		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
C KO 54º29’36” 18º35’30” C P110 54º30‘00“ 19º06‘48“ C P104 54º34‘54“ 18º47‘24“ C P116 54º39’06” 19º17’36 C ZP6 54º39’24’’ 18º 31’18’’	Gulf of Gdansk Puck Lagoon – secluded, internal part of the G.Gdansk	1999–present	COMBINE	1999–2003	COMBINE			IMWM (Elzbieta Lysiak-Pastuszak)
O P1 54º50’00“ 19º20’00” O P140 55º33’18” 18º24’00” O P5 55º15’00” 15º59’00”	Gdansk Deep SE Gotland Basin Bornholm Deep	1987–present 1993–present 1993–2000	COMBINE	1999–2003 earlier data (1987–1998) not available in electronic form	COMBINE; Up to 1995 formaline fixation, afterwards Lugol	1985(?)–1994 results not available in electronic form	C-14	IMWM (Elzbieta Lysiak-Pastuszak)

Station	Area	Chlorophyll *a*		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
C MR 54º10’00” 15º16’00” C K6 54º15’24” 15º32’00” C DR 54º27’00” 16º20’00” C P16 54º38’00” 16º48’00” C LP 54º41’00” 17º02’00” CŁ7 54º50’00” 17º32’06	Coastal zone (acc. to HELCOM definition)-central Polish coast	1999–present	COMBINE	2004–2006* 1999–2003 2004–2006 1999–2003 2004–2006 1999–2003	COMBINE			IMWM (Elzbieta Lysiak-Pastuszak)
C SW3 53º56’53” 14º15’47” C SK 53º59’00” 14º30’00” C DZ6 54º02’30” 14º43’00”	Pomeranian Bay	1999–present	COMBINE	1999–2003	COMBINE			IMWM (Elzbieta Lysiak-Pastuszak)
2GD 19.1E-54.6N	Gulf of Gdansk	1978–1984 2004	Acetone extraction, Spectrophot./ Fluorometer			1978–1984	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)

Station	Area	Chlorophyll *a*		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
92A 18.666E-54.833N	Gulf of Gdansk	1987–1991	Acetone extraction, Spectrophot./ Fluorometer			1987–1991	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P1 19.333E-54.833N	Gulf of Gdansk	1977–2006	Acetone extraction, Spectrophot./ Fluorometer			1977–2006	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P110 19.116E-54.5N	Gulf of Gdansk	1983	Acetone extraction, Spectrophot.			1983	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
5–10 stations	Gulf of Gdansk	2003–2006	Acetone extraction, Fluorometer			2003–2006	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
ZP	Puck Bay	1978–1981	Acetone extraction, Spectrophot.			1978–1981	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P2 18E-55.3N	Gulf of Gdansk, Southern Baltic	1983–1984	Acetone extraction, Spectrophot.			1983–1984	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P40 18.6E-55.633N	Gulf of Gdansk, Southern Baltic	1983–1986	Acetone extraction, Spectrophot.			1983–1986	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
R6 18.442E-54.958N	Gulf of Gdansk Southern Baltic	1987–1989	Acetone extraction, Fluorometer			1087–1989	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P140 18.4E-55.55N	Southern Baltic	1987–1999 2004	Acetone extraction, Spectrophot./ Fluorometer			1987–1999 2004	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)

Station	Area	Chlorophyll a		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
Gt1 18.433E-55.6N	Southern Baltic	1977–1991	Acetone extraction, Spectrophot./ Fluorometer			1977–1991	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
5 – 10 stations	Southern Baltic (Polish EEZ)	2004–2006	Acetone extraction, Fluorometer			2004–2006	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
B1 15.75E-55.333N	Bornholm Sea	1977–1978	Acetone extraction, Spectrophot.			1977–1978	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
IBY5 15.983E-55.233N	Bornholm Sea	1986–1991 2004–2006	Acetone extraction, Spectrophot./ Fluorometer			1986–1991 2004–2006	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
B2 17E-55.2N	Slupsk Furrow	1977–1978	Acetone extraction, Spectrophot.			1977–1978	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
B3 18E-55.333N	Slupsk Furrow	1977–1983	Acetone extraction, Spectrophot.			1977–1983	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
B4 16.5E-55.283N	Slupsk Furrow	1977–1988	Acetone extraction, Spectrophot.			1977–1988	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
P5 16.983E-55.24N	Slupsk Furrow	1983–1998	Acetone extraction, Spectrophot./ Fluorometer			1983–1998	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)

Station	Area	Chlorophyll *a*		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
B12 14.416E-54.333N	Pomeranian Bay	1983	Acetone extraction, Spectrophot.			1983	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
4 15.1E-54.55N	Pomeranian Bay	1996–1997	Acetone extraction, Fluorometer			1996–1997	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
27 14/427E-54.067N	Pomeranian Bay	1996–1997	Acetone extraction, Fluorometer			1996–1997	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
31 14.342E-54N	Pomeranian Bay	1996–1997	Acetone extraction, Fluorometer			1996–1997	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
38 14.262E-53.947N	Pomeranian Bay	1979–1982 1996–1997	Acetone extraction, Spectrophot./ Fluorometer			1979–1982 1996–1997	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
49 14.138E-54.226N	Pomeranian Bay	1996–1997	Acetone extraction, Fluorometer			1996–1997	C-14 *in situ*, C-14 incubator	SFI Gdynia (Mariusz Zalewski)
20°33’-21°09’E 54°55’-55°10’N	Curonian Lagoon (zone of Russia)	1992–2006 Seasonally (from 1992 to 1994) and monthly (from 1995 to 2006) from April to October–November	Extraction, fluorescent method, 10-12 stations	1992–2006 Seasonally (from 1992 to 1994) and monthly (from 1995 to 2006) from March to October–November	Formaline fixation, 5-12 stations	2001–2006 (monthly from April to October–November)	Oxygen modification of the bottle method, 5–6 stations	AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°00’-22°00’E 54°30’-58°00’N	Baltic Sea economic zone of Russia			May 1992, fixation41 stations, 219 samples	Formaline			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)

Station	Area	Chlorophyll a		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
17°00'-21°30'E 54°30'-58°00'N	Baltic Sea economic zone of Russia			October 1992, 144 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°10'-19°50'E 54°30'-55°40'N	Baltic Sea economic zone of Russia			March 1993, 13 stations, 59 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
18°50'-20°40'E 54°30'-56°30'N	Baltic Sea economic zone of Russia			April – May 1993, 42 stations, 200 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°00'-21°20'E 54°30'-58°30'N	Baltic Sea economic zone of Russia	October 1993, 45 stations		October 1993, 104 stations (304 samples)	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°00'-21°30'E 54°30'-57°30'N	Baltic Sea economic zone of Russia	March 1995, 30 stations						AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
18°30'-21°00'E 54°30'-57°30'N	Baltic Sea economic zone of Russia			March 1996, 11 stations, 33 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
18°30'-21°00'E 54°30'-57°30'N	Baltic Sea economic zone of Russia			October 1996, 10 stations, 30 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°00'-21°00'E 54°30'-56°00'N	Baltic Sea economic zone of Russia			March 1997, 17 station, 51 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
18°30'-21°00'E 54°30'-57°30'N	Baltic Sea economic zone of Russia			October 1997, 12 stations, 36 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)

Station	Area	Chlorophyll a		Phytoplankton biomass/species composition		Primary productivity		Data originator
		Period covered	Method used	Period covered	Method used	Period covered	Method used	
19°00’-20°00’E 54°30’-56°20’N	Baltic Sea economic zone of Russia			October 1996, 11 stations, 33 samples	Formaline fixation			AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
19°20’-20°53’E 54°45’-55°35’N	Baltic Sea economic zone of Russia	May 2003 July 2003 October 2003 March 2004 May 2004 July 2004 October 2004 March 2005 May 2005 July 2005 October 2005 March 2006 July 2006 October 2006	17–23 stations (54–80 samples)	May 2003 July 2003 October 2003 March 2004 May 2004 July 2004 October 2004 March 2005 May 2005 July 2005 October 2005 March 2006 July 2006 October 2006	14–16 stations (49-54 samples)	May 2003 July 2003 October 2003 March 2004 May 2004 July 2004 October 2004 March 2005 May 2005 July 2005 October 2005 March 2006 July 2006 October 2006	10–21 stations	AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
14°04’-26°59’E 54°32’-60°08’N	Baltic Sea from Gulf of Finland to territorial waters of Germany	October 2005	89 stations, 134 samples	October 2005, 59 stations, 59 samples	Fixed in Lugol’s solution	October 2005, 15 stations (180 samples)	Radiocarbon modification of the bottle method	AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
14°31’-26°32’E 54°37’-60°03’N	Baltic Sea from Gulf of Finland to economic zone of Germany	April–May 2006	54 stations, 111 samples	April–May 2006, 39 stations, 48 samples	Fixed in Lugol’s solution	April–May 2006	19 stations, 228 samples	AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)
14°31’-26°54’E 54°37’-60°07’N	Baltic Sea from Gulf of Finland to economic zone of Germany	July–August 2006	47 stations, 92 samples	July–August 2006, 38 stations, 47 samples	Fixed in Lugol’s solution	July–August 2006	15 stations, 180 samples	AtlantNIRO (Sergej Aleksandrov, Svetlana Semenova, Olga Dmitrieva)

STATION	AREA	CHLOROPHYLL A		PHYTOPLANKTON BIOMASS/SPECIES COMPOSITION		PRIMARY PRODUCTIVITY		DATA ORIGINATOR
		PERIOD COVERED	METHOD USED	PERIOD COVERED	METHOD USED	PERIOD COVERED	METHOD USED	
Several predominantly coastal stations	Gulf of Finland	1969–present		1966–present	Utermöhl, oldest keefe solution fixation and afterwards Lugol			Marjut Rasanen, City of Helsinki Environment Centre
	Baltic Proper	1979–present, older data not digitized	Reported to HELCOM database	1979–present, older data not digitized	Reported to HELCOM database	1979–present, older data not digitized	Reported to HELCOM database	Susanna Hajdus, Stockholm University

Annex 7: Baltic productivity indicator case study

Baltic productivity indicator case study - testing approaches to assess Baltic marine primary productivity

Michael Olesen, Lars Edler and Bärbel Müller-Karulis

How to describe productivity

What do we mean with the term *productivity*? If we use a system approach a straight forward definition of productivity can be defined as of much organic produced matter which can be "harvested" from a system on a regular basis (crop approach).

The concept of new production determining the carrying capacity of marine pelagic system has been introduced in the 1960s by Dugdale and Goering (Dugdale and Goering, 1967) and has since then been applied to many pelagic marine ecosystem. Eppley and Petersen (1979) expanded this concept and introduced the idea of using export production as proxy for new production. According to this definition new production, and therefore the harvestable part of system productivity, is identical to the export of autochthonous organic matter from the euphotic zone over time frames long enough to represent steady state between production and export. For stratified systems the exported "crop" usually sinks below the upper mixed layer (Figure 1) or is channelled into pelagic top predator biomass which then in turn is removed from the system. A third way of loss may be due horizontal or vertical flow, where entrainment and advection moves production from productive areas to less productive areas. This will especially be a feature of coastal systems or of front and up/downwelling systems. These systems are usually characterized by strong horizontal or vertical gradients with respect to biomass. Independent of its loss mechanism, autochthonous matter leaves the euphotic zone is considered as "export production".

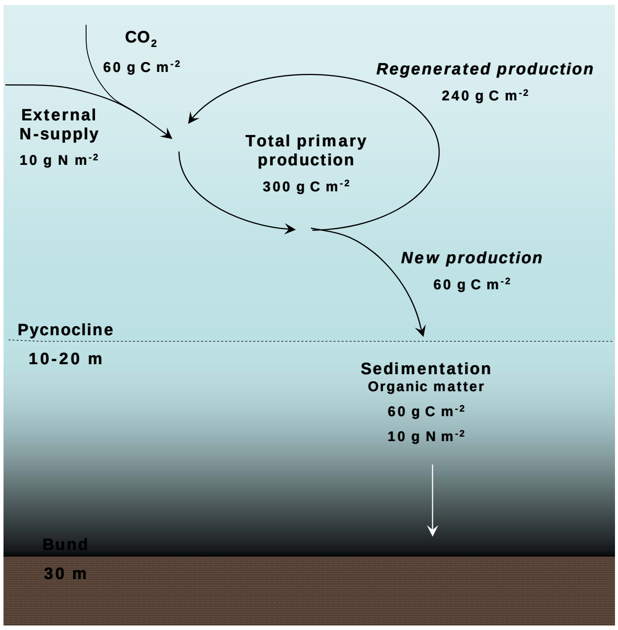

Figure 1. Diagram showing the tight quantitative relation between nutrient supply and export of organic matter, i.e. sedimentation. The example is from the seasonal outcome of primary production in the Kattegat (Mar.–Nov.). In stratified waters inorganic nutrients limiting primary production will fast be incorporated into organic matter. Some of these nutrients are remineralised within the mixed layer and will nourish an additional production. Primary production based on external nutrients is called new production whereas primary production based on local remineralized nutrients is called regenerated production.

Over time export production will necessarily equalize the import of elements associated this amount of organic matter removed (Figure 1). This mean that the harvestable parts of primary production (export production) must be tightly coupled to the import of limiting nutrients to the eupotic zone (Platt *et al*., 1989). Primary production based on the external supply of nutrients is also known as new production (sensu Epply and Petersen 1979). Because elements in biomass within certain limits is stoichiometric related one another, the least available of the essential elements (relative to this stoichiometry), determines the size of the achievable biomass (Liebig's law of the minimum). The maximum potential phytoplankton biomass that can be attained in light saturated systems is therefore given by the availability of limiting nutrient at any time. This upper level can be seen as the ecological carrying capacity of the system.

For non-stratified marine systems a definition of system productivity is more subtle. The reason is that in such systems there is no clear spatial separation between where growth takes place and where produced matter is remineralised. This implies that the classical partition of primary production into new and regenerated becomes less obvious. Therefore quantifying the export production of non-stratified systems is more difficult than of stratified systems. Even when the benthic community is included as part of the system delimitation, the export of organic matter will not necessarily reflect the external supply of nutrients to the system. A fraction of the organic bounded nutrients will be lost again as inorganic nutrients due to denitrification or remineralisation during the non-productive part of the year.

Measuring export production

Since system productivity is closely related to the input of limiting nutrients during the productive period, it should be obvious to quantify the potential export production by measuring the external nutrient supply. This is however extremely difficult since it require a hardly attainable knowledge of the horizontal flow, vertical entrainment and atmospheric deposition of nutrient to the system. A better way is to measure the vertical flux of particulate organic matter. In open marine systems usually most of the export production (> 95%) sooner or later will sink from the euphotic zone. If used carefully sediment trap therefore provides a good technique for achieving an integrate expression of export production.

How regenerated production is governed

As described the overall amount of export production is a result of the external load of limiting nutrients to the system during the productive period. Hence, system productivity is almost entirely given by outer physical conditions governing the supply of nutrients to the system and thereby determining the outcome of organic matter. In other words: As long growth is nutrient limited (which usually is the case for the mixed layer of stratified systems) the trophic structure *per se* of the mixed is of minor importance for the quantity of organic matter that can be harvested or exported from the system. The biological structure and composition of organism, however, is crucial for the turn-over and quality of this matter. Primary production will either sink out of the euphotic zone as intact cells or be channelled to higher trophic levels within the mixed layer. Some of the organic matter channelled through the pelagic food chain will be remineralized within the euphotic zone. Nutrients associated this remineralized organic matter are readily reassimilated by phytoplankton and thus nourish an additional primary production. This fraction of primary production based on internal remineralized nutrients is called regenerated production. While new production is a result of the external supply of nutrients, regenerated production is entirely a result of the internal biological structure of the system.

How to express new and regenerated production for stratified systems in a simple mathematical way

TPP= total primary production

NPP= new production = export production ≡ import of limiting nutrients ≈ sedimentation of autochthonous organic matter

RPP= regenerated production

Note that new production represents the external supply of limiting nutrients and thus represent the carrying capacity of the system, i.e. achievable biomass of the system. During the productive season the mayor part of export production leaves the mixed layer via sedimentation.

