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Executive Summary

The Study Group on Baltic Sea Productivity Issues in Support of the BSRP (SGRPOD) met in Klaipeda, Lithuania, from 2–4 December 2004. The meeting continued the work on a comparative analysis of Baltic Sea foodwebs, started during an ECOPATH modelling workshop in November 2004. The ECOPATH models were seen as a useful tool for system comparison, potentially also for the derivation of productivity indicators, however, difficulties arise in fine-tuning models to obtain comparable estimates across different Baltic Sea subsystems. Further, the meeting refined the definition of productivity indicators. As the most important criteria, productivity indicators should have a measurable impact on the next trophic level, i.e.,, changes in indicator value cause significant measurable change of quantitative parameters on the next trophic level. Key species within trophic networks should be used as indicators. The group further reviewed the list of parameters currently monitored in the Baltic Sea with respect to their suitability as productivity indicators, and also discussed a few additional variables. Linked to productivity indicators selection was an overview of cost efficient monitoring methods to obtain Baltic Sea productivity data. Towed undulators, with a minimum sensor package of CTD, fluorometer, PAR sensor, autonomous plankton sampler, and dissolved oxygen sensor, could supplement measurements at a fixed station network and provide higher spatial coverage at given ship time. Fast repetition rate fluorometry was seen as an efficient way to replace ^{14}C measurements of primary production, which would then only be required for calibration purposes. The meeting also agreed that an efficient monitoring strategy should follow a multi-platform approach, including fixed station measurements, data from undulators, and satellite information. The meeting suggested forming a working group within the BSRP to apply statistical methods for defining a cost-effective sampling strategy for BSRP phase II. SGPROD also reviewed the work of the BSRP productivity module in 2004, especially the planned open sea and coastal survey work programs.

1 Opening of the meeting

The Chair, Bärbel Müller-Karulis, welcomed the participants to the meeting, which aims to provide scientific advice to the Baltic Sea Regional Project (BSRP) Productivity module. With its expertise, SGPROD assists in designing and implementing a productivity assessment strategy for ecosystem based management of the Baltic Sea.

Bärbel Müller-Karulis introduced the meeting agenda (Annex 6), which was adopted. The group agreed to form working groups to discuss Baltic Sea foodwebs (ToRs a and e), productivity indicators (ToR b), and cost effective productivity monitoring strategies (ToR c), as well as to review the BSRP productivity module work program (ToR d). Subgroup results were presented and discussed further in plenary. The report follows the organization of the meeting by subgroups and reflects the discussion of the terms of references.

2 Comparative analysis of Baltic Sea foodwebs

ToR a) describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;

ToR e) organize a BSRP training workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;

To prepare the analysis of Baltic Sea foodwebs, a workshop on ECOPATH modelling of Baltic Sea carbon and nutrient networks was arranged in Jūrmala (Latvia), 18–22 October 2004. Supported from the GEF-funded project “Promoting Ecosystem-based Approaches to Fisheries Conservation and LMEs" Villy Christensen and Sherman Lai (Fisheries Centre, University of British Columbia) taught the use of ECOPATH to 19 participants from Baltic Sea monitoring and research institutions. In the course of the workshop 10 ECOPATH models were constructed for foodwebs of open and coastal Baltic areas.

During the SGPROD meeting the participants reviewed the state of their carbon-based mass-balance models produced using the EWE (ECOPATH with ECOSIM) software during the ECOPATH-workshop in Jurmala, October 2004 (for full information on the models see http://sea.helcom.fi/dps/docs/folders/Baltic%20Sea%20Regional%20Project%20(BSRP).html). During the detailed discussion it became clear that most of the models need further improvement, especially with respect to the collection of reliable data for all compartments of the models. In consequence, the group considered the models as premature for a reliable description and comparison of the trophic networks between subareas. Additionally, the group expressed their caution against the identification of productivity indicators based on the knowledge gained during the modelling exercise. Nevertheless, the group conducted a preliminary description and comparison of the models available at the SG meeting.

Overview of the modelled networks

The developed mass-balance models covered a range of coastal and open Baltic areas. Two models covering the open Baltic waters were developed for two different periods: the 1980s and 1990s. The area described by this model comprised mainly the 3 deep basins of the Central Baltic Sea, i.e., the Bornholm Basin, the Gdansk Deep and the Gotland Basin. Another model, called the Gulf of Gdansk model, covers only the southern part of the central Baltic Proper, a part of the Gotland Deep and Gdansk Deep including the Gulf of Gdansk with the Vistula River outlet (about 11000 km^2 with the average depth of about 70 m, with the Gulf of Gdansk making about 20% of its total volume).

Other models focused primarily on coastal areas. Two models covered the open coast – one at the open Lithuanian coast (about 7000 km^2 area of the Lithuanian Economic Zone) and another model was situated in the Gulf of Riga (Ainazi - Dzeni region), located at the northeastern part of the Gulf of Riga with a total area of 46 km^2 and a mean depth of 5 m (the study site is a coastal zone with maximum depth of 10 m). Two other studies represented more enclosed coastal areas, one in Pärnu Bay - a shallow semi-enclosed water basin of the 700 km^2 and a depth between 7.5 and 23 m, and one in the Curonian Lagoon - a shallow lagoon (with the area of 1584 km^2 and an average depth 3.8 m) connected to the south-eastern Baltic Sea through a narrow strait.

Most of the models represented annual average trophic networks using average data from longer periods. The Baltic Proper model covered two decades separately, while the Gulf of Gdansk model used data from the period 1977–1998. The Lithuanian coast model is based on measurements between 1984 and 2003, the Pärnu Bay between 1993 and 2000, and the Curonian Lagoon between 1996 and 2004. Only the Ainazi - Dzeni region model was based on combined data for two summer months only, i.e., July-August during 1997–2003.

The main groups of species were phytoplankton, benthic producers, bacteria, microzooplankton, mesozooplankton, macrozooplankton, benthic meiofauna, benthic macrofauna, pisci/benthivorous and planktivorous fish, other vertebrates and detritus (particulate organic matter). The Baltic Proper model focused on pelagic groups and the zooplankton groups were detailed to the species level representing most important species. The model also included juvenile stages of main fish species as separate groups and seals as top predators. The other open sea model – the Gulf of Gdansk model was less resolved with respect to the pelagic groups and has no top predators, but otherwise it covered all major groups of pelagic and benthic species. The models covering the open Lithuanian coast and the open coast of the Gulf of Riga (Ainazi–Dzeni region) were close to the general model structure proposed during the

ECOPATH workshop in Jurmala (phytoplankton, benthic producers, bacteria, microzooplankton, mesozooplankton, macrozooplankton, benthic meiofauna, benthic macrofauna, pisci/benthivorous and planktivorous fish, other vertebrates and detritus (particulate organic matter). These models also included birds as top predators since they are expected to play an important role in the systems. Coastal models focused more on the benthic structure in their systems. The Curonian Lagoon model and the Pärnu Bay included various groups of zoobenthos.

Detailed description of the modelled networks

Ainazi - Dzeni area

The study site Ainazi–Dzeni is located in the NE part of the Gulf of Riga, close to the border with Estonia. The total area is about 46 km^2, with a mean depth of 5 m. The concentration of total P in the coastal zone (close to the river Daugava) fluctuated between 0.55 to 2.79 µmol/l, the concentration of total N - 21 to 91 µmol/l in summer.

The model includes 10 species groups and simulates trophic relationships in the period July-August. Average values of data collected during the time period 1997–2003 were used.

The following problems exist:

- Estimation of phytobenthos production and biomass in the modelled area. Using survey data only very low biomass of planktivorous fish exists in the system. Using these data the model could not be balanced and instead an ecotrophic efficiency (EE) of 0.95 was assumed for planktivores. The final model will be compared to other coastal models, e.g., Pärnu Bay.

Pärnu Bay

Pärnu Bay is located in the NE part of the Gulf of Riga and it is an eutrophic bay with a surface of about 700 km^2 and a mean depth less than 10 m. Most of the biomass data are annual means for the late 1990s sampled in the area. On the other hand most of the production and diet data are taken from published work in other areas of the Baltic Sea. The model includes 14 trophic groups. The input values to the model are presently very rough and further reformulation with data from other sources is needed.

Further extensive datasets are available for different groups from Pärnu Bay. These will be used to define seperate periods, potentially influenced by climate change, which allows the construction of separate models for the periods. Further, two important invasions of one pelagic (*Cercopagis pengoi*) and one benthic species (*Marenzelleria viridis*) approximately 15 years ago provide the possibility to compare pre and post invasion trophic interactions. Finally, three subareas (Pärnu, Tallinn, and Narva Bay) of Estonian coast have been monitored in last five years with the same methods and sampling frequency which allows the construction of area-based models.