TPP = NPP + RPP

Since regenerated production is proportional to the turn-over of organic matter and remineralisation of limiting nutrient, RPP can be expressed as:

RPP = μ RT NPP,

where μ is the community remineralisation rate (t^{-1}) and RT the retention time of limiting nutrient (t), while NPP as mentioned express the amount of limiting nutrient supplied.

Note that μ RT (= RPP/NPP) express the number of times the limiting nutrient are recycled within the system before it again is lost from the productive layer

TPP = NPP (1 + μ RT)

How is the partitioning of export production between sinking and pelagic fish production?

It has earlier been stated that sedimentation usually makes up > 95 % of new/export production and that only a few percent goes to fish production (Figure 2)

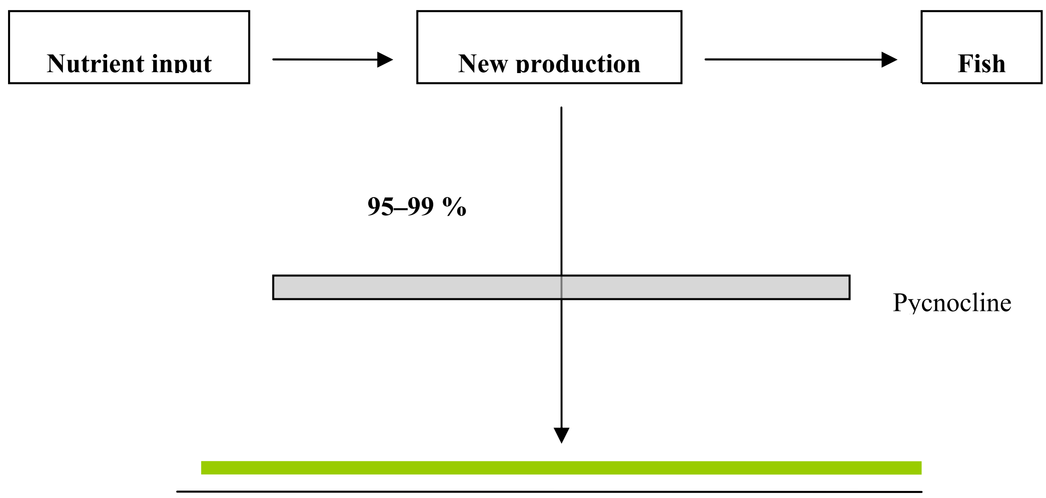

Figure 2. Diagram showing the partitioning of the export production for most stratified systems. Less than 5 % of the new production over time goes to higher trophic levels of the pelagic foodweb, whereas the main part feeds the benthic system

Comparing the ratio of fish landing to new production in different Baltic systems with the famous fish area off Peru shows quite surprisingly that the ecological transfer efficiency is higher in the Baltic (Table 1).

Table 1. New production and pelagic fish production in different part of the Baltic in comparison with the Peruvian upwelling system.

	AREA KM2	NEW PRODUCTION G C M^{-2} Y^{-1}	LANDINGS OF PLANKTIVOROUS FISH X1000 T C/Y	ESTIMATED PELAGIC FISH PRODUCTION X1000 T C/Y	ECOLOGICAL TRANSFER EFFICIENCY (%)
Kattegat/Skagerak	60.000	42 (Stigebrant 1991)	11.3 (2001–2003)	34	1.35
Baltic Sea	275.000	29 (Wassmund *et al.*, 2001)	54.6 (2001–3)	154	1.93
Gulf of Riga	35.000	40 (Olesen *et al.*, 1999)	9.0 (2001–2003)	27	1.93
Peruvian upwelling system	220.000 (max 1997-99)	1100 (Nixon and Thomas, 2001)	1000 (max. 1961–1972)	3000	1.24

Even though the benefit of the export production for pelagic fish seems small a difference from one to two percent has a tremendous consequence for the fish production of a system. However, since only a few percent of the new production over time is left for higher trophic levels of the pelagic food web, obviously a direct correlation between the nutrient load and pelagic fish production must be difficult to identify. Nevertheless, an apparent higher ecological efficiency in the Baltic Sea than in upwelling systems, where the classical food chain prevails, 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 food webs (Table 2).

Table 2. The relation of new and total primary production in different part of the Baltic Sea region, reflected in the so call *f*-ratio.

	AREA KM^2	NEW PRODUCTION G C M^{-2} Y^{-1}	TOTAL PRIMARY PRODUCTION G C M^{-2} Y^{-1}	*F*-RATIO
Kattegat/ Skagerak	80.000	42 (Stigebrant, 1995)	200-300 (Richardson 1992)	0.14 - 0.21
Baltic Sea	275.000	29 (Wassmund *et al.*, 2001)	175-255 (Wassmund *et al.*, 2001)	0.11 - 0.16
Gulf of Riga	35.000	40 (Olesen *et al.,*1999)	350 (Olesen *et al.*, 1999)	0.11
Peruvian upwelling system	220.000 (max 1997-1999)	1100 (Nixon and Thomas, 2001)	1200 (Nixon and Thomas, 2001)	0.92

The composition autotrophs and heterotrophs so to say determine how efficient nutrients are retained and remineralised in the system. The trophic structure does not only determine the magnitude of regenerated production, but also have an impact of how much of the organic production that is channelled to fish biomass. Even thought the more detailed mechanism behind this relationship is still quite unknown there seem to be a correlation between the *f*-ratio of stratified systems and the partitioning of new/export production between the benthic system and pelagic fish production. Conclusively assessing productivity of a system must involve knowledge of both new and regenerate production.

New and regenerated production in the Baltic

In the Baltic Sea the situation is further complicated by the strong seasonality of mixing and primary production, as well as by the presence of nutrient rich bottom waters at relatively shallow depth, e.g., in the Kattegat. During the light-limited winter period, nutrients accumulate in the water column and are later consumed during the phytoplankton spring bloom. Physical conditions during the bloom (mixing, onset of stratification) determine both the intensity and duration of the bloom as well as the amount of nutrients remaining below the forming thermocline. Therefore the spring bloom, which to a large extend sediments out of the euphotic zone, not only influences the organic matter supply to deeper water layers and to the benthic ecosystem, but affects also the nutrient partitioning between the spring and summer phytoplankton communities. Thus the spring bloom also impacts new and regenerated production during the stratified summer period.

Transfer efficiency to higher trophic levels in the Baltic

In addition, the ecological transfer efficiency to higher trophic levels in the Baltic is not only bottom-up controlled by the supply of new nutrients, but also affected by "top-down" controls as well as by physical controls. Commercial fish stocks are to a large degree controlled by fisheries. In addition, fish are long-lived organisms and short-term fluctuations in their stocks are often influenced by the occurrence of strong year classes, i.e. years with good conditions for recruitment (e.g. cod, herring, sprat). The peak of a strong year class is visible over a period of several years and represents the long-term memory of top-down control in the Baltic ecosystem.

Physical processes, i.e. fluctuations in temperature and especially salinity, represent an additional control for the ecological transfer efficiency to higher trophic levels in the Baltic. For example, salinity in the halocline region affects the biomass of the marine copepod *Pseudocalanus acuspes* in the Baltic Proper, which is in turn a preferred food item for Baltic planktivores.

Baltic productivity case study

We propose to conduct a case study to investigate a) the role of new/regenerated production for the ecological transfer efficiency to higher trophic levels in the Baltic Sea and its control mechanism, b) test the sensitivity of the suite of productivity indicators proposed earlier (ICES 2005, ICES 2006) to the amount of organic matter transferred between different food web levels, c) propose measurement methods for new and regenerated production in the Baltic.

The case study will use published information on productivity and foodwebs in several sub-systems of the Baltic Sea (e.g. Kattegat, Baltic Proper, Gulf of Riga) an develop hypothesis to explain the partitioning of total primary production into new and regenerated production as well as for the differing ecological transfer efficiencies. The role of different controls and the sensitivity of different productivity indicators will be further analyzed by means of a simple, semi-quantitative dynamical food web model. Indirect effects will be studied by network analysis tools (e.g. Schramski *et al*., 2007 for a recent publication).

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Annex 8: Zooplankton indicators

Summer zooplankton dynamics in the Eastern Gotland Basin

Bärbel Müller-Karulis

Zooplankton dynamics in the Central Baltic Sea (Möllmann *et al.,* 2005, Möllmann and Köster, 2002) are affected by physical forcing (temperature, salinity) as well as by predation from herring and sprat. Simulation models imply that also primary producers have a significant impact on zooplankton dynamics because changes in primary productivity translate to the trophic levels of zooplankton and planktivorous fish (e.g. Hansson *et al*., 2007). The present analysis uses statistical methods (generalized additive models, Hastie and Tibshirani, 1986) to empirically clarify the relative importance of phytoplankton, top down controls (planktivorous fish) and physical forcing factors (temperature, salinity, oxygen) on the long-term dynamics of mesozooplankton in the Eastern Gotland Basin. Data analysis focuses on the summer season, because coupling between mesozooplankton and phytoplankton in the Baltic was expected to be most pronounced during the nutrient deplete stratified summer conditions. Representative for the total mesozooplankton community, its main species, *Temora longicornis, Acartia spp*., and *Pseudocalanus acuspes* were selected for statistical analysis. Except during mass development of the cladoceran *Bosmina coregoni maritima*, these three species represent approximately 70 % of the total summer mesozooplankton biomass. Zooplankton data were collected by the Latvian Fish Resources Agency from three transects in the Latvian Economic Zone of the Eastern Gotland Basin.

Temora longicornis and *Acartia spp*. live in the upper part of the water column in the Baltic, while the adult stages of *Pseudocalanus acuspes* populate the halocline region in the central basins (Hansen *et al*., 2005). Accordingly, physical factors (temperature, salinity, oxygen) were selected to describe the ambient conditions in the potential habitat layers (0 – 20 m and 40–60 m for *Acartia* and *Temora*, 80 m for *Pseudocalanus*). Alternatively, since little is known whether *Pseudocalanus* follows the deepening halocline during Baltic stagnation periods, also temperature, oxygen concentrations and depth of the 10 PSU isohaline, which is located around 80 m depth under regular saline water inflow regimes, were used in the modeling of *Pseudocalanus*. Primary producers were characterized by chlorophyll *a* concentrations in the 0 – 20 m layer, as well as by particulate nitrogen concentrations. Also winter DIN was used as a proxy for the productivity conditions, but showed no significant correlation with mesozooplanton. All oceanographic, nutrient and phytoplankton parameters were taken from the ICES oceanographic database (www.ices.dk). Predation by planktivorous fish was included into the analysis as the ICES stock assessment estimates for sprat and herring, as well as for sprat recruitment. Sprat recruitment data (number of one-year-old at the beginning of each year) were lagged to the year in which the recruits were spawned. Herring recruits were not included into the analysis since herring spawns in coastal areas during spring and juveniles were not thought to have reached the Eastern Gotland Basin until the time of zooplankton sampling in August. All modelling runs also included the respective spring zooplankton biomass, but correlations between spring (May) and summer (August) biomasses were not significant.

Both generalized additive models (GAM) and general linear models (GLM) were used to describe the 1974–2005 mesozooplankton dynamics. All models used a Gaussian error distribution with a log-link function and were implemented in R, using the mgcv package (Wood, 2006, 2007) for GAM and GLM parameter estimation. In contrast to GLM, which fit linear relationships between target variable and independent variables, GAM use non-linear smoothing functions. The "wigliness" of the smoothing function is optimized by the fitting routine, but the number of knots was restricted to three to avoid overfitting.

Temora longicornis

The summer biomass of *Temora longicornis* was best represented by a model using salinity in the 40–60 m layer, summer chlorophyll *a*, herring SSB, sprat SSB, sprat recruits and *Pseudocalanus* biomass as predictors implemented by GAM smoothers (Temora ~ s(salinity$_{40-60}$)+s(summer chlorophyll)+s(herring SSB)+s(sprat SSB)+s(sprat recruits)+s(Pseudocalanus), link=log). All independent variables except sprat SSB were significant on the 0.05 or 0.1 (*Pseudocalanus*) level and overall model fit was R^2_{adj} = .64. However, a closer analysis of the model terms showed that the model postulated that the predation impact by herring on *Temora* was by an order of magnitude larger than the effect of sprat and sprat recruits. In the model, the large negative effect herring was offset by a positive effect of salinity on *Temora*. As both sprat and herring are known to predate on *Temora* (e.g. Möllmann *et al.*, 2004, 2005; Möllmann and Köster, 2002), and because salinity fluctuates only in the narrow range 6.9–8.0 PSU, this model structure seemed not plausible. Salinity in 40–60 m depth shows a strong negative correlation with herring SSB (R^2_{adj} =.70), therefore the modeled effects of both predictors tended to compensate each other. This effect was removed by using the residuals of the salinity-herring correlation as input variable to the Temora model (Temora ~ s(residual salinity$_{40-60}$)+s(summer chlorophyll)+s(herring SSB)+s(sprat SSB)+s(sprat recruits)+s (Pseudocalanus), link=log). The resulting residual salinity time series is uncorrelated to herring SSB and prevents the compensating effect of the herring-salinity autocorrelation in the model output. As the type of information supplied to the model did not change, this did not affect the model fit and the significance of input parameter time series. However, now the model attributes grazing pressure to both adult herring as well as to sprat recruits (Figure 1 right). The fitted model attributes the increase in *Temora* biomass during the 1980s mainly to a release of herring predation, while the sprat stock was still low. Starting from the mid 1990s, fluctuations in *Temora* were mainly explained by years with high sprat recruitment or high sprat stock. The salinity residuals still had a significant impact on *Temora* dynamics, especially during the 1980s and early 1990s. High absolute values of the salinity residual correspond to low salinity "spikes" in the time series, which might be caused by the mixing dynamics of surface and deep water. High residuals correspond to comparatively low salinity and are reflected by depressed *Temora* biomass, e.g. in 1988 and 1994. A potential causal chain to explain this effect is that low mixing prevented nutrient replenishment of the surface water, led to lowered primary production and in turn affected zooplankton biomass.

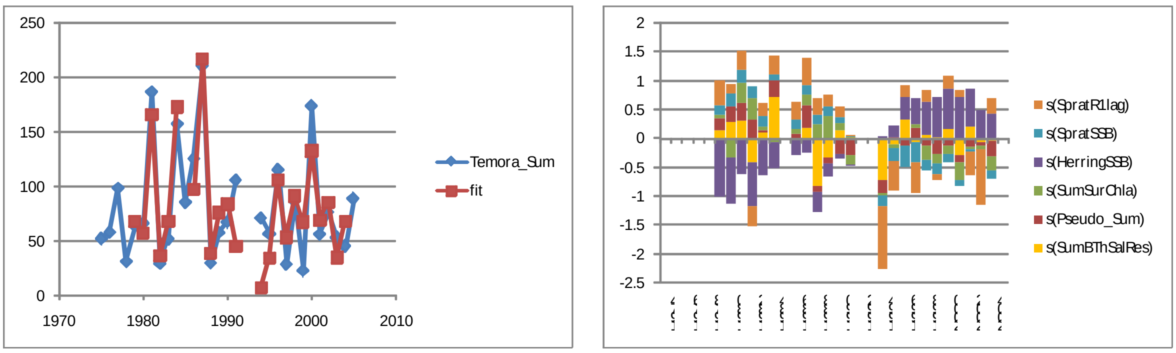

Figure 1. Modelled and measured *Temora* biomass (mg m^{-3}, left panel) and predictors contributing to the model fit (right panel).

The slopes of the smoothing functions (Figure 2) show, that the model regards adult herring and sprat recruits as the main zooplankton grazers, followed by a smaller impact of adult sprat. Correlation with chlorophyll *a* is negative, indicating grazing control of phytoplankton during summer. *Pseudocalanus* biomass in turn showed a positive co-variance with *Temora*. This indicates that high biomass of the preferred herring and sprat food item *Pseudocalanus* partially counteracts the predation pressure on *Temora*. Temperature correlations (both summer temperature in the 40–60 and 0–10 m layer as well as winter SST) were not significant for the summer dynamics of *Temora* biomass.

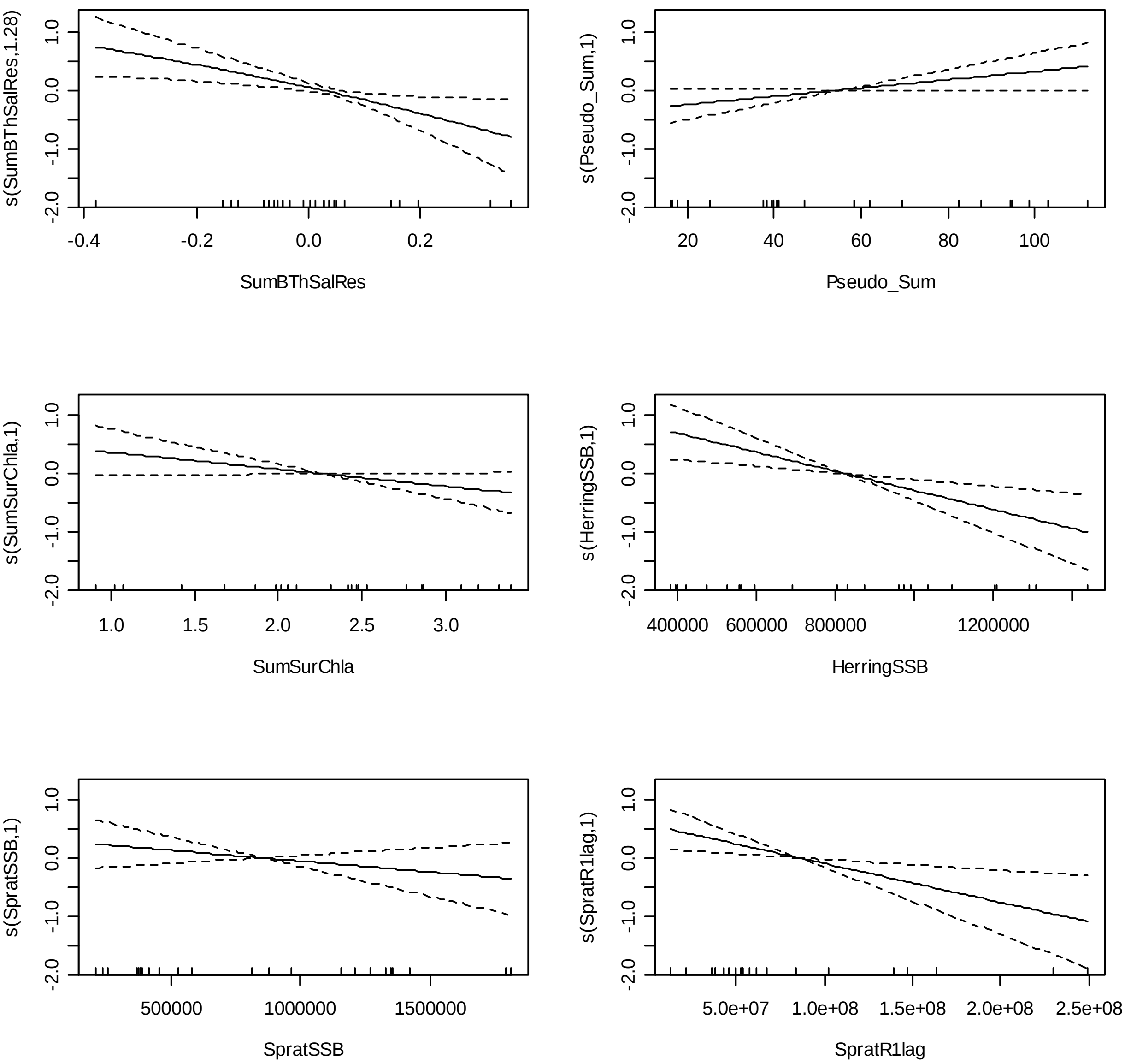

Figure 2. *Temora longicornis* GAM smoothing functions for residual salinity in the 40 – 60 m layer (top left), *Pseudocalanus acuspes* biomass (top right), surface layer chlorophyll a concentration (middle left), herring SSB (middle right), sprat SSB (bottom left) and sprat recruits (bottom right).

Upper layer copepods

The same parameter set was also used to model the combined biomass of *Temora* and *Acartia spp.* (Temora + Acartia ~ s(residual salinity$_{40\text{-}60}$)+s(summer chlorophyll)+s(herring SSB)+s(sprat SSB)+s(sprat recruits)+s(Pseudocalanus), link=log). All input parameters were significant on the 0.01 or 0.1 (Sprat SSB) probability level, after excluding years 1994 and 2003 with extremely high sprat recruitment (R^2_{adj}=.79). This implies that the dynamics of copepods in the upper part of the water column is driven both by changes in hydrography ("salinity spikes") and predation by planktivores, which was partially set off by the abundance of *Pseudocalanus acuspes* as preferred food item (e.g. Möllmann *et al.*, 2004; Möllmann and Köster, 2002). In turn, the copepods in the upper part of the water column exerted significant predation pressure on phytoplankton. Temperature signals were not significant for explaining the summer biomass of the combined upper layer copepod biomass.

Acartia spp.

Acartia spp. was fitted best with a similar parameter set than *Temora*, except that values for physical parameters from the 0–20 m layer provided a slightly better fit. To remove the salinity – herring autocorrelation (R^2_{adj}=.58), salinity residuals were used as independent variable (Acartia ~ s(residual salinity$_{0\text{-}20}$)+s(summer chlorophyll)+s(herring SSB)+s(sprat SSB)+s(sprat recruits)+s(Pseudocalanus), link=log). Sprat recruitment had only significant impact on the model result during two years with extremely high recruitment, 1994 and 2003. Both years were removed from the model as outliers. In contrast to *Temora*, no significant relations between *Acartia spp.* biomass and summer chlorophyll *a* were found and planktivore predation is attributed to adult herring and adult sprat (Figures 3 and 4). The release of predation pressure by *Pseudocalanus* is indicated by the model, but not statistically significant.

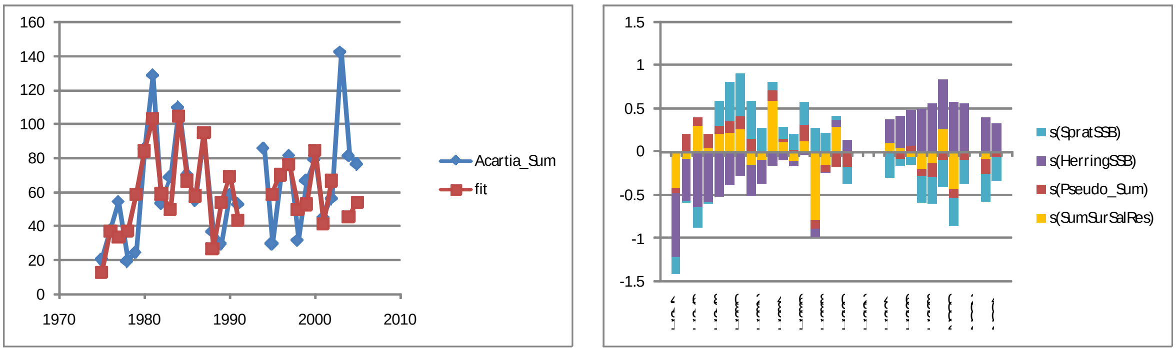

Figure 3. Modelled and measured *Acartia spp.* biomass (mg m^{-3}, left panel) and predictors contributing to the model fit (right panel).

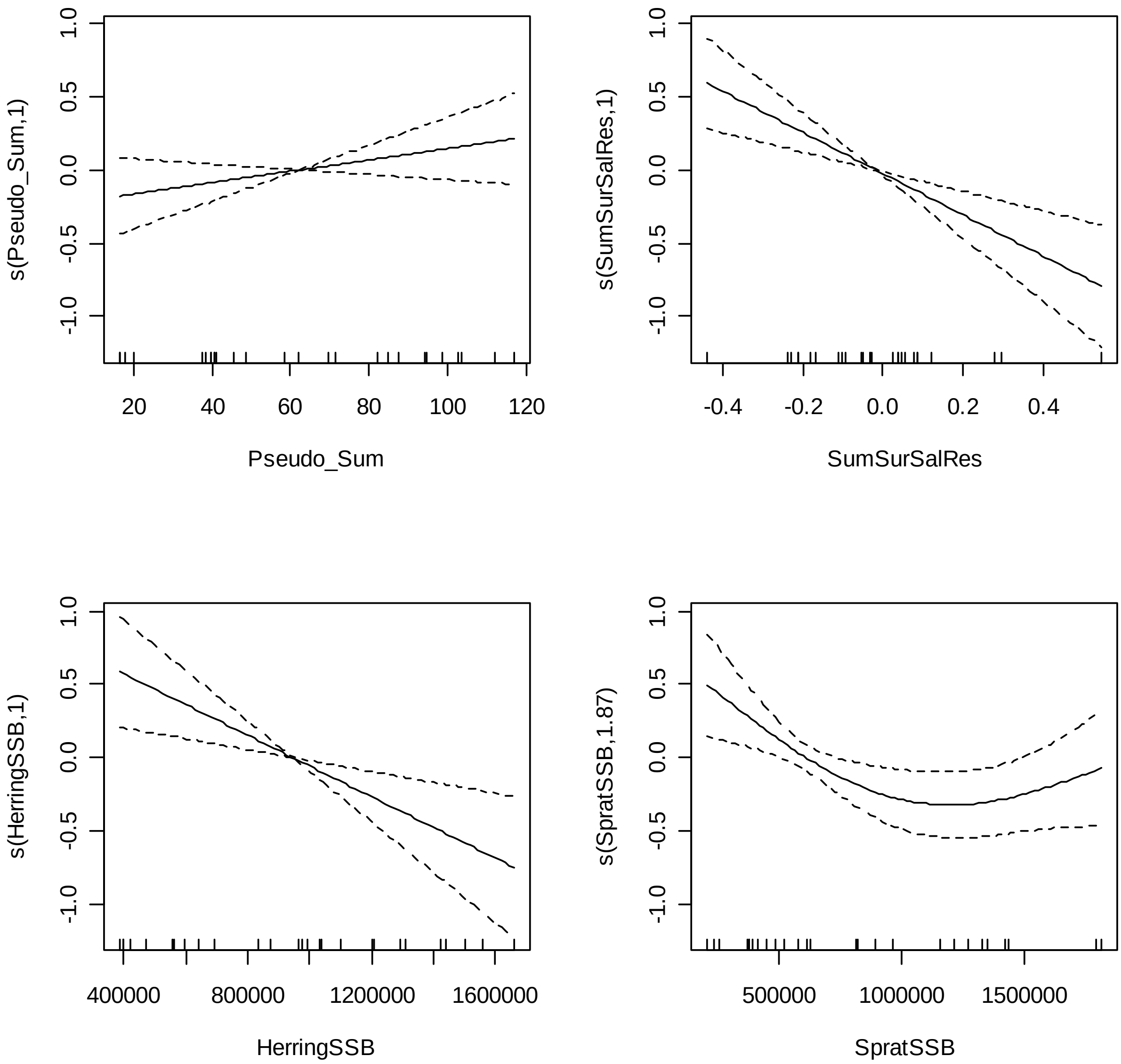

Figure 4. *Acartia spp.* GAM smoothing functions for *Pseudocalanus acuspes* biomass (top left), residual salinity in the 0–10 m layer (top right), *Pseudocalanus acuspes* biomass (top right), surface layer chlorophyll a concentration (middle left), herring SSB (bottom left), and sprat SSB (bottom right).

Pseudocalanus acuspes

The adult stages of *Pseudocalanus acuspes* live in the halocline region of the Eastern Gotland Basin. If the 80 m layer is thought representative of its physical environment, only weak correlation was found between herring biomass and salinity (R^2_{adj}=.11). Consequently, no adjustments were made to remove the herring – salinity autocorrelation. Physical factors at the 10 PSU isohaline performed slightly better than those in fixed depth (80 m) and *Pseudocalanus acuspes* dynamics were best described by depth of the 10 PSU isohaline, oxygen content at 10 PSU, sprat SSB and herring SSB (Pseudocalanus ~ s(10 PSU depth)+s(10 PSU oxygen)+s(herring SSB)+s(sprat SSB), link=log). The model fits the data well (R^2_{adj}=.60, Figure 5 left), but significance levels for all independent parameters were low except for sprat SSB, which was significant at p<0.1. The model attributes the decline in the

Pseudocalanus biomass to mainly to the deepening of the 10 PSU isohaline during the end of the 1980s. Low oxygen levels at the 10 PSU isohaline contributed to the decline but were only of subsequent importance. A plausible explanation for the large adverse effect of low 10 PSU depths on *Pseudocalanus* could be declining food quality with increasing distance to the productive layer, but could also be attributed to undersampling of *Pseudocalanus* in this depth range. Based on lipid biomarkers, *Pseudocalanus* in the Baltic was characterized as an opportunistic feeder that consumes sinking phytoplankton, detritus and microzooplankton (Peters *at al.* 2006). At least for sinking phytoplankton and detritus a decline in food quality during sinking is to be expected. The smoothing functions (Figure 6) show an interesting relationship between *Pseudocalanus* and planktivorous fish. While sprat is depicted as a predator, herring SSB is positively related to *Pseudocalanus* biomass. This implies, that herring is not able to control *Pseudocalanus* biomass, but on the contrary, that *Pseudocalanus* has a noticeable bottom-up effect on herring stock. Dependence of herring condition on *Pseudocalanus* as food source has been previously demonstrated by Möllmann *et al*. (2005).

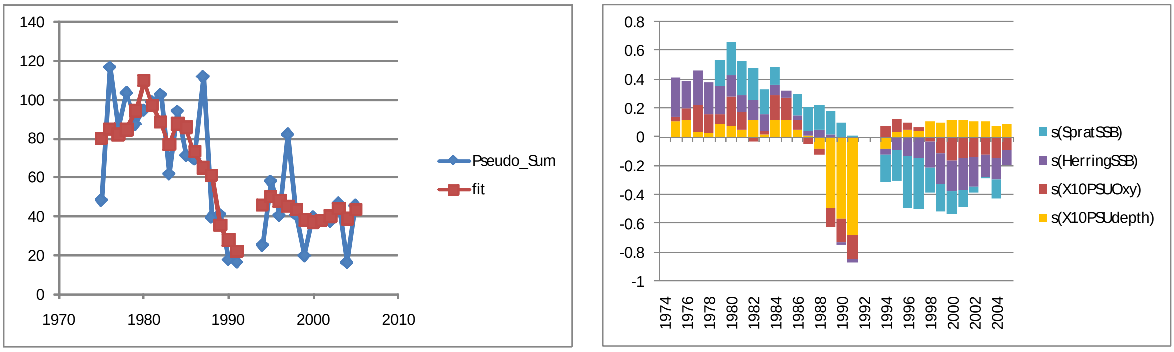

Figure 5. Modelled and measured *Pseudocalanus acuspes* biomass (mg m^{-3}, left panel) and predictors contributing to the model fit (right panel).