Economic zone of Lithuania

The model comprises a 7000 km^2 area which is mainly (2/3 of the area) covered by sandy bottoms. The model includes 13 groups with the main photoautotrophs being phytoplankton and macrobenthos. The other groups except detritus are users, i.e., zooplankton, macrozoobenthos, mysids, fishes, birds and seals. The macrozoobenthos and fish compartments were split into functional groups, i.e., detritus and suspension feeders. The data represent averages from 1984 to 2003. The model imitates an exposed coast which is affected by inflowing water from the Curonian Lagoon.

The model is still not balanced (too high ecotrophic efficiency of mysids and planktivorous fish and detritophagous zoobenthos). Data on mysids are taken from the Gdansk Basin (Witek

1995) as local data were not available. In a future model we will exclude the mysid compartment and represent them in the fish diet as import. The high predation on planktivorous fish could be due to underestimated food sources for predatory fish, because non-commercial fish species were not included and will be modelled in a future version as import. The bird consumption per year will be checked and modified as the estimations in the model are based on wintering/migrating birds and no data on other birds were available.

There are no data about the export and exchange of organic matter between the study site and other open parts. One way to improve it could be the re-calculation of the import of organic matter from the Baltic Proper.

The Lithuanian economic zone comprises mainly coastal area and the open sea part constitutes the smaller part of it. The fish stocks and landing data are calculated as an average for all the area, but not as weighted averages for coastal and open regions. Differences between inshore and offshore fish communities and the fish catch composition are evident. So the model is still hardly comparable to other Baltic coastal areas. The suggested option is to restrict the modelled system to coastal zone and recalculate the fish stocks and landings adequately.

The final model will be compared to other coastal models for Ainazi - Dzeni or Pärnu Bay, equalizing the foodweb structures of models.

Curonian Lagoon

The Curonian Lagoon is a shallow transitory freshwater basin (average depth 3.5 m), connected to the south-eastern Baltic Sea through the narrow Klaipėda strait. The Curonian Lagoon phytoplankton dynamics follow a seasonal pattern typical for temperate freshwaters with diatoms dominating during the spring and cyanobacteria being generally dominant from late spring until the end of September, being sometimes abundant even until October. The green algae usually do not dominate the phytoplankton community, but are abundant from April to September. The seasonal succession of freshwater zooplankton is characterized by a sequence of dominant species: *Cyclops* spp. in spring until the mid-May, followed by *Daphnia* spp. until mid-July, and *Chydorus sphaericus* later. From the middle of September Cyclopoida start to dominate again. About 50 fish species live in the Curonian Lagoon; most common are roach (*Rutilus rutilus*), perch (*Perca fluviatilis*), redeye (*Scardinius erythrophalmus*), white bream (*Blicca bjoerkna*) and common bream (*Abramis brama*). Pike (*Esox lucius*), pike-perch (*Lucioperca lucioperca*) and eel (*Anguilla anguilla*) are also present in the lagoon. Ice fishing for smelt (*Osmerus eperlanus*) is very popular in the winter season. The bottom fauna is generally represented by sestonofagous species (chironomids, oligochaets) as well as suspension feeders of which the zebra mussel (*Dreissena polymorpha*) is the most abundant.

The ECOPATH model constructed for the pelagic part of the Curonian Lagoon comprises 19 compartments, 18 of those are living: 5 birds at species level, 3 fish, 5 benthos and 6 plankton groups. The network was quantified in carbon units per square meter per year. A general feature of the network is the low EE of phytoplankton (less than 0.5) and low predation of planktivorous fish on zooplankton, which is rather recycled in between 2 zooplankton compartments. The impact of water birds on fish populations is comparable to that exerted by the fishery. The reliability of the network quantification is generally acceptable except for two groups (bacteria and mysids) where consumption/production values are slightly too high. In future, the modelled network will be enlarged to 32 compartments including 16 fish (including 5 multistanza) groups.

In the future separate ECOPATH models will be developed to:

- compare two years with very different climatic conditions;
- compare periods with different cormorant populations; and
- compare trophic networks in 1960 (before the introduction of Ponto-Caspian crustaceans) and in 2000 (present conditions).

Gulf of Gdansk

The area studied was the western part of the Gdansk Basin – a subarea of the Baltic Proper – covering the Gulf of Gdansk with the Vistula River outlet, the Gdansk Deep and the south-western part of the Gotland Deep. The total area considered in the model covers about 11000 km^2 with an average depth of about 70 m, and the Gulf of Gdansk contributing about 20% of its total volume. The average annual primary production of this region ranges from about 190 g C/m^2 within the Gulf of Gdansk to about 150 g C/m^2 in the open waters. Species biomass and trophic interactions were described in the model after Witek (1995) who used data collected during 1977–88. The model structure is based on 11 trophic groups, both pelagic and demersal. There is one phytoplankton and one group of bacteria in the model. No phytobenthos is included in the model since it does not play an important role in the system, even along the coast which is mostly sandy. Zooplankton is divided into three groups: protozooplankon (ciliates, dinoglagellates and flagellates); mesozooplankon (with the main biomass components being *Acartia* ssp., *Pseudocalanus elongatus* and *Temora longicornis*) and macrozooplankton (the main species being *Mysis mixta*, *Neomysis integer*). There are three zoobenthos groups: meiofauna (mainly Nematoda), macrozoobenthos (non predatory) (main species being *Mytilus edulis*, *Macoma bathica*, *Cardium glaucum*, *Mya arenaria*) and predatory macrozoobenthos. Three groups of fish are considered: one group of planktonivorus fish (herring and sprat) one group of predatory fish – representing cod and one group representing demersal fish. Detritus stocks were approximated. The Vistula River was considered as an external source of organic matter.

The model needs to be refined with respect to more recent data on bacteria, detritus concentrations, fresh literature information e.g. on the production/biomass (P/B) ratio for different species has to be integrated and the description of the fishing fleet has to be updated. Also data from the 1990s can be introduced into the model for comparison with the present configuration for the 1970/1980 period. A possible future development could be a comparison between the open waters of the Baltic Proper and the coastal costal zone within the Gulf of Gdansk or the most enclosed and shallow area – the Puck Lagoon. Long term data on fish and zooplankton communities can be checked to find patterns of changes and to possibly attribute them to driving forces in the region, e.g., fishing pressure.

Baltic proper: 1980s vs. 1990s

The area described by this model, the Baltic proper, comprises mainly the 3 deep basins of the Central Baltic Sea, i.e., the Bornholm Basin, the Gdansk Deep and the Gotland Basin. The goal of the exercise was to reproduce the major changes in the pelagic part of the ecosystem at the end of the 1980s, commonly referred to as a climatically induced "regime shift" (Alheit *et al.,* 2004). Changes in temperature and salinity have caused dominance changes on all trophic levels, but especially in the fish and mesozooplankton communities (Köster *et al.* 2003, Möllmann *et al.* 2003). Generally, the ecosystem is characterized by 3 dominant commercially important fish species, i.e., cod, herring and sprat, while the mesozooplankton community is dominanted by the calanoid copepod *Pseudocalanus* sp. *Acartia* spp. and *Temora longicornis*.

We built contrasting foodweb models for the 1980s and 1990s to mimic the "regime-shift" at the end of the 1990s. The models incorporate a top-predator (seals) and 3 dominant fish species, which are split into juvenile and adult pools (cod, herring, and sprat). These fish species are the goal of important fisheries which were incorporated in the model as one fleet. Earlier mass-balance models for the area had only one compartment for mesozooplankton. However, as recent studies showed species-specific trends in the standing stocks and their responsiveness to climatically induced changes in the hydrography, we splitted this pool into six parts, i.e., 4 copepod groups (*Pseudocalanus* sp., *Acartia* spp., *Temora longicornis*, other copepods) as well as other mesozooplankton and cladocerans). Macrozooplankton is represented by mysids only, and one group of microzooplankton was incorporated. The benthic part of the ecosystem was split into Meio- and Macrobenthos. Beside the pelagic (Phytoplankton) and benthic primary producers, the model further comprises pelagic bacteria and a detritus group.

To mimic the regime shift we used decadal averages for:

- biomass and P/B (Z) for the fish species from Multispecies-Virtual-Population Analysis (MSVPA) outputs (ICES 2003);
- cod, herring and sprat diet and consumption based on stomach content time-series and gastric evacuation models (ICES 2003; Möllmann *et al.*, 2002, 2004a);
- mesozooplankton biomass derived from time-series of the Latvian Fisheries Research Institute (LatFRI) in Riga (e.g. Möllmann *et al.*, 2000);
- P/B for mesozooplankton from mortality estimates for copepods from field data derived in 2002/2003 in the Bornholm Basin (Möllmann *et al.*, 2004b); productivity in the different periods was adjusted relative to the observed biomasses;
- consumption of mesozooplankton calculated from production assuming a 1/3 gross growth efficiency (Kiørboe *et al.*, 1985).