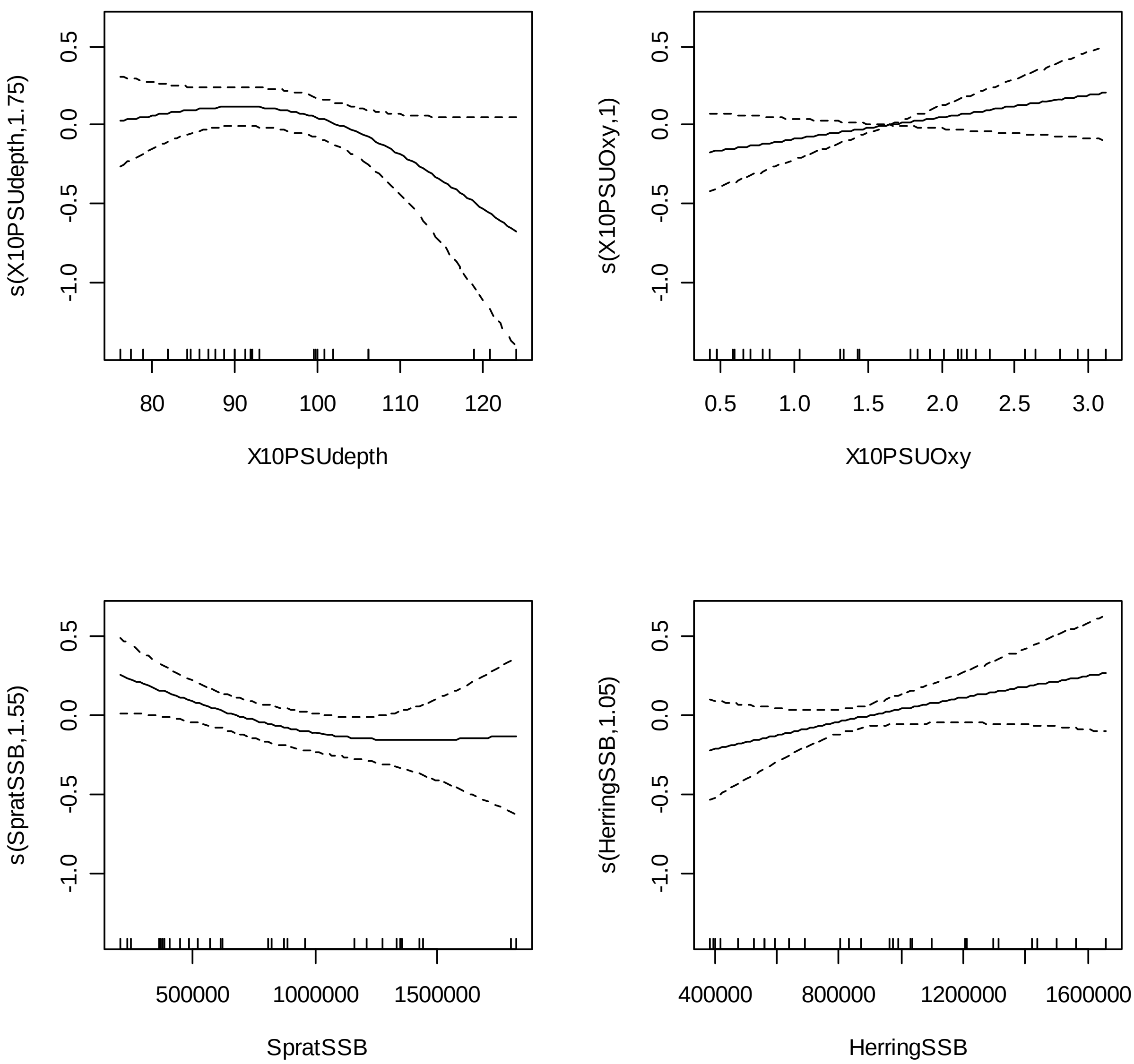

Figure 6. *Pseudocalanus acuspes* GAM smoothing functions for depth of the 10 PSU isohaline (top left), oxygen content at 10 PSU (top right), sprat SSB (bottom left), and herring SSB (bottom right).

Summary

The current analysis found significant clupeid predation on the summer zooplankton community (*Acartia*, *Temora*) in the upper part of the water column in the Eastern Gotland basin. Temperature appeared not to have a significant effect on upper layer zooplankton in summer. For *Temora*, a significant positive relationship with chlorophyll *a* suggested also partial bottom-up control by the summer phytoplankton dynamics. Halocline zooplankton (*Pseudocalanus acuspes*) was controlled by oceanographic conditions, especially by the deepening of the 10 PSU isohaline during the end of the 1990s, as well as by sprat predation. In turn, *Pseudocalanus* had a positive effect on herring stocks.

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Gulf of Riga analyses

Piotr Margoński, Solvita Strake, and Georgs Kornilovs

During 2006 new analyses were carried out, but first of all emphasis was put on database reconstruction to create a longer time-series, especially regarding fish and fisheries: herring mean weight-at-age data were collected from trawl fishery of Estonia and Latvia (ICES WGBFAS Reports 2000 & 2006) and recruitment estimates from XSA analyses (ICES WGBFAS Reports 2000 & 2006).

Part of the hydrological data appeared to be strongly intercorrelated, e.g. surface vs. near-bottom temperature, surface vs. near-bottom salinity, which is a consequence of the lack of a permanent halocline in the gulf. A strong positive correlation was also found between winter air temperature and surface water temperature in May.

A series of single Spearman Rank Order Correlations between herring recruitment and mean weight-at-age vs. hydrological and zooplankton data series were carried out (Table 1 and 2).

Table 1. Spearman Rank Order Correlations with hydrological data, significant at p <.05.

	-NewHRec	-NewHweightA1	NewHweightA0
R2AirTem	0.473	NS	NS
R2Tem50	0.480	NS	NS
R5Tem20	0.672	NS	NS
R5Tem50	0.631	NS	NS
R8Tem20	**0.775**	NS	NS
R8Tem50	0.618	NS	NS
R10Tem50	NS	NS	NS
R2Sal50	-0.520	0.386	NS
R5Sal20	-0.650	0.461	NS
R5Sal50	-0.684	0.393	NS
R8Sal20	-0.675	**0.489**	NS
R8Sal50	**-0.726**	0.438	NS
R10Sal50	-0.660	0.384	NS

Table 2. Spearman Rank Order Correlations with zooplankton data, significant at p <.05.

	-NewHRec	-NewHweightA1	NewHweightA0
R5ACR	**0.581**	NS	NS
R8ACR	NS	NS	NS
R5EURY	**0.632**	NS	NS
R8EUR	**-0.398**	NS	NS
R5LIMN	**-0.333**	NS	NS
R8LIM	NS	NS	NS
R5NAUP	NS	NS	NS
R8NAUP	NS	**0.389**	NS
R5BOSM	**0.332**	NS	NS
R8BOS	NS	**0.339**	**0.424**
R5EVAD	NS	NS	**0.499**
R8EVA	**-0.440**	NS	**0.377**
R5POD	NS	NS	NS
R8POD	**-0.366**	NS	NS
R5SPTOT	**0.486**	NS	**0.410**

Herring recruitment was significantly correlated with all temperature and salinity time-series. Weight-at-age of age group 1 was related to salinity only and no correlation was found for a similar data for age group O.

Recruitment was highly and positively correlated with *Acartia* and *Eurytemora* spring biomass. Also a much weaker but positive relation to *Bosmina* spring biomass and total spring zooplankton biomass were found. In four cases negative relations were identified with different zooplankton (mostly summer) data series. Those were regarded as spurious correlations between time-series presenting opposite trends without a cause-effect relationship. Weight-at-age data were related to zooplankton biomass only in very few cases. A positive relation with summer nauplii biomass does not seem to be justified as herring early life history stages very quickly switch to larger food items.

Analyses taking into account a climatic indix were carried out as well, selecting the Winter Baltic Climate Index (WIBIX, Hagen and Feistel, 2005). WIBIX is based on monthly values of the first principal component of winter anomalies (January–March) in air pressure differences between Gibraltar and Reykjavik to describe the NAO, sea level anomalies at Landsort (Sweden) to characterize the filling level in the Baltic Proper, and maximum Baltic

Sea ice cover to include the influence of continentally dominated alignments of atmospheric action centers.

WIBIX itself explained more than 30% of the variance in herring recruitment, but we found found no significant correlations with herring weight-at-age (Figure 1). During severe continental winters (WIBIX < 0) we therefore may expect significantly lower recruitment of the coming herring year class.

After discussions at the SGPROD meeting it was decided that weight-at-age data taken from the ICES WGBFAS Reports do not describe herring condition best as they are yearly averages and only autumn data should be used in further analyses.

It was also decided that the next step would be search for successful a model with a combination of hydrological (or climatic) and zooplankton independent factors

Reference

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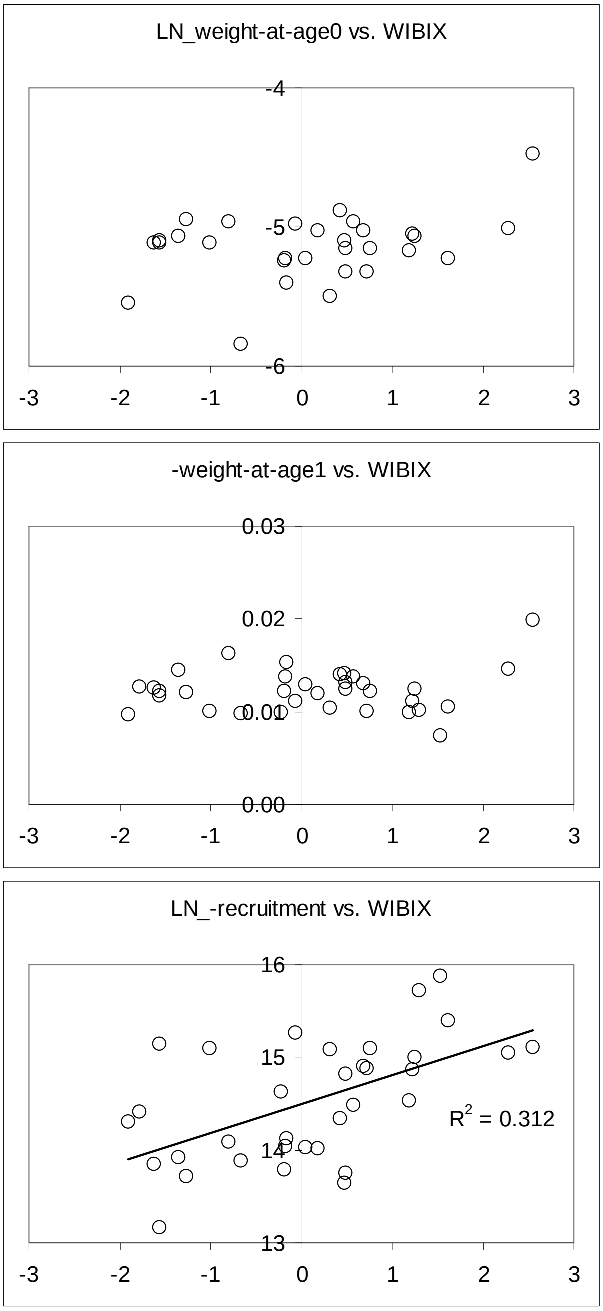

Figure 1. Herring weight-at-age and recruitment vs. WIBIX.

Gulf of Finland analyses

Arno Põllumäe

Available data

Long-term zooplankton samples are collected from three transects in Gulf of Finland since 1960s, there are 3–5 sampling stations per transect. However, zooplankton data before the 1974 are scarce and many ambient data are available only since the same year, so the real dataseries for analyses starts with 1974. For current analyses average zooplankton biomasses were calculated for each transect. Environmental factors for years before 1993 were obtained from the HELCOM monitoring database (ICES); data collected during the same month and within 1,5 longitude degree from transect were used to calculate monthly averages and connected to available zooplankton data. Since year 1993 ambient data were measured together with zooplankton sampling. Preliminary statistical analyses showed, that regional differences in zooplankton communities in the three transects are remarkable and using all three transects will cause large noise in the results. Therefore the transect from the central part of Gulf of Finland was chosen for further analyses, since this transect was best covered with zooplankton and environmental data and due to its central position in Gulf.

In a first step all fish-related parameters used for the Gulf of Finland analyses were taken from the Central Baltic Sea. Data of sprat and herring landings and average weight for Gulf of Finland were included later. However, the data series about herring is short for the Gulf of Finland and has strong correlation with the Central Baltic data. This applies also to sprat weight data. Only the trends of sprat landings in Gulf of Finland differ remarkably from those of the Central Baltic.

All zooplankton data and several other parameters were transformed prior analyses to improve normality.

Univariate analyses

For univariate analyses Pearson correlation coefficients were computed for zooplankton species and all available environmental parameters.

Correlation with fish

In spring the only crustaceans showing weak but significant correlation to herring were *Pseudocalanus minutus* and *Centropages hamatus.* Sprat landings were significally negatively and sprat weight positively related to *Limnocalanus macrurus* and *Cyclopidae.* Significant correlations to both fish landings and weight data were also found for rotifers.

In August similar significant correlations were found for rotifers. The weight of both fish species and herring landings showed negative correlation with rotifer biomass, while the sprat landing and rotifer biomass correlated positively. For crustacean zooplankton in August the results of sprat and herring were different. Herring catches and weight were positively correlated with *P. minutus* and *L. macrurus* and negatively with *Eurytemora affinis*. Sprat was most strongly correlated to copepod nauplii (R=0.70 and R=-0.63 for landings and weight respectively).

Abiotic environment

Strong and significant correlations between zooplankton data and environmental factors were scarce. Three taxa in the zooplankton spring community - *Frittillaria borealis, Synchaeta spp and Keratella spp.* - had more frequent significant correlations, often with the same environmental parameters: Negative correlation with silica in winter, positive correlation with low-layer temperature in spring also positive correlation with phosphorus and chlorophyll *a* concentration in later summer. *Bosmina coregoni maritima* showed best correlation with Baltic Sea climate Index and maximum ice cover.

PCA and Factor analyses

Results of PCA-analyses performed with spring zooplankton data are shown in Figure 1. Small zooplankton and fish components have highest loadings in Factor 1. *L. macrurus* had highest loading of all crustaceans. In Factor 2 climatic components prevail. The Baltic Sea Index had highest loading in Factor 2 together with salinity, temperature in the upper layer and maximum ice cover. Factor rotation (varimax raw) made this situation even more pronounced. The first factor gained even higher loadings for fish components and small zooplankton. Baltic Sea Index and maximum ice cover were now singled out to a single factor without any other component loading higher than 0.5 except for *B. c. maritima.*

As many environmental factors in the analyses performed with summer zooplankton data were the same as for spring, the overall description of both factors is similar (Figure 2). Among the summer zooplankton species again small species, together with fish, had high loads on factor 1. Factor rotation did not improve the first factor in the case of summer, but the climatic factor with high loading of *Bosmina* was even more evident.

The current analyses did not found clear bottom-up effects on the zooplankton community in Gulf of Finland. There is more evidence of relationships between herring and sprat and zooplankton, but whether it this is a top-down effect of fish on zooplankton or bottom-up control of zooplankton on fish is not clear. The result of the PCA analyses - small sized zooplankton is most strongly related to fish parameters - suggests some indirect influence, as this zooplankton component is not the preferred food for fish. The dynamics of the cladoceran *Bosmina coregoni maritima* was best explained by climatic changes.

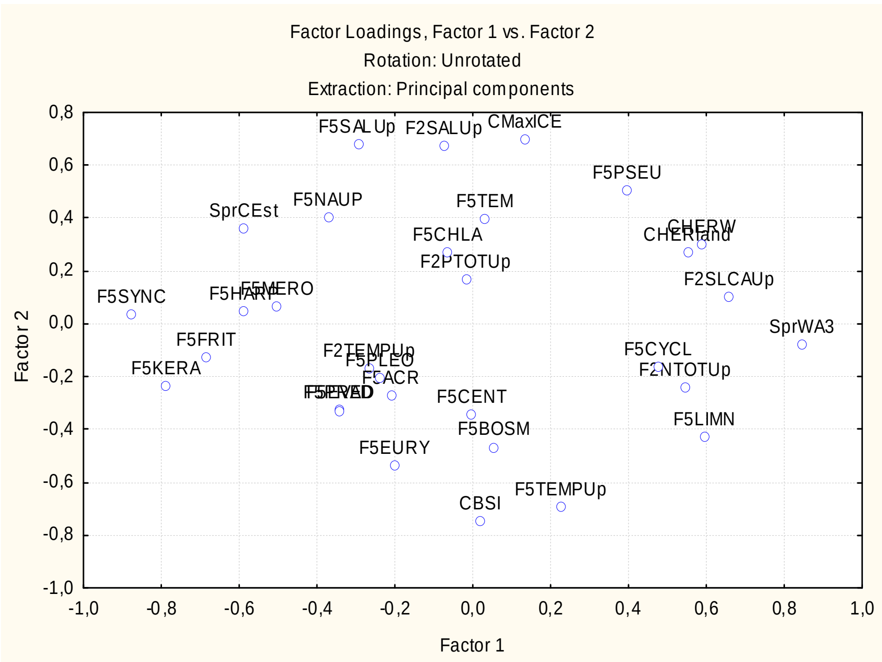

Figure 1. XY-plot of factor-variable correlations, computed for the zooplankton community in spring.

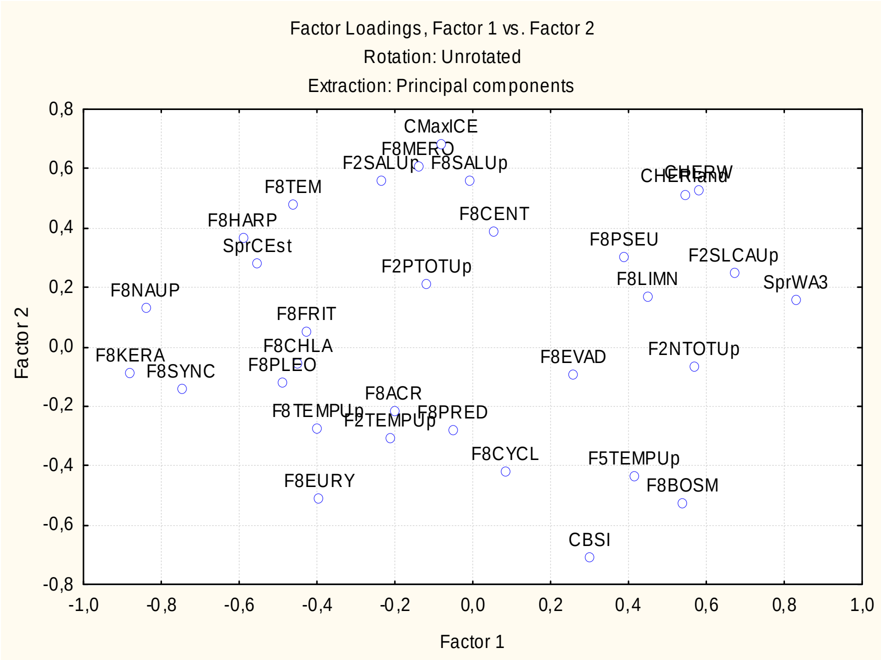

Figure 2. XY-plot of factor-variable correlations, computed for the zooplankton community in summer.

Utilization of environmental data in fish recruitment predictions in the Baltic Sea

Georgs Kornilovs

Gulf of Riga herring

Gulf of Riga herring is a slow-growing herring with one of the smallest length and weight-at-age in the Baltic and thus considerably differs from the neighbouring herring stock in the Baltic Proper (Sub-divisions 25–29).

The recruitment fluctuated at the level of 1,000–3,000 millions in the 1970s and 1980s. Since the 1989 the recruitment increased, reaching values up till 5.000 millions.

Environmental factors, particularly the winter temperature and zooplankton abundance are believed to have significant effect on recruitment of the Gulf of Riga herring. The severity of winter significantly influences the year-class strength, already observed by L. Rannak since 1950s (Rannak, 1971). Since 1989 a period of mainly mild winters resulted in a row of rich year-classes and increase of SSB. After severe winters of 1996 and 2003 poor year classes appeared. It is considered that after mild winters the spawning is distributed more evenly and spawning period is longer, the zooplankton abundance is higher improving the feeding conditions of herring larvae.

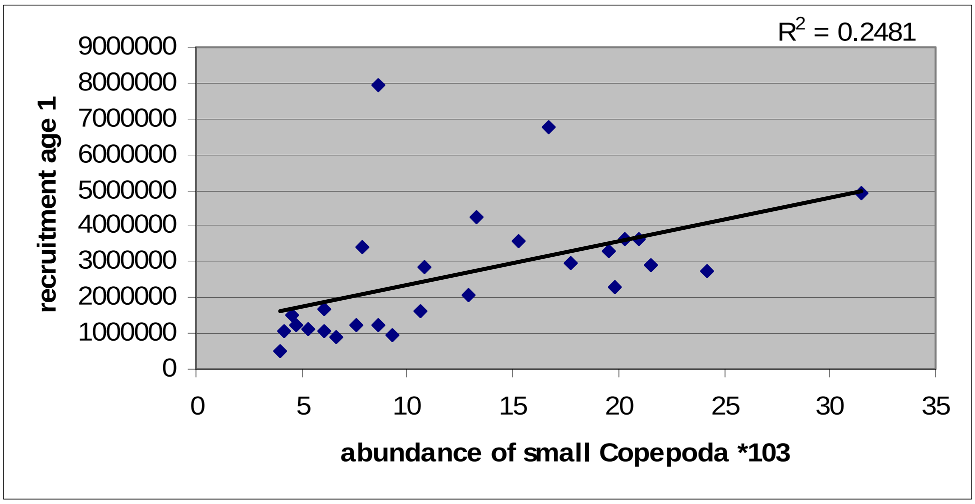

Figure 1. The relationship between abundance of small Copepoda (Eurytemora+Acartia) in May and abundance of 1 year old Gulf of Riga herring in 1977–2003.

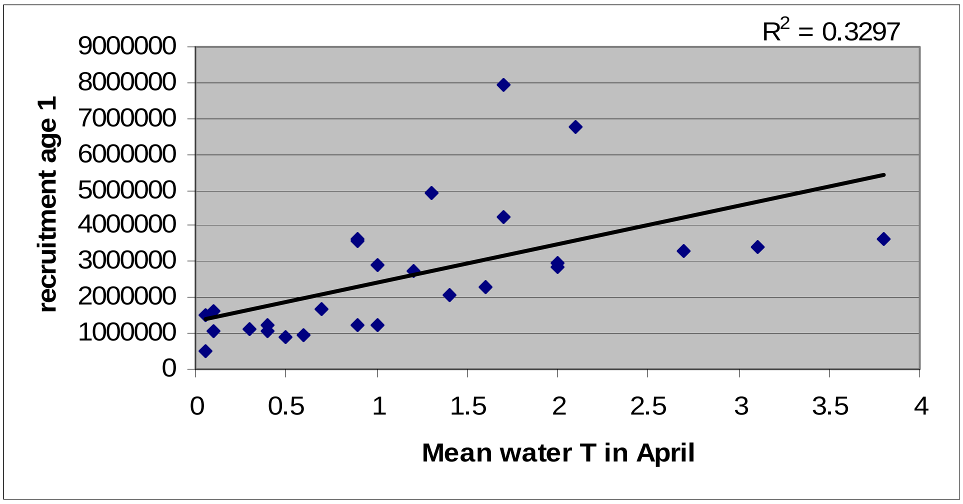

Figure 2. The relationship between mean water temperature in April and abundance of 1 year old Gulf of Riga herring in 1977–2003.

The relationships between recruitment (abundance of 1 year old herring) and water temperature in April and abundance of zooplankton in May was used for the prediction of recruitment in RCT3 analysis since 1995. However, the appearance of two record high year-classes in 2000 and 2002 with estimated from XSA abundances of 1 year old herring above 7,000 millions has significantly worsened these relationships, especially with zooplankton (Figure 1). The zooplankton abundance during regular surveys in May 2000 and 2002 was on average level and did not anticipate extremely high recruitment. As a result, with inclusion of data of 2000 and 2002, the R^2 values for relationship between recruitment and water temperature (Figure 2) decreased from 0.44 to 0.33 and for that with zooplankton from 0.65 to 0.25. However, the growth and condition factor of herring in 2000 and 2002 indicated that abundance of zooplankton was high and the feeding conditions were very good in these years. Moreover, the appearance of the summer zone on otoliths already in the end of June indicates that the zooplankton abundance could have considerably increased shortly after the survey. In the RCT3 prediction the weight of both predictors has significantly decreased and seemingly, it will especially disable to predict rich year-classes.

Prediction of Baltic sprat recruitment

MacKenzie and Köster (2004) found that sprat recruitment is significantly influenced by spring sea temperature, the area of Baltic Sea ice coverage, and the North Atlantic Oscillation. In general that means that rich year-classes appear after mild winters while severe winters have an opposite effect. However, prediction performed in 2006 revealed that the relationship has strongly weakened (R^2 of 0.1–0.3) due to appearance of a very strong year-class in 2003 after the coldest winter in the last decade. Therefore in Baltic Fisheries Assessment Working Group the prediction is performed using estimates of age-0 sprat in the hydroacoustic survey.

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Annex 9: State of the lower trophic levels

Eastern Gotland basin

Hydrography

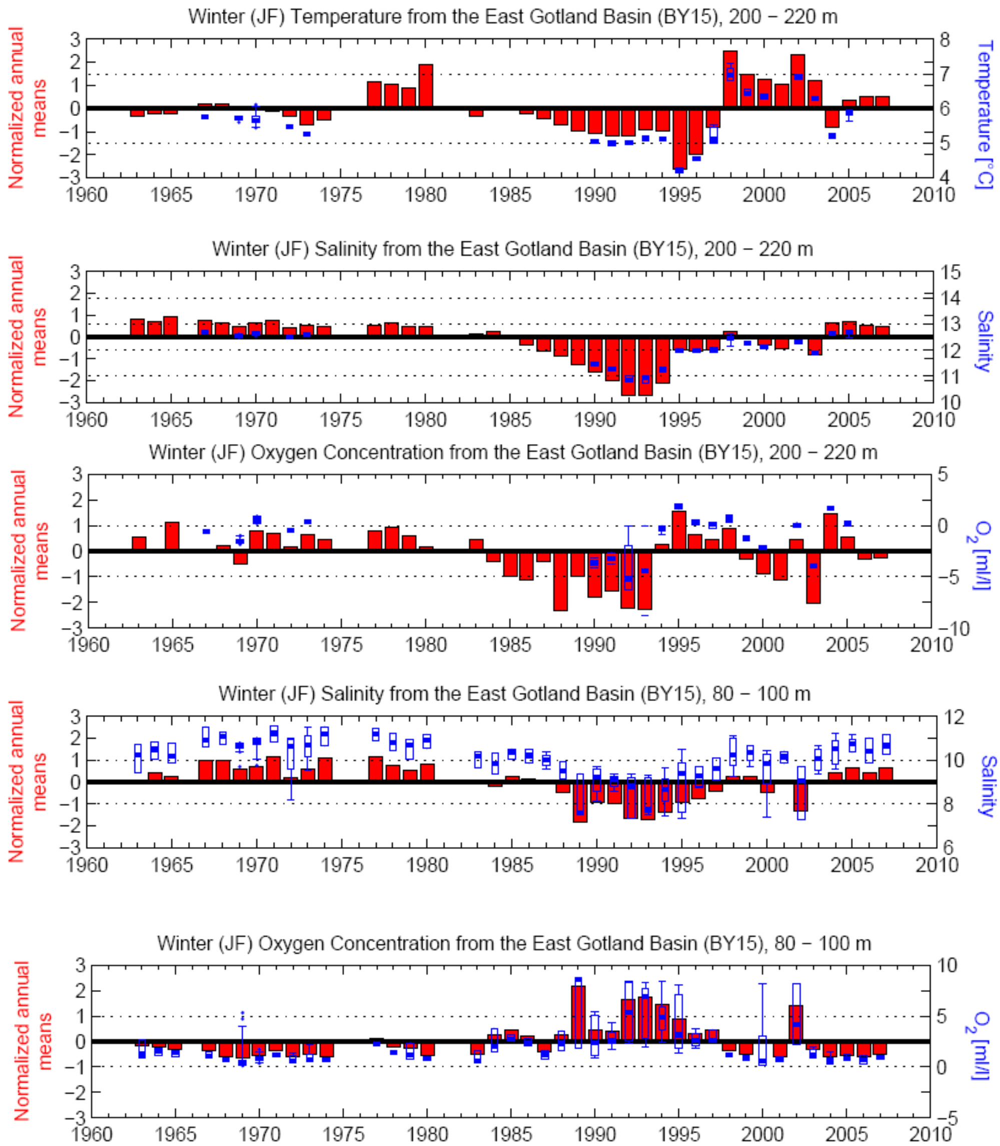

Figure 1: Temperature, salinity and oxygen concentrations in the bottom water (200–220 m) and the halocline region (80–100 m) of the Eastern Gotland Basin.

In winter 2007 the bottom waters in the Eastern Gotland basin were relatively warm and saline, but oxygen poor (Figure 1). In 200 – 220 m depth H_2S was present in concentrations about 2 ml/l, and in the halocline region (80–100 m) oxygen concentrations were only 0.9 ml/l. The last major Baltic inflow in 2003 obviously had improved the oxygen conditions in the Eastern Gotland Basin only temporally, and since summer 2005 the bottom water had again become oxygen free. The 2003 inflow had pushed the halocline upwards, noticeable by the increased salinity in the 80–100 m water layer, but with the upward movement of the halocline, also the oxygen poor waters extended upwards.

During 2005 and 2006 only weak baroclinic inflow activity occurred, which improved the oxygen conditions only in the western part of the Eastern Gotland Basin (Institut für Ostseeforschung, 2007). Similarly, also the weak saline water inflow transporting warm (> 6°C) and rather oxygen poor (about 1 ml/l) water into the Eastern Gotland Basin, which was observed end of March 2007, reached only the western part of the Eastern Gotland Basin (Institut für Ostseeforschung, 2007) and did not improve the oxygen situation significantly.

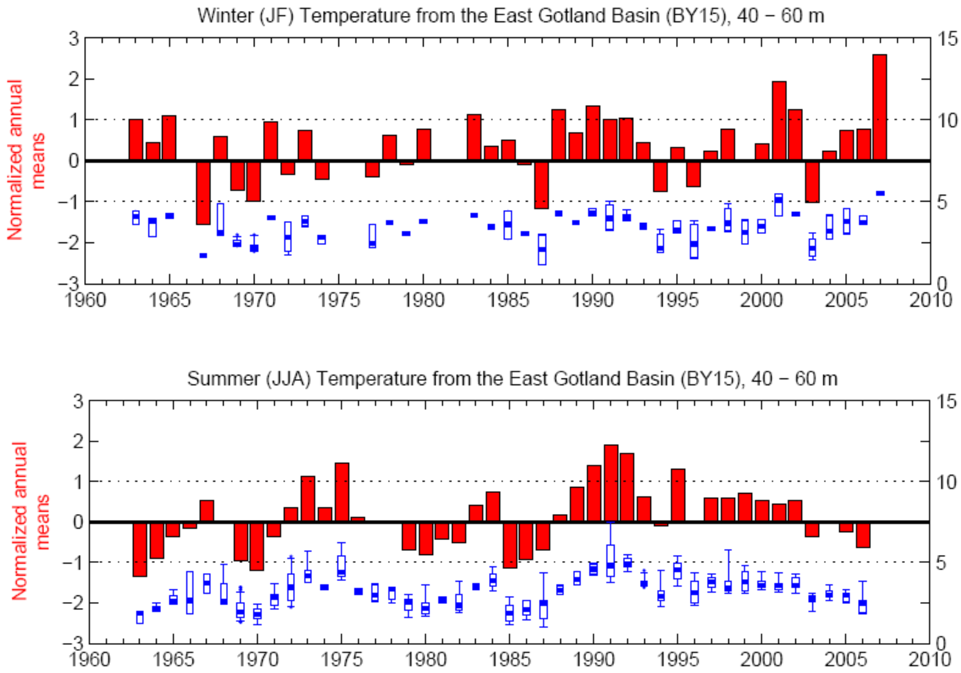

Figure 2. Winter water (40–60 m) temperatures in winter and summer in the Eastern Gotland basin.

The temperature dynamics of the Eastern Gotland Basin winter water (40 – 60 m layer) was exceptional during 2005 and 2006 (Figure 2). While the winter water remained relatively warm until January/February, temperatures dropped below average before summer. This reflects the warm autumn conditions in the Baltic in 2005 and 2006, followed by harsh, prolonged winters. Winter 2007 temperatures were exceptionally warm, but 2007 is characterized by relatively mild late winter air temperatures, so that warm winter waters can be expected in spring and summer 2007.

Summer surface water (0–10 m) temperatures (Figure 3) have continued their long-term increase also in 2006, which had the highest median summer temperatures in the measurement series in the Eastern Gotland basin.