All other information incorporated in the models was derived from earlier mass-balance models of the area (Jarre-Teichmann 1995; Harvey *et al.* 2003)

Balancing of the models required a number of adjustments in the input data:

- predation on adult and juvenile sprat by cod was always too high and was decreased via reducing their proportions in the cod diet;
- predation on microzooplankton appeared to be too high, which was corrected by adjusting the P/B of microzooplankton arbitrarily to a higher value (150 year-1) as well as by reducing their proportion in the diets of mesozooplankton species;
- predation on benthic producers by macrobenthos was too high, thus diet proportions were reduced.

In general the models reproduced the different foodwebs in the two modelled decades well. In the pelagic part of the ecosystem (which our modelling focused on) the copepod *Pseudocalanus* sp. and cladocerans clearly dominated the mesozooplankton during the 1980s. In the fish community adult herring and the cod stock contributed the highest biomasses. After the increase in temperature in the end of the 1980s and the parallel salinity decrease due to reduced inflow frequencies, species adapted to higher temperatures such as sprat, *Temora longicornis* and especially *Acartia* spp. increased drastically. In contrast "high salinity, low temperature species" such as cod and *Pseudocalanus* sp. decreased.

Although the balanced models reproduced the different foodwebs quite well, the models are very preliminary and a number of problems have to be solved, e.g.:

- The estimated primary production appeared to be high compared to other mass-balance model exercises for comparable areas, e.g., Sandberg *et al.* (2000) and Gulf of Gdansk model (this report). A further exploration of phytoplankton data (e.g. from HELCOM, satellite data) is needed to increase the reliability of the model.
- The mesozooplankton biomass used in our models is very high compared to older models, especially for the 1990s. A problem here could be the conversion of wet weight into carbon. Thus, species-specific conversion factors might increase the reliability data. These values will be checked and improved.

- A number of groups are not very well represented by presently available data; this relates especially to phytoplankton (as mentioned above), benthos and macrozooplankton. Also here further data exploration is needed, especially with respect to the two different periods. Until now the values for these groups are equal in both models and needed to be refined (if possible).

The final goal of this mass-balance modelling is to evaluate the effect of external forcing (such as fishery, climate, eutrophication) on the Central Baltic foodweb. Hence, after an evaluation and improvement of the used data, the ECOSIM simulation tool will be used to explore the relative effects of changes in fishing and environmental forcing (changes in temperature and salinity) in producing the observed ”regime-shift”. Therefore the 1980s-model will be used as a starting point and environmental forcing functions will be applied simulating the change in the environment.

Comparison of modelled networks with respect to productivity and functioning

The total primary production (Fig. 1) of the analyzed trophic networks varied in a range from 29 (Bothnian Bay) to 1800 g C/m²/year (Ainazi–Dzeni, Latvian coast). The latter value, however, should be treated with caution as it corresponds more to a macrophyte dominated biotope than a coastal ecosystem and should be fixed in that model later. The primary production values from the Baltic proper pelagic models appeared also to be too high and need to be checked in the future. Not surprisingly, flows to detritus (Figure 2) were highest in ecosystems with higher primary production, especially, where the benthic producers are important. The same is true for the total system throughput (Figure 3) following the primary production pattern. The P/B coefficients for primary producers are in a reasonable range except for the Lithuanian coast where this value appeared to be too low. System connectance (Figure 4) index being mainly determined by the level of taxonomic detail used to represent prey groups is the highest in the Curonian lagoon and the lowest in the Ainazi-Dzeni system. Gross efficiency (catch/net primary production.) (Figure 5) is the highest in the Gulf of Gdansk while being extremely low in the Ainazi-Dzeni system.

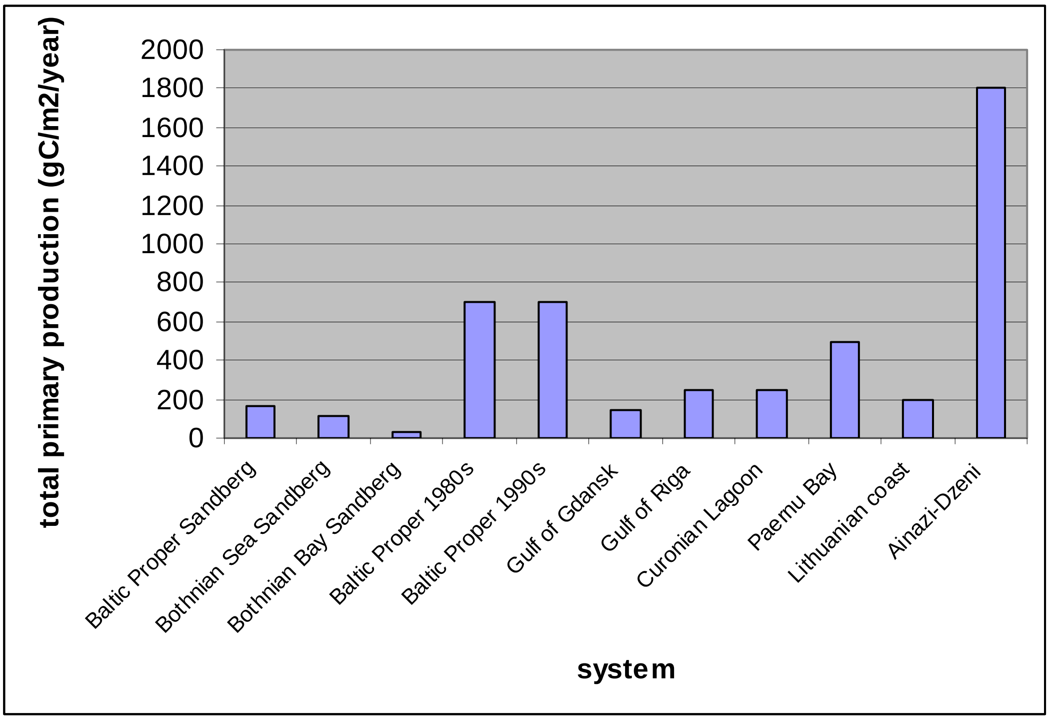

Figure 1. Total primary production in the modelled networks.

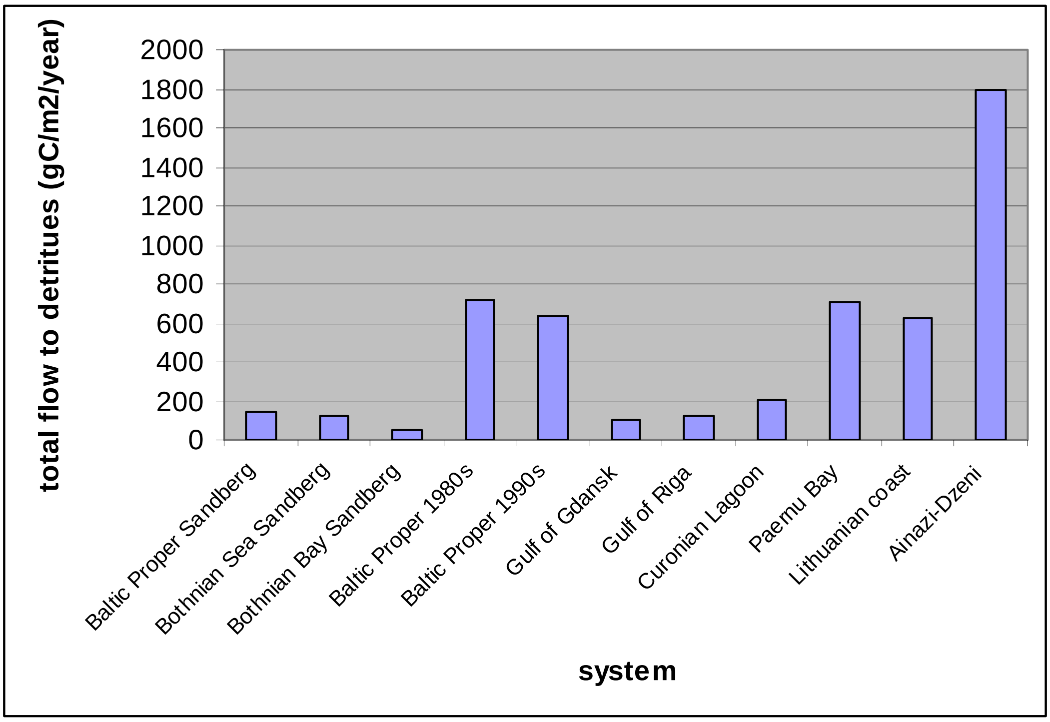

Figure 2. Total flow to detritus in the modelled networks.

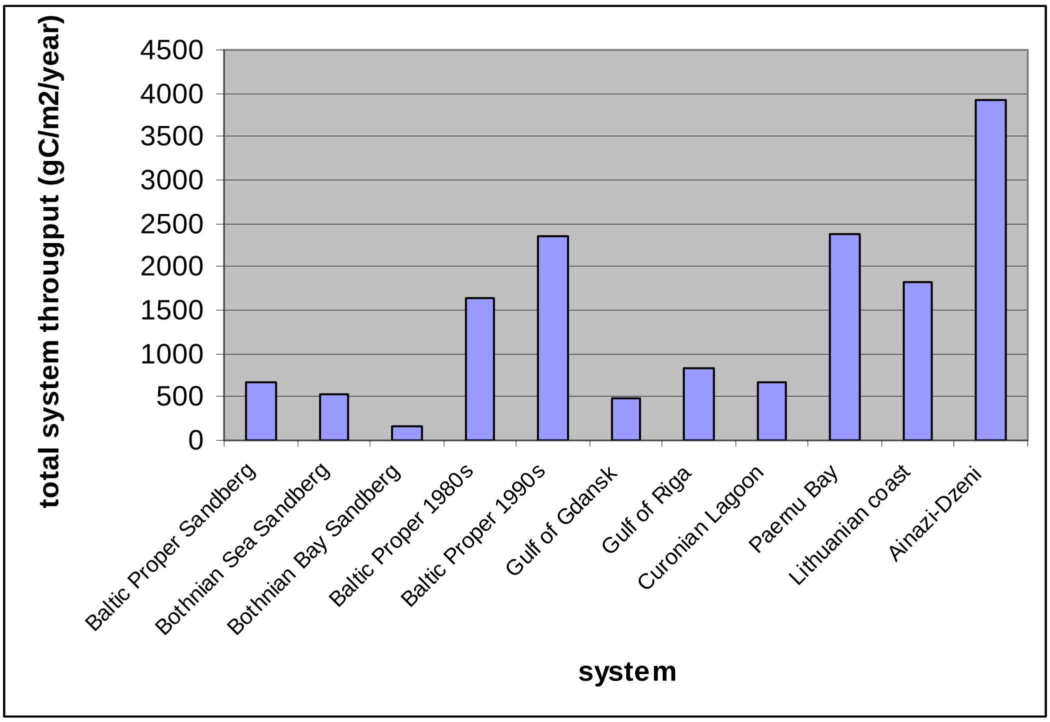

Figure 3. Total system throughput in the modelled networks.

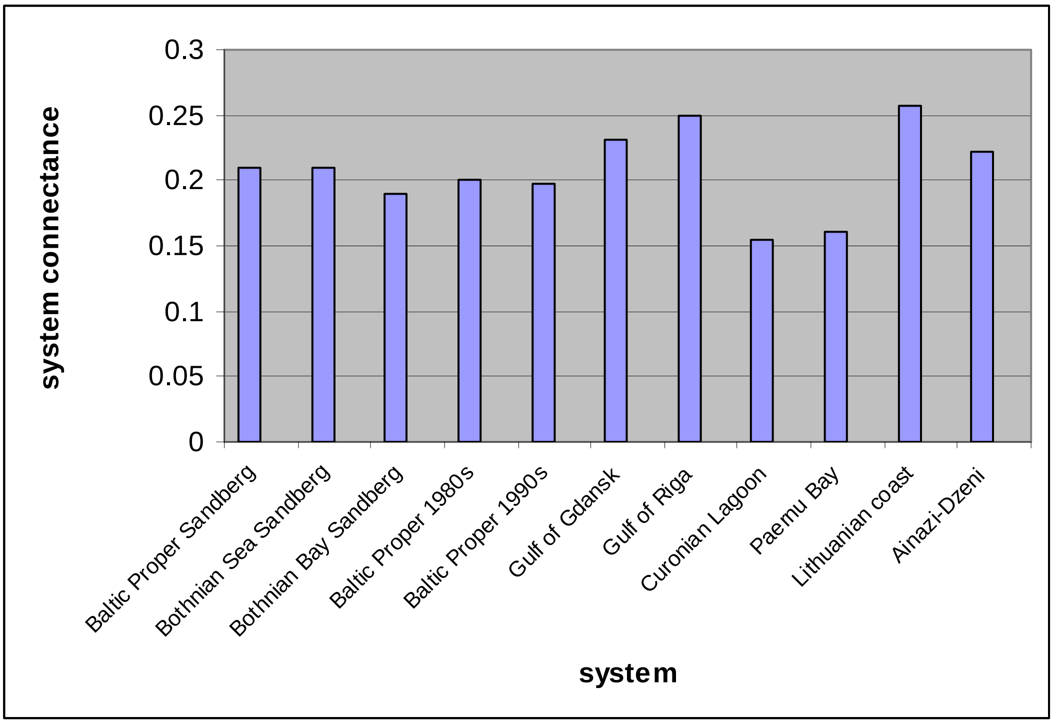

Figure 4. System connectance in the modelled networks.

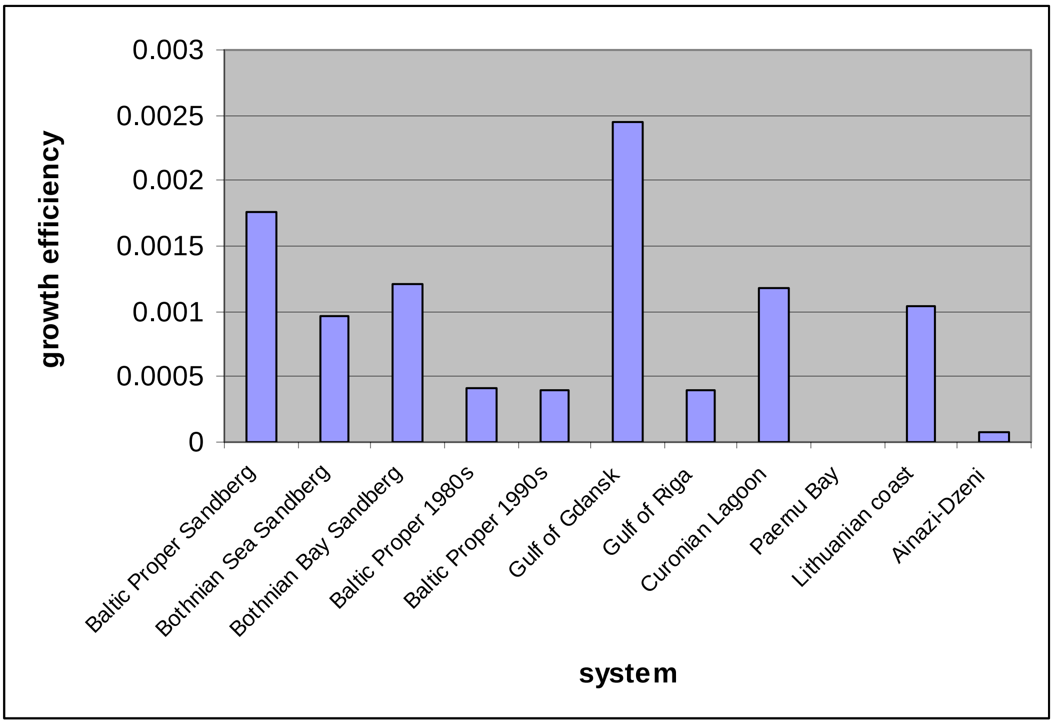

Figure 5. Growth efficiency in the modelled networks.

Important components, important flows

The comparison of the modelled systems should take into account differences between pelagic open sea systems and coastal systems that also include benthic compartments and where a significant share of primary production is restricted to macrophytes. So far many of the models still need significant improvement and deeper analysis will be possible only after refinements.

Potential productivity indicators

Total primary production (including also ratio between benthic and pelagic production) is one of the basic trophic characteristic and should be used as a productivity indicator. Plankton primary producers are far more important than benthic ones in terms of productivity since most of the benthic primary production goes directly to the detritus pool rather than being consumed by higher trophic levels.

Total biomass/total throughput ratio can be expected to increase for the most mature stages of a system and shows a recognizable trend of increase towards coastal systems vs. open sea. That could be further analyzed later after the model refinement.

Biomass of top predators could be quite important in terms of fish production.

Transfer efficiency from primary production to top predators should be also used as a productivity indicator.

Strategy for further work

During the meeting a strategy for the further work with the mass-balance models, especially with respect to the Theme Session on ”Impact of external forcing on marine trophic networks” at the ICES Annual Science Conference 2005 in Aberdeen (Scotland) was discussed (Co-Conveners B. Müller-Karulis, Arturas Razinkovas and Villy Christensen). It was especially indicated that papers to be submitted to the conference should address the influences of external forcing (such as eutrophication, fishery, climate change) on the foodwebs. Suggested ways to use the constructed static ECOPATH-models for the evaluation of the impact of external forcing are:

- use the sensitivity analysis procedure implemented in the ECOPATH software, i.e., changing the externally influenced variable (e.g., primary production) and evaluate the impact of the change on the system;
- construct separate models for periods known to significantly differ in an external forcing; e.g. periods of high an low fishing pressure, high and low eutrophication level, high and low temperature or salinity regime;
- construct seasonal models to show the varying influence of external forcing (e.g., fishery, temperature) on the foodweb;
- compare areas with differing external forcing, e.g. highly eutrophied coastal areas with oligotrophic open sea areas.