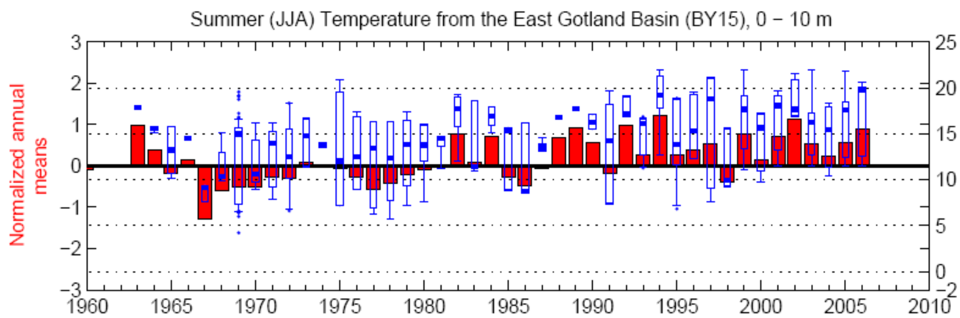

Figure 3. Summer surface layer (0–10 m) temperatures in the Eastern Gotland Basin.

Nutrients

Winter DIP and DIN concentrations in the surface layer of the Eastern Gotland basin showed differing trends since 1991 (Figure 4). While winter DIN concentrations decreased, winter DIP concentrations were again high in 2003 – 2007. Based on the high DIP surplus in the surface layer compared to the Redfield ratio ratio 2007 will be again favourable to cyanobacterial blooms.

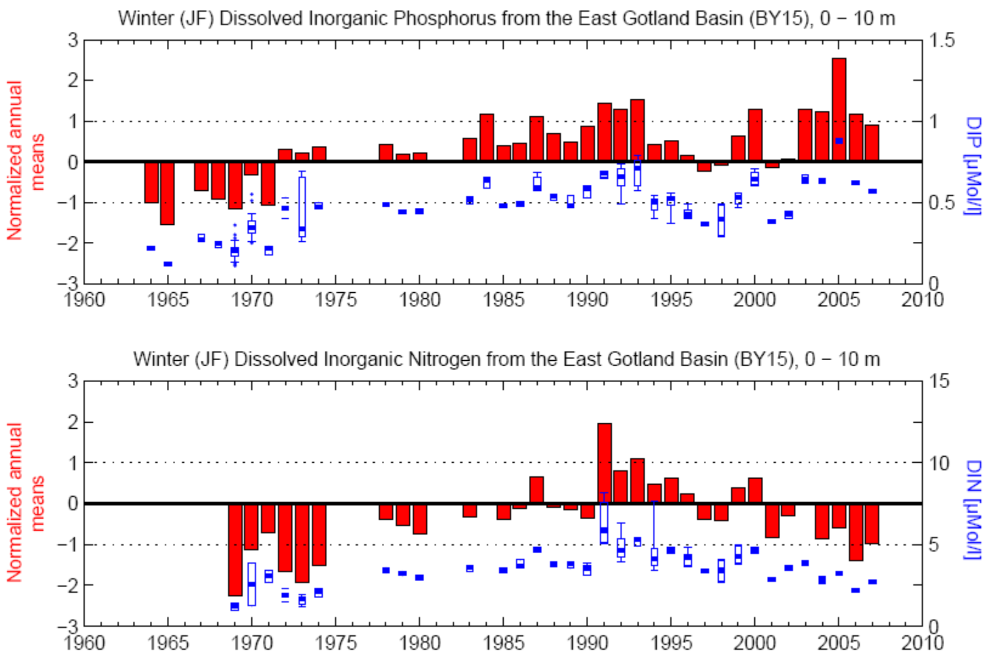

Figure 4. Winter DIN and DIP concentrations in the Eastern Gotland Basin (0–10 m).

Phytoplankton

Phytoplankton biomass data for 2006 were not available for the Eastern Gotland Basin yet. According to chlorophyll a measurements (Figure 5), phytoplankton concentrations were low in summer 2006. Slightly north of the Eastern Gotland Basin, in the northern Baltic Proper, SOOP measurements by Alg@line found that the spring bloom had about average peak height and timing, but declined faster than usual http://www.fimr.fi/en/itamerikanta/bsds/256.html). Surface accumulation of cyanobacteria in summer 2006 were intense, but mainly affected the Bornholm Basin.

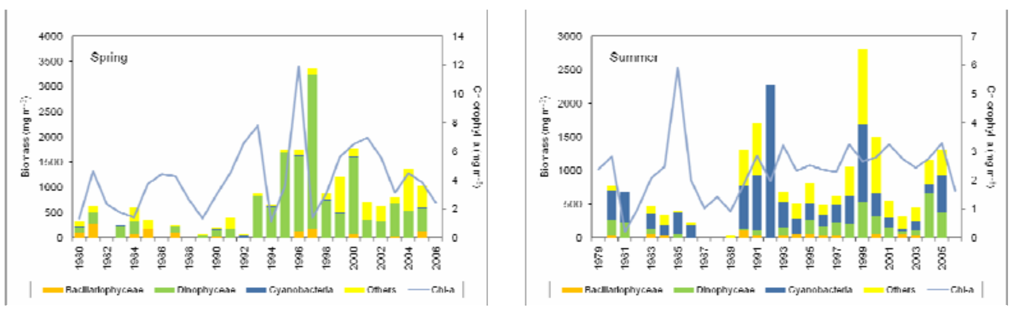

Figure 5. Phytoplankton biomass and chlorophyll a in the Eastern Gotland Basin in spring (left) and summer (right) (IO-Warmenmünde, marine monitoring data).

Zooplankton

In spring (May, Figure 6) 2006, the average total biomass of Copepoda was slightly lower than in the previous year, but it was 1.2 times higher than the long-term average. The dominant species was *Pseudocalanus acuspes*, the biomass of which increased more than 4 times compared to previous year and was slightly lower than the long-term average. The biomass of *Acartia* spp. and *Temora longicornis* was slightly over long-term average but were rather low concerning the levels in the last 10 years especially for *Acartia* spp. The total biomass of Cladocera was on the level of 2005 and 1.5 lower than the long term-average.

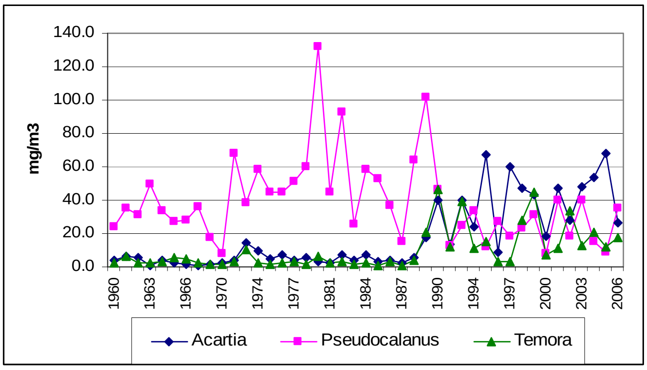

Figure 6: Biomass of the main zooplankton species in the Eastern Gotland Basin in May.

In summer (August, Figure 7) 2006 the total biomass of Copepoda was 2.6 times lower than in the summer of the previous year and 1.7 times lower than the long-term average. Especially low was the biomass of *Acartia* spp. and *Temora longicornis* while *Pseudocalanus acuspes* was close to the last year level and slightly below the long-term average. The biomass of Cladocera, which in summer is usually governed by *Bosmina maritima* was also low 2.6 times lower than in the previous summer and 1.7 lower than the long-term average.

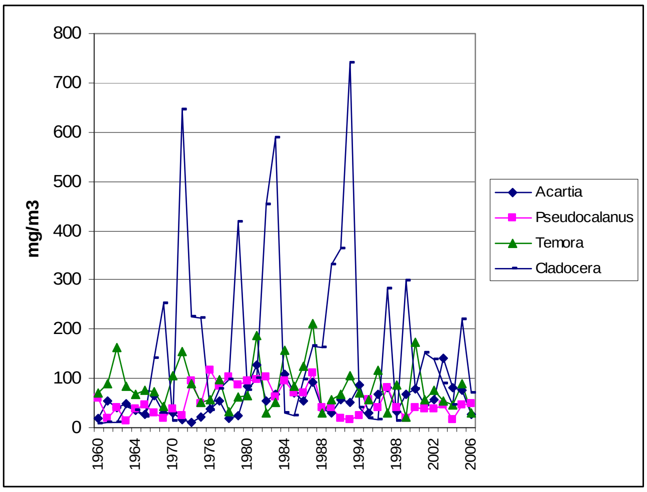

Figure 7. Biomass of the main zooplankton species in the Eastern Gotland Basin in August.

In autumn (October, Figure 8) 2006 the total biomass of Copepoda was slightly higher than in previous year and 1.4 times higher than the long-term average. The most abundant were *Acartia* spp. and *Temora longicornis*. *Pseudocalanus acuspes* biomass remained on the level of previous year but was 1.7 times lower than long-term average. The biomass of Cladocera was slightly higher than in the previous year and than the long-term average.

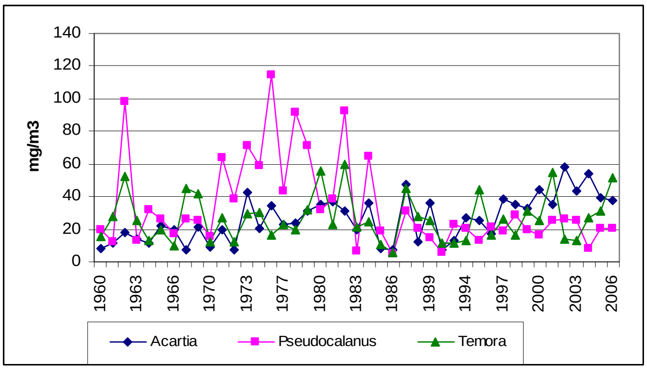

Figure 8: Biomass of the main zooplankton species in the Eastern Gotland Basin in October.

Bornholm Basin

Hydrography

In the Bornholm basin, the 2003 inflow had improved bottom water oxygen conditions, but already in 2004 bottom water oxygen concentrations were below the long-term average, dropping to anoxic conditions in summer 2005 (Figure 9). Unlike in the Eastern Gotland Basin, in the shallower Bornholm basin bottom water oxygen concentrations also carry a seasonal signal. Therefore oxygen concentrations in summer tend to be lower than during winter. Winter oxygen conditions have slightly improved in 2006 - 2007, which is also reflected in a higher cod reproduction volume in 2006, but it is difficult to predict, whether this trend will also be visible in the cod reproduction volume in 2007.

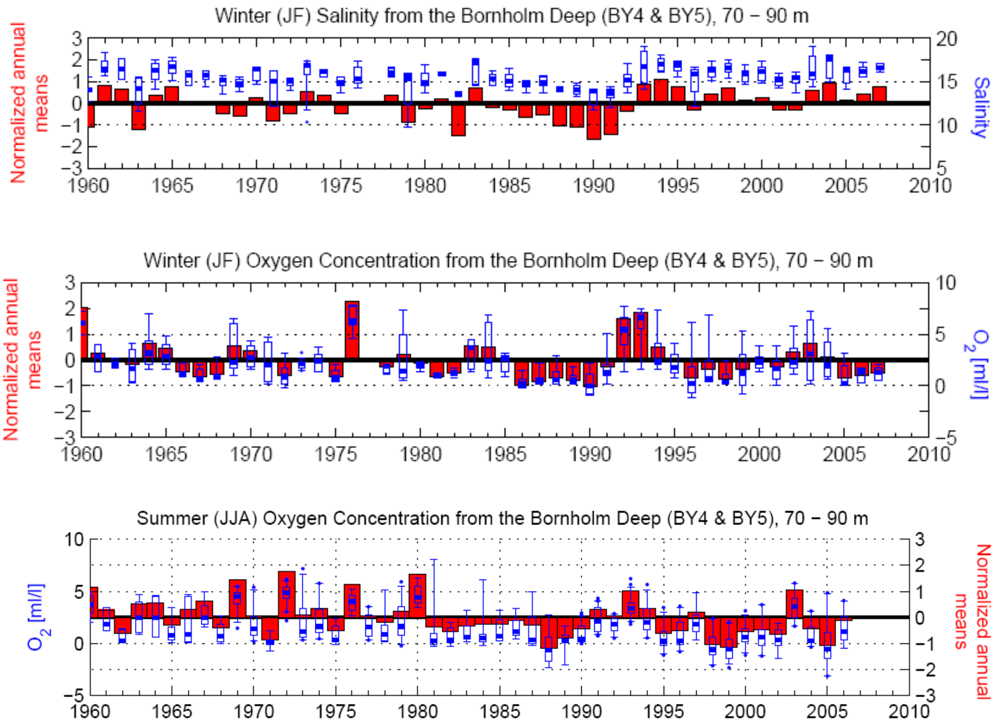

Figure 9. Salinity and oxygen conditions in the bottom layer (70–90 m) of the Bornholm basin.

In the surface layer of the Bornholm basin, the typical long-term freshening and warming of the Baltic Sea is evident (Figure 10). Similar to the Eastern Gotland basin, winter temperature in 2007 was exceptional high.

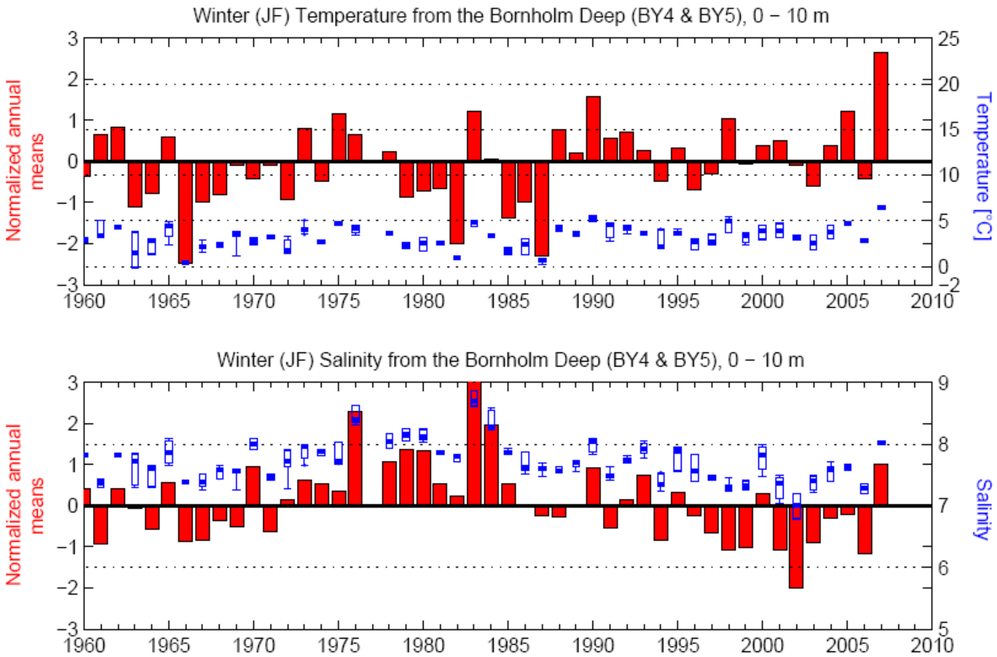

Figure 10. Winter temperature and salinity in the surface layer (0–10 m) of the Bornholm basin.

Nutrients

Similar, but much less pronounced than in the Gotland basin, low salinity/oxygen stagnation periods are characterized by accumulation of DIN and DIP in the bottom layer of the basin. Surface layer nutrient concentrations in winter (Figure 11) were similar to the Eastern Gotland basin and indicate high surface water exchange between both subbasins. The period 2004–2007 is characterized by high surplus DIP and therefore sensitive to cyanobacteria blooms.