In addition to comparisons with static ECOPATH models, the ECOSIM-module of the ECOPATH software can be used to simulate the influence of external forcing on the trophic networks by fitting time-series of fishing mortality and environmental forcing to the models. This will allow to evaluate the relative impact of bottom-up and top-down processes on the development of the ecosystems.

A general goal of the mass-balance modelling exercise was to compare the carbon flows in all different foodwebs of the Baltic Sea. To enable a comparison of the different areas, a simplified foodweb structure was proposed, i.e., phytoplankton, benthic producers, bacteria, micro-, meso-, macrozooplankton, meio-, macrofauna, planktivores, pisci-/benthivores, other vertebrates and a fishery. For the final common analysis, all models will be reduced to this structure. Based on these exercises the most important compartments in the different subsystems will be identified and productivity indicators proposed, based on the knowledge gained by the modelling study.

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3 Productivity Indicators

ToR b) continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;

For the lower trophic levels, systematic data collection in the Baltic Sea is driven by the HELCOM COMBINE monitoring program and the requirements of the EU Water Framework Directive (WFD). Both programs do not aim to describe productivity, but are geared towards the assessment of eutrophication (HELCOM COMBINE part C) or, more general, the evaluation of ecological status (WFD). SGPROD reached a consensus, that productivity indicators should make maximum use of parameters already included into Baltic Sea monitoring. The group also agreed that eutrophication and productivity indicators partially overlap.

Discussion on the criteria for productivity indicator selection led to formulating four basic criteria. Indicators that specifically describe marine lower trophic level productivity should:

- Respond to productivity conditions, i.e., changes in productivity conditions (e.g., nutrient conditions) cause significant change in the indicator value.
- Have a measurable impact on the next trophic level, i.e., changes in indicator value cause significant measurable change of quantitative parameters on the next trophic level
- Be indicative of specific conditions, i.e., it should be possible to infer what changes in biotic and/or abiotic factors have caused the indicator response.
- Involve key species within a community, i.e., characterize changes in productivity conditions for most dominant or ecologically important taxa in the community.

To deal with the ToR, the topic was divided into two parts and two subgroups were formed, discussing the development of the indicator system (a) and the relationship to HELCOM/WFD/Fish stock assessment.

a) Development of a productivity indicator system

Piotr Margoński (BSRP Lead Laboratory on Zooplankton and Ichthyoplankton) presented an overview regarding the current status of zooplankton indicators issues. First of all, zooplankton is not included among relevant quality elements to be used for the assessment of ecological status in the EU WFD (Water Framework Directive, Annex V 1.1.). It is also not listed among the HELCOM Indicators in 2004, which were proposed to describe the state of the Baltic Sea environment. A similar list of OSPAR indicators also contains no zooplankton elements.

The ICES Working Group on Zooplankton Ecology (WGZE 2004) noted that OSPAR and EU WFD have not included zooplankton status measurements in their recommendations for monitoring. The ecosystem role of zooplankton, mediating phytoplankton and fish production, and modulating nutrient fluxes makes this decision seem short-sighted, especially given that policy drivers are calling for an ecosystem approach to marine management. There is growing recognition of the essential role that zooplankton plays in regional and global biogeochemical fluxes and cycles, mediating the transport and the balance of particulate and dissolved matter in the system. It was expressed during the 3rd International Zooplankton Production Symposium on the "role of zooplankton in global ecosystem dynamics: Comparative studies from the world oceans" that zooplankton monitoring would do much to reveal the quality status of the ecosystem, natural large-scale variability and regime shifts, and therefore, it was strongly suggested to include zooplankton monitoring in the EU water directive at the same level as phytoplankton and benthic monitoring (ICES 2003).

On the other hand, despite the evidence that plankton dynamics are linked to recruitment in fish stocks, there is considerable skepticism in the WGZE and in the scientific community in general about the derivation and use of indices and indicators. WGZE realized that it was tasked with the development of indices that were relevant and useful for fisheries management. Also, WGZE realized that generating indices required exploring multiple factors and associations, so required multivariate techniques or multi-parameter models to produce simple, repeatable indices. According to WGZE (2004), the most important threat is that such results may be wrongly interpreted or applied, when all the known and unknown variability is reduced to single figure indices.

There are many examples that zooplankton organisms, especially copepods, may have a strong impact on fish growth, survival and condition and therefore they might be useful productivity indicators. Jürgen Alheit stated that a substantial decrease of individual weight of herrings and sprats at high biomass documented in the Baltic Sea is likely to be caused by food (mainly copepod abundance) limitation in the Baltic Sea (GLOBEC-Germany project description). Copepods of the genus *Pseudocalanus* serve as a major food organism for larval fish, determining their growth and survival (Hinrichsen *et al.* 2002, Möllmann *et al.* 2003), but also for adult pelagic planktivorous fish such as sprat and herring (Möllmann and Köster 1999 and 2002). Recent analyses of the feeding habits of Baltic sprat demonstrate a strong preference for nauplii and copepodites of *Acartia* spp., particularly by their larvae. These copepod species thus form an important link between phytoplankton production and fish recruitment in the foodweb of the Baltic Sea (Voss *et al.* 2003). Results from simulations with a coupled hydrodynamical/trophodynamical individual-based model (IBM) on survival and growth of cod larvae revealed the occurrence of non-optimal feeding conditions for first-feeding larval stages in the Baltic Sea. For this larval stage, exclusively feeding on nauplii stages of calanoid copepods, pronounced differences in nutritional condition and survival were observed due to variability in ambient temperature and the encountered feeding environment. Especially the biomass of *Pseudocalanus elongatus* was found to be critical for cod larvae (Hinrichsen *et al.* 2002).

The Project MANTRA-East (Integrated Strategies for the *Man*agement of *Tra*nsboundary Waters on the Eastern European fringe – The pilot study of Lake Peipsi and its drainage basin) provided evidence that zooplankton might be among useful biological quality elements for the assessment of ecological status. The set of zooplankton indicators used in the case of Lake Peipsi included total zooplankton abundance (increasing with lake trophy), total zooplankton biomass (increasing with lake trophy), mean individual weight (decreasing during eutrophication), number of rotifers (increasing with lake trophy), biomass of rotifers (increasing with lake trophy), percentage of rotifers in total zooplankton abundance (increasing with lake trophy), percentage of rotifers in total zooplankton biomass (increasing with lake trophy), biomass of copepods (decreasing with lake trophy), percentage of *Daphnia* in crustacean biomass (decreasing with lake trophy), and zooplankton/phytoplankton ratio (Nõges T. *et al.* 2003). This ratio has been considered a highly informative eutrophication index. It adequately reflects the trophic state of a water body, decreasing with increasing trophy.

Similar parameters were efficiently used in the case of the Vistula Lagoon (Margoński *et al.* 2003), together with other indicators. In particular, *Brachionus angularis* abundance was among the most successful indicators of an increasing lagoon trophy (Fig. 6). Despite the fact that MANTRA-East indicators were used for ecological status assessment rather than for measuring productivity, the project proved that it is possible to identify valuable and useful zooplankton indicators.

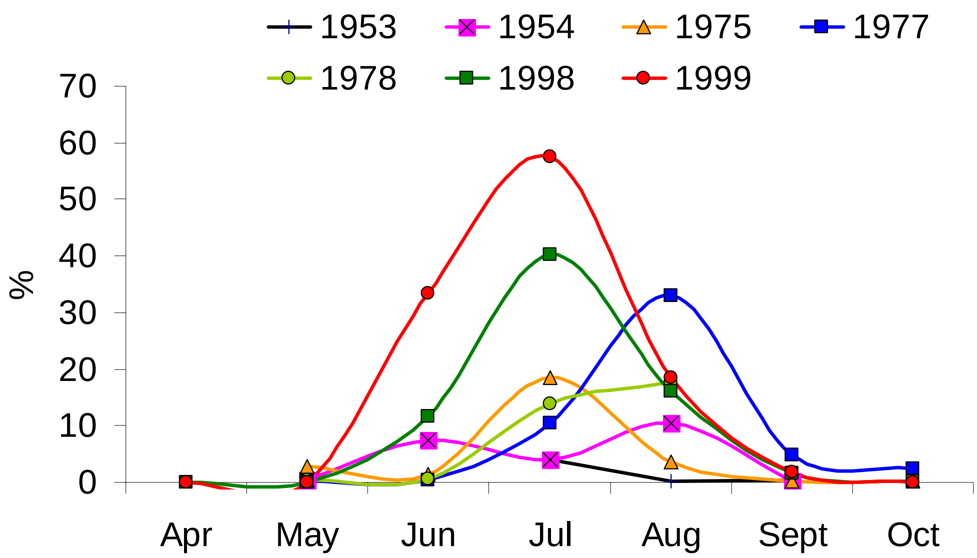

Figure 6. Percentage of *Brachionus angularis* in total zooplankton abundance in 1950s, 1970s and 1990s in the Polish part of the Vistula Lagoon (Margoński *et al.* 2003)

Lutz Postel (HELCOM MONAS Zooplankton Expert Network) provided a working paper regarding zooplankton parameters as useful indicators of productivity (Annex 2). Abundance and biomass might be an indicator of long term eutrophication processes. For example the Baltic Sea was known as an oligotrophic area until the middle of the last century. Then nutrient inputs from land increased drastically, resulting in a significant increase of all stock parameter starting with nutrients, via phytoplankton, zooplankton, and pelagic fish. Individual body mass provides important initial information for the calculation of production (P), respiration (R), and consumption (C) using individual specific P/B -, P/R- and R/C- ratios. Concerning temperature or salinity signals, there are some indicator species: *Pseudocalanus* spp. was substituted by *Arcatia* spp. in the long period of lower salinity in the central Baltic Sea before 1993 (Kononen *et al.*, 1996); *Acartia tonsa* is a typical warm water species mostly abundant during warm summer months (e.g., Arndt and Heidecke, 1973); *Bosmina* spp. indicate also warm summer seasons (Hernroth and Ackefors, 1979); and *Oithona similis* indicates effective renewal of deep water in Gotland Basin (Wasmund *et al.*, 2004).

Evaluating the seasonal production/consumption ratios (P/C) could be helpful to evaluate changes in the control of the system. For example the question whether diatoms regulate copepod production would require to compare diatom production (availability) to their consumption rate by copepods feeding on diatoms at the same time and place.

In order to identify ecosystem key species and processes a sensitivity analysis concerning various single influences on complex ecosystem level is needed.

Michael Olesen (Marine Biological Laboratory, University of Copenhagen) sent a paper describing the role of copepods in retention and remineralization of nutrients in the mixed layer (Annex 3).

The major part of Baltic Sea primary production is based on recycled nutrients. By comparing primary production data for the whole Baltic with figures of new production for different regions of the Baltic, it can be demonstrated that regenerated production makes up between 50 and 75 % of total production. Since copepods are the most important grazers on phytoplankton in the Baltic, the magnitude of regenerated production is likely to be tightly coupled to the presence of copepods.

Interesting fields for further work on this topic were proposed:

- studies on the interaction between copepods and primary production,
- studies on retention and degradation of matter processed by copepods,
- compilation of data for comparing the magnitude of regenerated production and the presence of zooplankton in stratified systems,
- studies of mechanisms regulating copepod dynamics.

b) Evaluation of HELCOM/WFD/EEA indicator list

To evaluate the suitability of indicators used in different ongoing monitoring and measurement schemes for usability in productivity monitoring it was decided to evaluate these indicators against the agreed productivity indicator selection criteria. The result of this exercise are presented in Table 1 and also summarized in the following section of the report:

Table 1: Productivity indicators (1: core variable, 2: main variable in supporting studies).

Variable/Substance	EU Water Framework Directive	HELCOM COMBINE	HELCOM Indicator reports	HELCOM EcoQO project[1]	EEA indicator reports[2]	BSRP productivity indicators		
						Productivity suitability	Purpose	Comments
HYDROGRAPHY								
Temperature	1	1	*			+	has an impact on species composition, stratification, growth rate of phyto-, zoo- and ichthyoplankton	whole water column
Salinity	1	1	*			+		
Oxygenation conditions	Oxygenation conditions	1	*	*	Oxygen in bottom layer	+	has an impact on species composition	low levels are important
H_2S	Oxygenation conditions	1	*	*		+		presence/absence is important
pH		2				-		
Alkalinity		2				-		
Transparency	1	1		*		+	limits the depth range and community structure of phytobenthos, limits the vertical distribution of phytoplankton	Secchi depth is a very common parameter, PAR is also very useful
NUTRIENTS								
$NO_3 + NO_2$	Nutrient conditions	1		Nutrient conditions	*	+	limits the level and nutritional quality as food for higher trophic levels of primary production	winter concentration mostly; limiting nutrient is important; NH_4 - indicator of recycling intensity
NH_4	Nutrient conditions	1		Nutrient conditions		+ (?)		
Tot-N	Nutrient conditions	1		Nutrient conditions		-		
PO_4	Nutrient conditions	1		Nutrient conditions	*	+		
Tot-P	Nutrient conditions	1		Nutrient conditions		-		
SiO_4		1		Nutrient conditions		+		
BIOLOGY								
Phytoplankton	Abundance, composition, biomass	Abundance, composition, biomass	*	Proportion of siliceous species, harmful algal blooms	Harmful species			
taxonomic composition						+	indicates the food quality; influence the flow of matter and energy	information on higher taxonomic groups and size classes is the most significant; as an indicator it needs to be combined with biomass
biomass						+	food quantity	needs to be combined with the information on taxonomic composition
bloom intensity and frequency						+	food quantity; it influences the flow of both matter and energy	high bloom intensity increases sedimentation and benthic production
internal nutrient content of phytoplankton						+	food quality	provides more specific information on food quality
Chlorophyll a		1	*	*	*	+	easy proxy of phytoplankton biomass	needs to be combined with information on taxonomic composition
Primary production		2				+	to assess production at the lowest trophic level	
Zooplankton		2						
abundance						+	food quantity for the next trophic level	population structure and mean weight of an individual are among useful measures; needs to be combined with information on taxonomic composition; zooplankton abundance and biomass in spring may be a useful indicator of potential productivity
biomass						+		
taxonomic composition and population structure						+	food quality for the next trophic level	particular copepodite stages should be treated separatly to enable cohort analysis
direct secondary production						+	in-situ growth assessment and food availability for the next level	bio-chemical markers; allometric methods

Table 1: Productivity indicators (1: core variable, 2: main variable in supporting studies). (Continued).

Variable/Substance	EU Water Framework Directive	HELCOM COMBINE	HELCOM Indicator reports	HELCOM EcoQO project[1]	EEA indicator reports[2]	BSRP productivity indicators		
						Productivity suitability	Purpose	Comments
Macrozoobenthos	Composition and abundance of benthic invertebrate fauna	Abundance, composition, biomass						
abundance						+	food quantity	needs to be combined with information on taxonomic composition; is especially relevant for the coastal areas; may influence the sedimentation in frontal areas
biomass						+		
taxonomic composition						+/-		only in connection with abunadance and biomass information
Phytobenthos	Composition and abundance of other aquatic flora	2						
total phytobenthos depth distribution						+/-		influences on productivity of the area, but not directly; creates nursery grounds and shelter areas for fish in coastal waters; grazing on phytobenthos is rather limited
coverage						+/-		
taxonomic composition						+/-		
internal nutrient content of phytobenthos						+/-		
Fish	Transitional waters	2			*	+	important for the overall production of the water body	
Non-indigenous species					*	-		is already covered by abundance and biomass measurements in general

Abiotic indicators:

Covered by current monitoring programs:

Salinity: Determines the existence and abundance of some important fish species in the Baltic Sea (Baltic herring, sprat and cod). Salinity influences zooplankton species composition and size distribution and therefore has an effect on herring productivity through the food quality. Phytoplankton is affected by changes in water column stratification.

Salinity effects occur in the whole water column and affect species composition, distribution growth rate of phyto- zoo- and ichtyoplankton.

Temperature: Temperature directly affects the growth rate of species. Some phytoplankton/ zooplankton/ichtyoplankton species prefer cold conditions, some benefit from warm water (e.g., diatoms in early spring, cyanobacteria in summer etc.). Temperature stratification determines the onset of the phytoplankton spring bloom, limits the supply of new nutrients to the upper layer in summer, and determines timing/occurance of autumn blooms. Temperature effects occur in the whole water column – impact on species composition through stratification, direct effects on growth rate of phyto-, zoo-, and ichtyoplankton.

Oxygen: Oxygen oversaturation is an indicator of high phytoplankton productivity, whereas low oxygen concentration indicate bad conditions. Low oxygen conditions mostly occur near the bottom and/or below the permanent halocline. Negative effects occur mostly for species spending parts of their life cycle in these regions, like macrozoobenthos and larvae of some fish species (e.g., cod). It was agreed that especially low levels of oxygen are important - oxygen conditions (deficiency) can have significant impact on species abundance and composition.

H_2S: presence is important – impact on species composition and abundance.

Transparency (Secchi depth): Limits the depth range and community structure of phytobenthos, limits the vertical distribution of the phytoplankton

Nutrients: Essential for primary producers. Higher supply of the growth limiting nutrient (N, P or Si) generally leads to higher phytoplankton and phytobenthos productivity.

Winter nutrient concentrations: Determine the intensity of phytoplankton spring bloom.

Similarly, nutrient concentrations in the layers below the summer thermocline are important for summer phytoplankton production as these nutrients are transported to the upper layers via coastal upwelling events (like in Gulf of Finland) or through several vertical transport mechanisms i.e., turbulent vertical transport or transports along the inclined isopycnals in frontal zones.