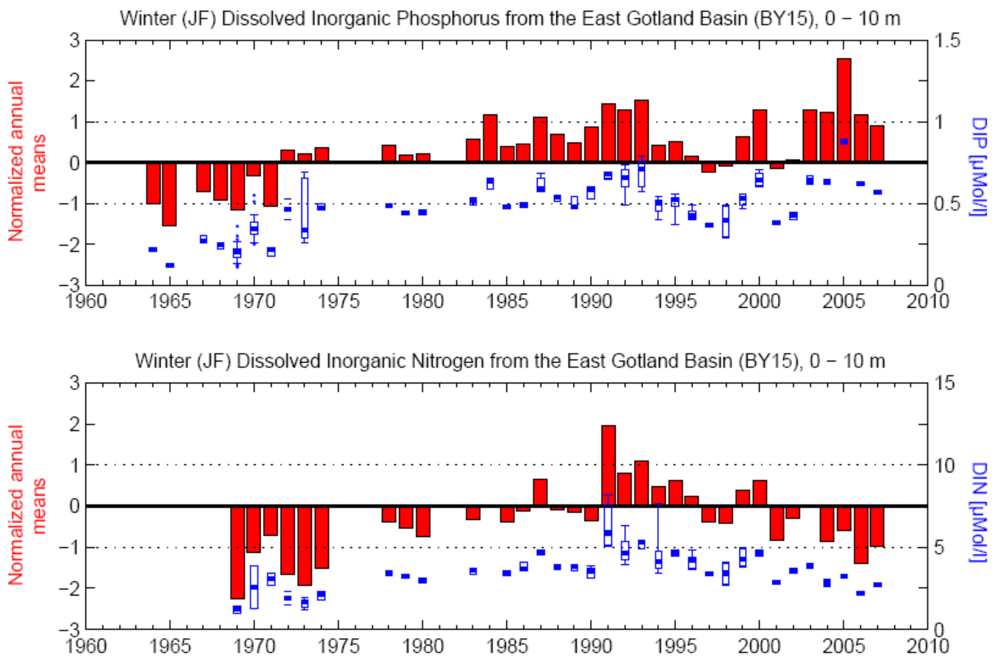

Figure 11. Winter DIP and DIN concentrations in the surface layer (0–10 m) of the Bornholm basin.

Phytoplankton

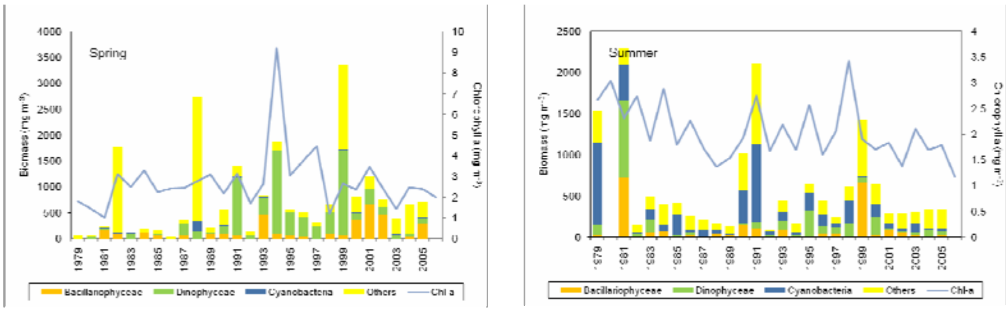

Figure 12. Phytoplankton biomass and chlorophyll a in the Bornholm Basin in spring (left) and summer (right) (IO-Warmenmünde, marine monitoring data).

Phytoplankton biomass data for 2006 were not available for the Bornholm Basin yet. According to chlorophyll a measurements (Figure 12), phytoplankton concentrations were low in summer 2006. However, satellite observations detected extensive surface algal blooms in summer 2006, mostly focused in the Bornholm basin (Figure 13). In the Bornholm basin, toxic *Nodularia spumigena* was present, whereas further northward, the surface accumulations consisted mainly of non-toxic *Aphanizomenon* (http://www.helcom.fi/environment2/ifs/ifs2006/ en_GB/cyanoblooms/)

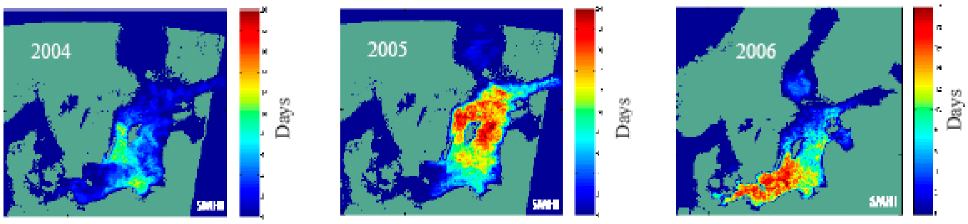

Figure 13. Surface accumulations of algae in summer (http://www.helcom.fi/environment2/ifs/ifs2006/en_GB/cyanoblooms/_.

Cod reproduction volume

Baltic cod eggs require saline water (> 11 PSU) with suitable oxygen concentrations (> 2 ml/l) and temperature conditions (> 2 ºC) for survival. Cod recruitment success strongly depends on the "reproduction volume", i.e. the volume of water masses with suitable salinity and oxygen conditions.

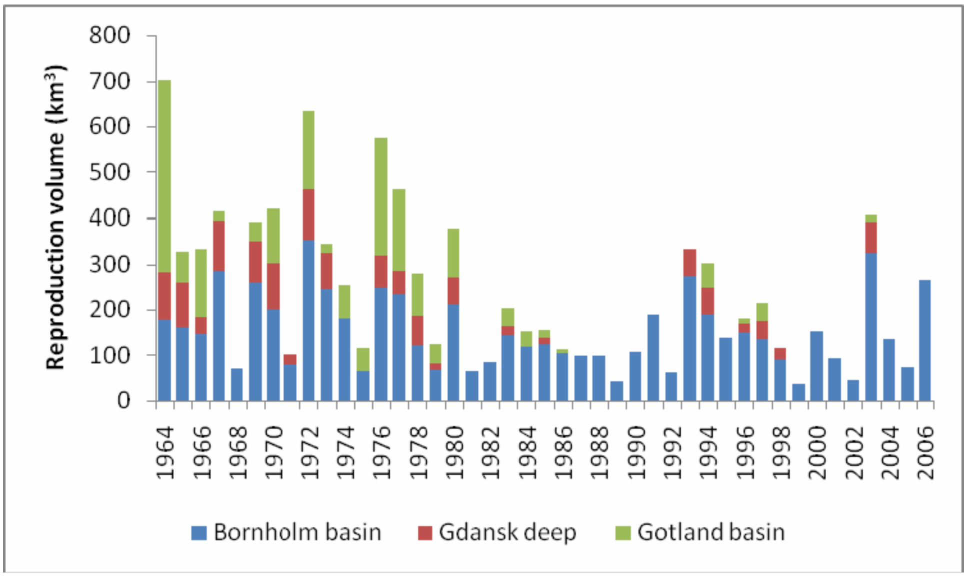

Figure 14.Cod reproduction volume in the Baltic.

Since the mid-1960s, cod reproduction volume has steadily declined (Figure 14). Starting from the mid-1980s, cod reproduction was mainly restricted to the Bornholm basin, while in the Gdansk and Gotland deep suitable reproduction conditions occurred only occasionally.

After the 2003 saline water inflow, cod reproduction conditions improved only briefly and already in summer 2004 the bottom water in the Gotland deep was again anoxic. Even though the basin was replenished with saline water and salinity in the 80–100 m layer maintained appr. 10.5 PSU from summer 2004 until present (winter 2007), oxygen concentrations were insufficient for successful cod reproduction in the Eastern Gotland basin (see Figure 15, bottom).

In contrast to the Gotland basin, cod reproduction conditions in the Bornholm basin have a strong seasonal signal. Oxygen content at 11 PSU is generally highest in March/April, before thermal stratification is established, and lowest in October/November, before winter mixing replenishes the deeper water layers with oxygen (Figure 15, top).

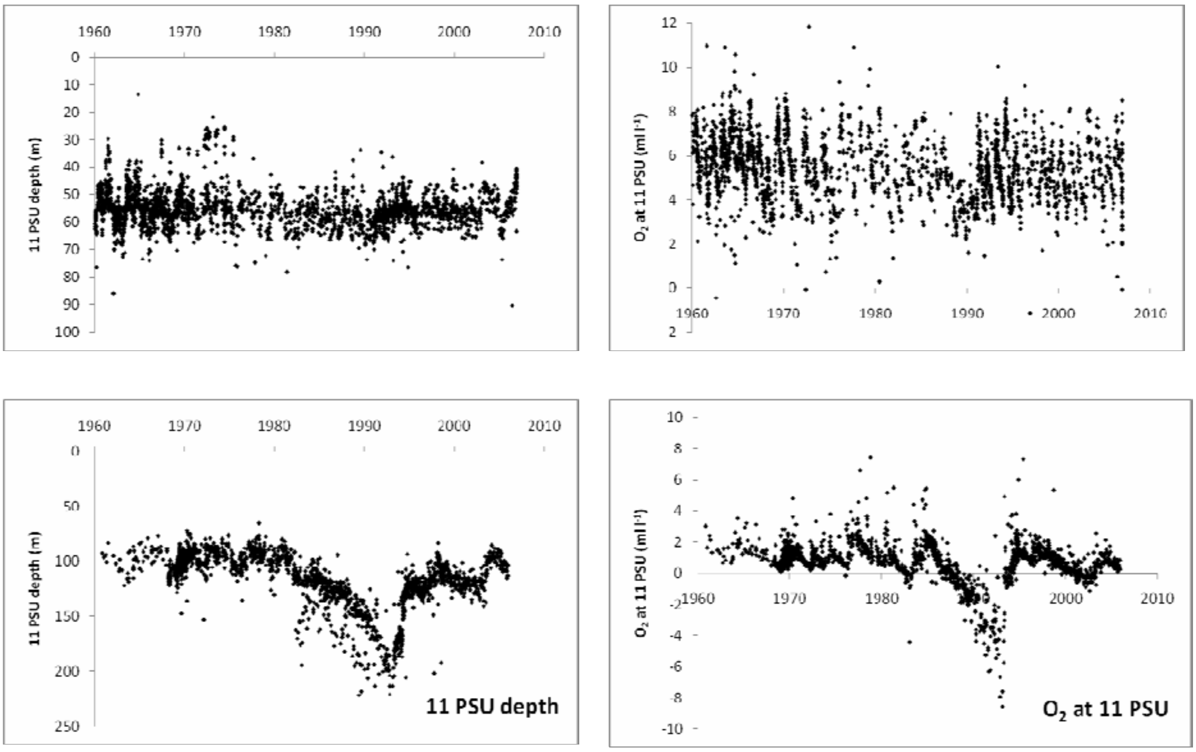

Figure 15. Depth of the 11 PSU isohaline and oxygen content at 11 PSU in the Bornholm (top) and Eastern Gotland Basin (bottom).

Gulf of Riga

Hydrography

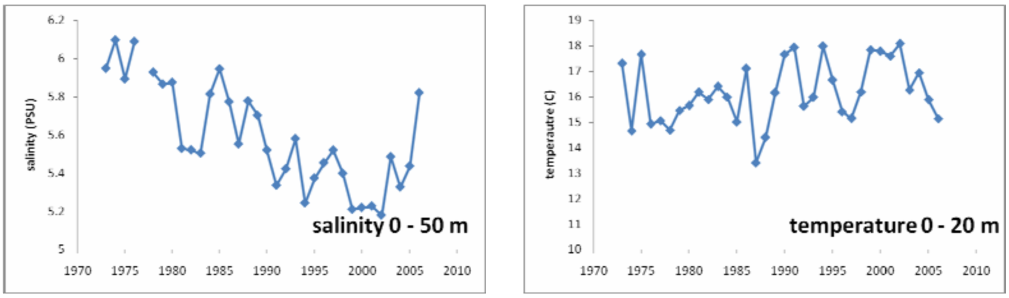

Figure 16. August salinity (left) and mixed layer temperature (right) in the Gulf of Riga.

The most conspicuous recent change in the hydrographic conditions in the Gulf of Riga was the inflow of saline water from the surface layer of the Baltic Proper in 2006, which increased the water column salinity by 0.4 PSU (Figure 16, left). The inflowing water spread along the seafloor and was, in the course of the year, mixed into the water column (Figure 17, top left). Due to the high bottom layer salinity, the water exchange between bottom and surface was restricted, leading to low oxygen conditions in the near-bottom water in autumn 2006 (Figure 17, top right).

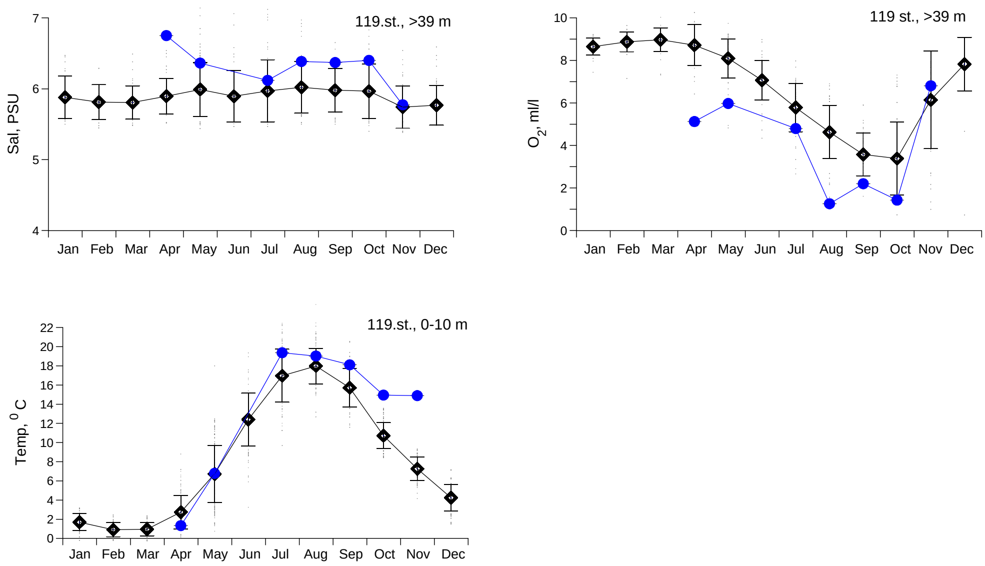

Figure 17. Near bottom salinity (top left), oxygen concentration (top right), and surface temperature (bottom) in the central Gulf of Riga. Squares with standard deviation bars represent averages from 1973–2004, circles represent 2006 (Aigars and Berzinsh, manuscript in preparation).

The winter 2005/2006 was severe, with extensive ice cover in the Gulf of Riga, which is reflected by the low February temperatures. The cold winter was followed by rapid warming of the upper part of the water column and quick formation of the seasonal thermocline. Temperatures in the 0 – 20 m water layer in May reached the long-term average (4.4 °C). Most striking is the unusual temperature development in autumn, where sea surface temperatures stayed at 16 °C and the breakup of the seasonal thermocline was delayed (Figure 17, bottom).

Nutrients

Winter nutrient concentrations in 2007 were large, both for DIN as well as DIP (Figure 18). Therefore high phytoplankton productivity can be expected during 2007.

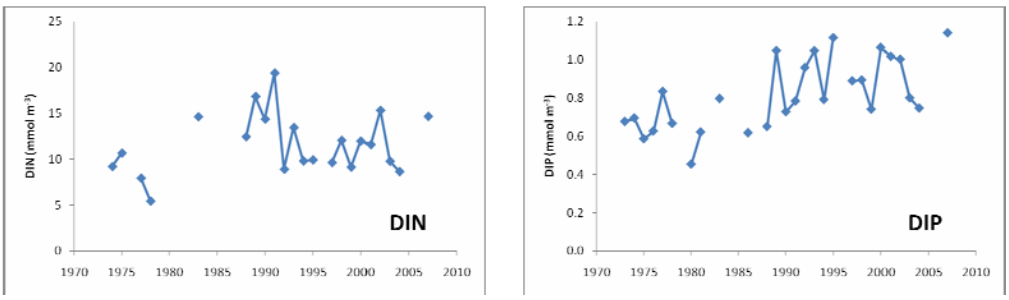

Figure 18. Winter nutrient concentrations in the Gulf of Riga.

Phytoplankton

Assessment of the phytoplankton spring bloom dynamics based on the available monitoring survey data is difficult because of the high temporal and spatial dynamics of the bloom. Temporal trends are clearer during the relatively stable summer period (Figure 19, right panel). Consistent with the long-term increase in summer chlorophyll a in the Gulf of Riga, chlorophyll a concentrations in 2006 were on a high level, reflected also in low transparency, and the summer phytoplankton productivity therefore seems to remain on a high level.