N:P, C:P ratios and nutrient limitation: determine the dominance of different phytoplankton groups, while the supply of the limiting nutrient controls the primary production. The limiting nutrient is most important as it limits the amount and nutritional quality of primary production as a food source for higher trophic levels.

Currently not included in monitoring programs:

PAR (Phtosynthetically Active Radiation): Would give better information for phytoplankton and phytobenthos depth distribution, and can also contribute to explaining the occurrence of cyanobacterial blooms during summer, but not commonly measured. Indicator with very high potential in the future due to very easy measurement procedure.

Biotic indicators:

Covered by current monitoring programs:

Phytoplankton:

Taxonomic composition: Indicates the food quality for secondary producers; influences the flow of matter and energy (export vs. retention). Information on higher taxonomic groups and/or size classes is most significant. Taxonomic composition needs to be combined with information on phytoplankton biomass.

Biomass: Indicates food quantity for secondary producers - needs to be combined with information on taxonomic composition due to food preferences of secondary producers and because of high export (sedimentation) of some species.

Bloom intensity and frequency: Phytoplankton blooms represent a mismatch between phytoplankton production and consumption in the euphotic zone. With the exception of cyanobacteria blooms, a large part of the bloom production is exported from the euphotic zone and provides high food quantity for the benthic organisms. Blooms therefore influence the flow of matter and energy. Generally, they do not have to mean high food quality, but they facilitate sedimentation of organic matter and hence result in higher benthic production. On the other hand, increased sedimentation of organic matter can also lead to negative effects – increased consumption of oxygen during decomposition processes and decreased light climate for benthic vegetation hence leading to unfavorable living conditions for the benthic fauna and decrease in the benthic flora.

Cyanobacteria blooms mostly decay in the upper part of the water column (Larsson *et al.* 2001). Cyanobacteria have been considered as low quality food for zooplankton because of poor nutritional value and toxicity (Ahlgren *et al.* 1992, DeMott *et al.* 1991), and their filamentous structure (Infante & Abella 1985). In the Baltic, negative effects on feeding, egg production and/or survival have been observed in copepods and mysids (Koski *et al.* 1999, Engström *et al.* 2001). On the other hand, a cyanobacteria bloom has been shown to be an active site for heterotrophic production: certain zooplankton species are able to feed and reproduce in a cyanobacteria bloom by feeding on flagellates and ciliates that thrive amongst the decaying cyanobacteria aggregates (Engström-Öst *et al.* 2002, Koski *et al.* 2002).

Chlorophyll *a*: easy proxy of phytoplankton biomass. Chlorophyll *a* needs to be combined with information on taxonomic composition

Primary production: the only direct phytoplankton productivity measure. Unfortunately primary production is very rarely used in present monitoring schemes, even though it is the most suitable indicator for phytoplankton productivity monitoring purposes. However, it also has to be taken into account that primary production is highly variable and measurements are for example influenced by, e.g., the light history of the plankton cells.

Zooplankton:

Abundance: Zooplankton abundance characterizes food quantity for higher trophic levels. It is especially important during spring when fish larvae are abundant in the water column. Zooplankton abundance should be combined with taxonomic composition/population structure and information on individual biomass.

Biomass: Zooplankton biomass describes food quantity for higher trophic levels. Population structure and mean individual biomass are useful measures and should be combined with the taxonomic composition.

Taxonomic composition and population structure: Describe food quality for higher trophic levels; should be combined with the biomass value. Moreover, cohort analysis based on population structure allows estimation of population growth and production, provided that sampling is carried out with high temporal frequency; it is therefore important to identify all copepodite stages to enable cohort analysis;

Secondary production: Describes the supply of food available for the next trophic level. Several methods are available to estimate secondary production - *in situ* growth assessment using bio-chemical markers (e.g., enzymes and nucleic acids, Dahlhoff, 2004), cohort analysis of a species following the development of distinctive cohorts, and allometric methods based on biomass specific growth rates, temperature-dependent empirical models, etc. Empirical methods for growth estimation should be calibrated and validated with growth experiments (e.g., egg production experiments).

Currently not included in monitoring programs:

Internal nutrient content of phytoplankton/zooplankton: Characterizes food quality in relation to consumer demands; this would provide better information on the feeding conditions for higher trophic levels and their growth limiting factors, because consumer growth is affected by the elemental composistion of resource. Zooplankton is known to react to nutritional quality of food by altering their feeding rate, food selection, growth efficiency and population growth rate (Sterner and Elser, 2002).

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4 Cost-effective productivity monitoring

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

4.1 Design of a monitoring program for the lower trophic levels

Mark Berman (US NOAA Narragansett Bay Laboratory) gave a presentation on monitoring strategies used in the US for assessing the lower trophic level of marine ecosystems. The US National Marine Fisheries Service MARMAP program, which assessed the US northeast continental shelf ecosystem, was also the first, prototype Large Marine Ecosystem (LME) study. During its ten year run, MARMAP sampled a grid of 180 stations up to 6 times per year, using traditional sampling techniques of vertical CTD casts, net tows and ^{14}C incubations. MARMAP was a major success in advancing knowledge of the ecology of the Northeast Shelf, but the large commitment of personnel and resources it required taught that more efficient sampling techniques were necessary to make the LME approach practical throughout the world.

The indicators study group at this meeting has developed an ambitious list of productivity indicators for the Baltic LME (see Section 4, table 1). Techniques will have to be identified to make measurements of these indicators cost effective.

4.2 Automated technolgies for *in situ* measurements

4.2.1 Measurement platforms

One technology that is already being used in the Baltic is the continuous plankton recorder (CPR) deployed from a ship of opportunity. The availability of the Autonomous Plankton Recorder, a motor driven device advancing the CPR net material which can use fine mesh Nitex as the filtering medium makes this useful for the small zooplankton prevalent in the Baltic

A second technology to consider is towed undulating samplers. These are platforms that can deploy large suites of instruments through the water column while being towed from a research vessel. The NuShuttle, ScanFish and Acrobat are good examples of this class.

Siegfried Krüger (IOW Warnemünde) provided a working document (Annex 4) regarding Towed Undulating Samplers. The ScanFish Mk II is a second generation of flying underwater wing with flap control of the EIVA A/S (Denmark). It is towed behind the vessel, undulating self-controlled downwards and upwards according to pre-programmed or from the deck unit transmitted tow parameters. In addition to the electronic and mechanical controls the ScanFish can be equipped with a broad range of sensors and samplers. Data are transferred on-line via the tow cable. Therefore, areas with complicated structures and high variability can be screened in a short time.

4.2.2 Sensors

Minimum proposed sensor package

The meeting agreed that for the Baltic a undulator should be equipped with a minimal instrument package including CTD, fluorometer, PAR sensor, autonomous plankton sampler, and dissolved oxygen electrode. Optional sensors could include an optical plankton counter (OPC), a nutrient sensor, and a fast repetition rate fluorometer (FRRF).

Fast repetition rate fluorometer (FRRF)

The FRRF uses variable fluorescence responses by the phytoplankton to directly measure primary productivity. US NOAA has good success with this, and the Finnish Institute of Marine Research has used it successfully in the Baltic. Its manufacturer, Chelsea Technologies, is willing to construct an instrument with an excitation wavelength suitable for the pigments in the Baltic phytoplankton (including cyanobacteria). Use of the FRRF will greatly reduce, or eliminate entirely the need for ^{14}C or oxygen incubations to measure primary productivity. The value of FRRF extends itself to a wide variety of applications from state-of-the-art research to local monitoring programs providing information of the photosynthetic activity, the true target size of the photosynthetic machinery, and the electron transfer rate. The system is fully applicable to water column measurements up to 500 m depth, and is sensitive enough for studies on natural phytoplankton populations. The FRRF measurement protocol allows measurements on dense scale (time lag between measurements ~ 1 to 2 s), and measuring can be performed *in situ* leaving the object intact.

The present optical set-up of the FRRF does not permit the meaningful mapping of the Baltic Sea cyanobacteria (it functions fine with eukaryotic algae), but this feature will be optional in future releases of the instrument. The FRRF approach of primary productivity measurement circumvents many features in the incubation-based PP measurements that have been seen as deficiencies in the measurement protocol. However, the use of the FRRF will function as the supplementary source of information of the algal photosynthetic dynamics, but the current understanding of the algal photophysiology, or rather; the lack of conversion of the current knowledge into to-the-point-tailored measurement systems prevents the use of FRRF as an stand-alone tool for primary productivity measurements. Hence, the ^{14}C or the oxygen incubations are still needed for primary productivity probing.

Newly developed nutrient sensors also make rapid, in situ characterization of a number of chemical species practical, but these systems have not been tested in the Baltic Sea yet. Narragansett Bay Laboratory is evaluating the SubChemPak system that can analyze 1 sample per second with very low (.01 µM) detection limits for nitrate/nitrite, ammonia, phosphate and silicate. There are also attempts to construct a system enabling pumping of water from the sampler through a special cable to the research vessel, providing sample material for nutrient and other analysis.