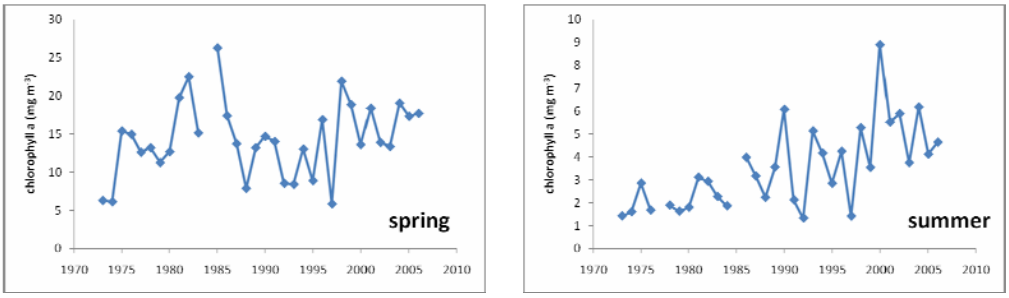

Figure 19. Chlorophyll *a* concentrations in the Gulf of Riga in spring (left) and summer (right).

The share of cyanobacteria in the summer phytoplankton biomass fluctuated between 25 % and 50 % in the time period 1996 – 2006, for which detailed species composition data are available. Non-toxic *Aphanizomenon* dominated the cyanobacteria composition. Also during summer 2006 no exceptional summer blooms of cyanobacteria or high biomasses of potentially toxic phytoplankton were noticed (Latvian Institute of Aquatic Ecology, unpublished data).

Zooplankton

Characteristic for the long-term trends in the Gulf of Riga zooplankton (Figure 20) are increasing biomasses of the dominating copepods, *Acartia spp*. and *Eurytemora affinis*, in spring, while their biomass decreases in summer.

In spring (May) 2006 the total biomass of Copepoda was 2.2 times lower than the long-term average and 3.2 times lower than in the previous year. All Copepoda species (*Acartia spp., Eurytemora affinis, Limnocalanus grimaldii*) were on a low level in comparison. Also the biomass of Cladocera was 4 times lower than the long-term average.

In summer (August) 2006 the total biomass of Copepoda was 1.3 times lower than in the previous year and close to long-term average. According to biomass the most abundant was *Limnocalanus grimaldii* which was 1.5 times higher than the long term-average but 2.6 lower than in the previous year when a sharp increase in the abundance of this species was observed. The biomass of *Acartia spp*. was close to long-term average and the biomass of *Eurytemora affinis* was below long-term average. The biomass of Cladocera was 6 times lower than the long-term average.

In autumn (October) 2006 the total biomass of Copepoda was 1.8 times higher than the long-term average and close to the level of the previous year. The biomass of *Limnocalanus grimaldii* was 2.7 times higher than the long-term average and close to the level of the previous year. The biomass of *Acartia spp.* and *Eurytemora affinis* was higher than the long-term average, respectively 1.6 and 1.4 times. Although the total biomass of Cladocera was 2.5 times higher than the long-term average it was almost 20 times lower than the biomass of Copepoda.

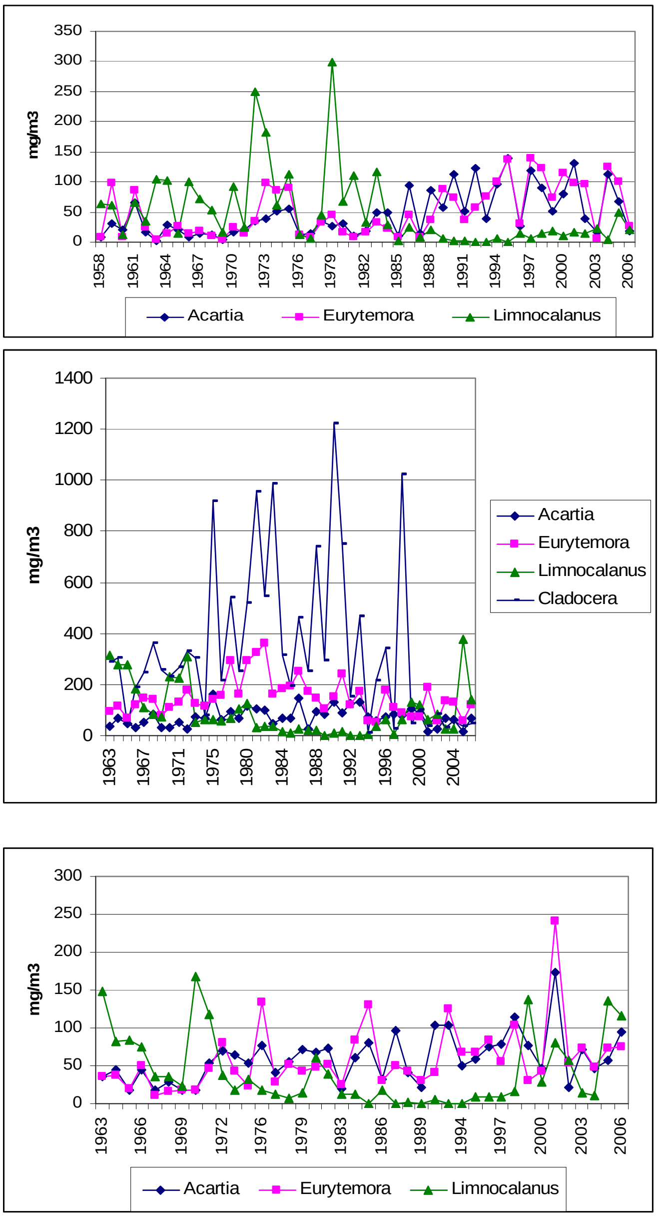

Figure 20. Biomass of the main zooplankton species in the Gulf of Riga in May (top), August (middle) and October (bottom).

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Institut für Ostseeforschung Warnemünde. 2007. Cruise Report r/v "Prof. A. Penck", Cruise-No. 07PE / 07 / 07, 23 March–2 April, 2007.

Annex 10: Phytoplankton and primary productivity research at AtlantNIRO

Phytoplankton and primary productivity research at AtlantNIRO

Sergey Alexandrov

Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO) is a leading scientific institute of Russia to investigate biological resources in the Baltic Sea, Central and Southern Atlantic. The research fleet of the Institute consists of 2 seagoing vessels to conduct surveys in any part of the World Ocean.

The Laboratory of Hydrobiology is a biological subdivision of AtlantNIRO and it is included in Department of Special Investigation. Researches of Laboratory of Hydrobiology are carried out in coordination with Laboratory of Hydrochemistry and Water pollution, Laboratory of Parasitology and also Laboratories of Department of Baltic Sea and Lagoons which carry out mainly researches of fish resources.

Laboratory of Hydrobiology carries out complex hydrobiological researches, including studying of regularity of biological productivity, structural and functional organization of the basic components water ecosystem (phytoplankton, zooplankton, zoobenthos, riverside vegetation) and influences on them of abiotical factors, estimation of anthropogenous influence and water quality and carrying out of ecological monitoring of water body. Now it is one of the largest laboratories AtlantNIRO in whom 12 scientists work, from them 8 person have age till 30 years. Scientists participate in numerous sea researches. Students of universities also participate in researches. Now the Laboratory of Hydrobiology is equipped by the modern equipment for performance of researches, including radiometers for research of primary production, spectrophotometer and fluorometer for measurement of chlorophyll, microscopes for studying plankton and benthos organisms. In particular, in last year within the bounds of BSRP we have received modern microscope for phytoplankton research.

Now the area of researches is very extensive: from the rivers in the Kaliningrad region up to extensive oceanic areas in the Central and Southern Atlantic. Last fifteen years intensive researches are carried out in Baltic Sea and Lagoons. We have an opportunity to research all components parts of ecosystem Baltic Sea. Researches are carried out:

1) on the catchment area (the rivers Pregolia and Deyma),
2) in Curonian and Vistula Lagoons where these rivers empting,
3) in coastal zone and southeast part of Baltic Sea
4) and last two years seasonal researches were carried out in Baltic Sea along transect extended from the Gulf of Finland to the territorial waters of Germany.

Researches of catchment area of Baltic Sea are carried out on the rivers Pregolia and Deyma. The river Pregolia is the largest river run in Vistula Lagoon, it also is the major source of water supply of Kaliningrad.

Studying of the rivers were carried out monthly or seasonally with 2000 for 2005. Researches were carried out on 12 standard stations. There were 6 stations on the river Pregolia and 6 stations on the river Deyma. Researches species composition, abundance, biomass phytoplankton and benthos, primary production, chlorophyll and nutrients concentration and other hydrochemical and hydrological parameters were carried out.

Complex researches of Curonian and Vistula Lagoons are carried out by AtlantNIRO during several decades. The Curonian and Vistula Lagoons are enclosed freshwater and brackish water basins, connected to the Sea by narrow straits. These are the largest coastal lagoons of the Baltic Sea.

The first complex research phytoplankton and primary production these Lagoons has been executed by scientists AtlantNIRO with 1974 for 1976. The researches were carried out monthly from March to October at 24 stations in the Curonian Lagoon and at 10 stations in the Vistula Lagoon. In Curonian Lagoon researches were carried out on all water area including the Russian and Lithuanian zones.

The ecological monitoring Curonian and Vistula Lagoons have been begun in 1992. The monitoring was carried out seasonally (from 1991 to 1994) and monthly (from 1995 to 2006) from March to November at 12 stations in the Curonian Lagoon and at 9 stations in the Vistula Lagoon. In the current period, these Lagoons may be characterized as a highly eutrophicated water bodies. Eutrophication affected all trophic levels. The species typically abundant in eutrophicated waters prevailed in the phytoplankton (It is *Aphanizomenon flos-aquae, Microcystis aeruginosa, Actinocyclus normanii, Stephanodiscus hantzchii*).

The processes of eutrophication and water "blooming" were most pronounced in the southern and central parts of the Curonian Lagoon, where the environment conditions (high concentrations of nutrients, slow water exchange, fresh water) were exclusively favorable to Cyanobacteria development. In hydrological and hydrochemical conditions existing in the most part of the Lagoon, the water temperature appears the key environment factor determining the seasonal and long-tern variability of the primary production and abundance of phytoplankton, and therefore, the trophic status of the Curonian Lagoon. In figure distinctions in seasonal dynamics of the biomass of phytoplankton which are caused by small distinctions in summer warming-up of water in 2002 and 2003 are submitted.

The Curonian Lagoon is characterized with high variability (by 2–4 times) of the trophic status indices in different years. Note that the years with "hyperblooming" of Cyanobacteria coincide with the years of the maximum water warming-up. The more intensive water warming-up and increase number of the "warm" years in 1990s-2000s created exceptionally favorable conditions for development of Cyanobacteria. Phytoplankton production in hypereutrophic Curonian Lagoon is utilized mostly via microbial trophic web, thus leading to a considerable decrease in the efficiency its transformation toward the upper trophic levels (including fish).

The Vistula Lagoon is characterized with rather low variability of the trophic status parameters in different years. The values of the primary production, phyto-plankton biomass, chlorophyll and nutrients concentrations are considerably lower than in the Curonian Lagoon. The biological productivity and eutrophication of the Vistula Lagoon does not attain its potentially possible level. The water exchange between the Lagoon and the Baltic Sea is very important for the water body trophic level decrease. Hydrodynamic activity (high flowing velocity) and brackish water due to intensive inflow of the sea water prevent the prolonged intensive development of Cyanobacteria, in particular, no "bloom" *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*, causing "hyper-blooming" of the freshwater Curonian Lagoon. In the Vistula Lagoon the highest concentrations of nutrients and chlorophyll, biomass and production of phytoplankton occurred in the freshwater areas and decreasing towards the sea strait.

It is important to note, that on the average for the five years' period of researches Lagoons primary production exceeded mineralization of organic matter in 1,7 times in Vistula Lagoon and in 1.4 times in Curonian Lagoon. Such ratio testifies to accumulation of organic matter in Curonian and Vistula Lagoons. It conducts to secondary or biological pollution of Lagoons and to their further eutrophication, especially Curonian Lagoon where on a greater part of water area slow water exchange is observed. In Vistula Lagoon the most part of organic matter, which does not mineralization, possibly, is carried out to sea. It promotes pollution and eutrophication coastal zone of Baltic Sea.

Researches of phytoplankton and concentration of chlorophyll in the South-East of the Baltic Sea have been begun in 1992. With 1992 for 2003 г. 17 research cruises were carry out. Researches of species composition, abundance, biomass phytoplankton were usually carried out; chlorophyll concentration was measured in separate cruises. The most stations have been located in economic zone of Russia, separate stations were carried out in zone of Lithuania. Researches were usually carried out in winter (March), spring (May) and autumn (October) periods.

Regular seasonal ecological monitoring in economic zone of Russia in the South-East of the Baltic Sea has begun with 2003. Researches are carried out in winter (March), spring (May), summer (July) and autumn (October) periods. Researches are carried out by AtlantNIRO in cooperation with Institute of Oceanology RAS. In particular, phytoplankton and concentration of chlorophyll is researched in AtlantNIRO and primary production in Institute of Oceanology. Scientific results are united for preparation of general report and joint articles. In total from May, 2003 till October, 2006 14 ecological cruises are carry out. Special attention is focused on the area of oil production. Maximal values of chlorophyll concentration and primary production are observed in the summer when "blooming" Cyanobacteria is observed. During the winter period these values are minimal. Maximal values of biomass phytoplankton, chlorophyll concentration and primary production are observed in coastal zone. This values at coastal stations in 2-3 times above, than at deep-water stations in open area Baltic. Eutrophication and decrease water quality from beginning of researches are not observed. Values of biomass phytoplankton, chlorophyll concentration and primary production in area of oil production was at level which is characteristic for adjacent water area.

Complex seasonal researches of phytoplankton, zooplankton, zoobenthos on a most part of the open area of Baltic Sea were carry out during 3 complex research cruises in October 2005, April-May and July–August 2006 in the framework of the project of the “ North European Gas Pipeline ”. The investigations were executed on the transect extended from a deep-water part of the Gulf of Finland to the Arkona Sea and passing through economic zones of Russia, Finland, Sweden, Denmark and Germany. Research of economic zone of Germany was carried out only in October 2005.

Chlorophyll concentrations were measured at 190 stations (337 samples), phytoplankton at 136 stations (154 samples), and primary production was measured at 49 stations (588 samples). Primary production was measured at 4 depths according to the radiocarbon method. Chlorophyll was measured with spectrophotometer. At stations where primary production was measured, the chlorophyll was determined at the 4 depths; at other stations the chlorophyll was determined at surface.

At present time the analysis of obtained data are carried out and it is possible to do only the preliminary conclusions.

In phytoplankton of the Baltic Sea in autumn 2005, in spring and summer 2006 179 species were recorded and 15 of them were potentially toxic. The spatial distribution and seasonal changes reflected typical condition of phytoplankton communities during spring, summer and autumn seasons. However the maximal biomass of phytoplankton and chlorophyll concentration that is typical for the periods of spring blooming of diatoms and summer blooming of toxic Cyanobacteria have not been recorded during researches.

Dominant complexes of species were identified for each season. Use of the statistical analysis has allowed to clustering four (autumn of 2005), three (spring of 2006) and four (summer of 2006) phytoplankton communities at the investigated area of the Baltic Sea.

In the autumn of 2005 chlorophyll concentration and primary production in open part of the Baltic Sea were approximately at the same level and they increased in the Gulf of Finland and the Arkona Sea. The highest values in the Gulf of Finland and Arkona Sea accordingly the higher trophic level of waters of these areas.

In the spring and summer 2006 the significant decrease of parameters of phytoplankton development and primary production was observed along the transect from northeast to southwest of Baltic. The maximal abundance, biomass, primary production of phytoplankton and chlorophyll concentration were observed in the most eutrophic area of Baltic Sea - in the Gulf of Finland. Minimum of this parameters were typical for the Southern part of Baltic (the researches of the Arkona Sea were not carried out).

On the basis of comparison with hydrological, chemical (nutrients concentration) and biological (phytoplankton and zooplankton) parameters the main factors, which influence the level of biological production, are indicated. In autumn the structure, chlorophyll concentration and other parameters of phytoplankton development had significant correlation with such factors of environment as salinity, the silicon and ammonium nitrogen concentration, in spring - with salinity and the concentration of silicon, phosphates, sulfates, and in summer with salinity and temperature of water. In autumn, spring and summer the parameters of phytoplankton development and primary production were positively correlated among themselves and in spring and summer had negative correlation with zooplankton abundance.