Optical plankton counter (OPC)

The OPC measures fine scale distribution of plankton sized particles in real time. It produces particle size-spectra, but no taxonomic information. Its lower detection limit (250 µm) might limit its utility in the Baltic. Interference from non-biological particles in shallow areas might also be a problem.

4.2.3 Monitoring strategy

The meeting agreed, that measurements from towed undulators cannot replace traditional monitoring of a fixed station network. For nutrient and plankton sampling an ordinary vertical station grid should be also available for single point measurements and quality assurance. On the other hand, given the same amount of ship-time, towed undulators can provide higher spatial coverage, producing continuous 2D or 3D coverage. The meeting also agreed, that an undulator for Baltic Sea monitoring should be a shared resource among several countries, with a dedicated team of technicians responsible for its maintenance and supervising its usage. SGPROD encouraged the BSRP to further investigate the technical possibilities for monitoring physical parameters (temperature, salinity), nutrients, phytoplankton (chlorophyll *a*), primary production, and zooplankton using towed undulators.

Finally, remote sensing of both temperature and ocean color from satellites could be useful in the Baltic. Despite the limited number of cloud free days this data stream could be quite useful because of its true synopticity, and low cost. Specific algorithms for interpreting Baltic data will need to be developed further; the current state of algorithm development for chlorophyll a is summarized in HELCOM, 2004.

An intriguing possibility is combining data from an undulator and satellite to produce a synoptic three dimensional picture of Baltic productivity.

4.3 Use of remote sensing for productivity monitoring

Kati Tahvonen (Finnish Environment Institute) gave an overview of remote sensing activities at her institute, which is active in the field of operative near-real time monitoring of the Baltic Sea. At the moment the Finnish Environment Institute (SYKE) routinely produces Sea Surface Temperature (SST), algae bloom intensity and snow melt maps. Land cover inventory and monitoring is also included in the operative products. SYKE's remote sensing research focuses on water quality monitoring (e.g., turbidity, chlorophyll-*a*), snow, land cover, oil spills, SST and phenology.

Sea Surface Temperature maps are calculated daily from May to October. In case of extremely cloudy conditions no data are available. The results are published on SYKE's web pages (see below) and in late summer 2004 the data were also distributed in numeric form via the BOOS data delivery network. Algae bloom maps indicating surface algae intensity, are also calculated daily from July to August. The images are used as additional information for weekly national algae reports. The resulting maps are also available on the SYKE web pages.

SYKE's current research aims to provide operational products, including chlorophyll-a and turbidity. In 2005, production of turbidity maps will be tested as a preoperational product.

Related web pages:

Remote Sensing activities in SYKE:
http://www.ymparisto.fi/default.asp?contentid=92697&lan=fi&clan=en

Sea Surface Temperature maps:
http://www.ymparisto.fi/default.asp?node=11779&lan=en

Surface algae bloom maps:
http://www.ymparisto.fi/default.asp?contentid=70628&clan=EN

Snow covered area maps:
http://www.ymparisto.fi/default.asp?node=11777&lan=en

In 2004 SYKE conducted a questionnaire considering the use of remote sensing directed to Finnish professionals working on sea and lake water quality. The main goal of the survey was to specify the need for operative remote sensing data – what kind, how often and in what format the data is needed. At the same time questions concerning accuracy, modelling and GIS–systems were asked. Altogether 150 answers were received, with most of the respondents interested in lakes. Some preliminary results were presented for the participants in SGPROD. For example, according to the people working mostly with marine areas, the most desirable parameters observed by remote sensing would be: chlorophyll-*a*, location of surface algae, secchi depth and sea surface temperature.

Seppo Kaitala (Finnish Institute of Marine Research, FIMR) gave an overview of remote sensing activities at FIMR. Conventionally chlorophyll-*a* estimates are obtained from satellite data using empirical reflectance ratios. High concentrations of coloured dissolved organic matter (CDOM) and high turbidity due to high contents of suspended matter make the predictions more difficult. Also the specific structure of phytoplankton communities, e.g., in the case of blue-green algae blooms, create extra challenge for predictions. In these multicomponent cases more complex hyperspectral models are needed.

At FIMR multivariate calibration was applied to validate MODIS satellite data against automated fluorescence records of chlorophyll-*a* on board the ferry Finnpartner with regular route from Travemünde (Germany) to Helsinki (Alg@line data). Partial least square (PLS) regression analysis was used to validate chlorophyll-a records against satellite data with a spatial resolution of 1 km.

Satellite data was received from the NASA GES Distributed Active Archive Center (DAAC) Data Pool through Internet in L1b format. Cloud masks were loaded as Level 2 Cloud Mask (MOD35 L2, http://daac.gsfc.nasa.gov/data/datapool/). Data for each band were extracted with HDFLook-Modis software and further analyzed together with chlorophyll-a data using GRASS GIS (Geographic Resources Analysis Support System) software (http://grass.navicon.dk/index.html). Statistical analysis was done with the PLS and PCR package in the R statistical software (http://www.r-project.org/). PLS analysis showed that only bands with wavelengths from 562 to 920 nm (i.e., b11, b12, b13L, b13H, b14L, b14H, b15, b16, b17) contributed to the chlorophyll-avariance. R^2 reached 72 % with 6 latent variables recommended for modelling.

Bärbel Müller-Karulis presented the results of a questionnaire concerning the use of remote sensing data in Baltic Sea marine monitoring (http://sea.helcom.fi/dps/docs/folders/ Baltic%20Sea%20Regional%20Project%20(BSRP).html). Only two institutes involved in marine environmental monitoring in the BSRP beneficiary countries have started to develop access to remotely sensed information (Center of Marine Research/Lithuania, Institute of Meteorology and Water Management/Poland). Monitoring organizations in Estonia, Latvia, and Russia currently do not use satellite information. Baltic Sea monitoring organizations apply remotely sensed information mostly in the context of chlorophyll *a* and algal bloom mapping. Integration of these data into environmental assessments is at an initial stage in the BSRP beneficiary countries, but more advanced in "western" countries. Cost of equipment and data are claimed as the main obstacles in the beneficiary countries. As satellite data can in many cases be downloaded for free, also lack of information seems to play a role. All institutes involved in using remotely sensed information plan to continue or to expand their activities, while institutes that have not developed data access so far, have not stated future plans. Respondents to the questionnaire welcome BSRP funding for equipment and data. Activities to increase the networking between institutes were considered almost equally important. Technical training is needed by institutes in the initial stage of developing their access to remotely sensed information. A potential role of the BSRP might be promotion of the remotely sensed (satellite) information use in various aspects of scientific research and practical applications among scientists and decision-makers in the Baltic Sea region.

The meeting further discussed perspectives for the use of remote sensing in Baltic Sea productivity monitoring. Chlorophyll *a* and sea surface temperature, but also sea surface winds and cloud cover were perceived as useful satellite products. With respect to monitoring of phytoplankton, effort should also be put in distinguishing different kind of algae groups based on multispectral analysis of the satellite information. Availability and reliability of algorithms converting the satellite signal into chlorophyll *a* units was perceived as a problem. Presenting processed data, the underlying algorithms should be documented. Networking between institutes processing satellite data and the end-users is needed to drive improvements of processing algorithms and to provide field measurements as calibration data.

A major obstacle to the use of remote sensing information in Baltic productivity monitoring is the frequent cloud cover. The number of cloud free images is – depending on area and weather patterns - generally about 20 scenes within the productive season. This limits the usability of satellite information for generating time series data. For the same reason remote sensing cannot replace ship-board measurements of for example surface chlorophyll *a*.

As much remote sensing data is available without charge and can be downloaded from the internet (e.g., MODIS data), raw data and processed images can in principle be exchanged freely. The meeting therefore agreed that all organizations involved in marine monitoring would benefit from increased networking to exchange products derived from satellite data. For example SYKE would be very interested to co-operate with specialists on, e.g., productivity monitoring and get feedback from the end-users of the remote sensing information. Data should be available both as raw and processed information, providing thematic rasters for the

Baltic Sea marine areas. Processed data should be accompanied by a description of the underlying algorithm and an accuracy assessment of the product derived. Technically, data and products (processed maps) could be exchanged via internet in form of maps (intenet mapping service) or as numerical data. Data transfer could for example be arranged by ftp. A metadatabase that describes the available information, provides preview pictures, and/or predefined queries for cloud-free images of specific areas, would make the use of remote sensing data and products more efficient. Prerequisite for increased exchange of remote sensing data, processed images, and ground-truth calibration data, is a data policy regulating the further use of the exchanged information.

The BSRP should follow a dual strategy in supporting the use of remote sensing in productivity monitoring. As resources among the monitoring organizations are limited, the BSRP should support networking and exchange of satellite products between institutes. Further, the BSRP should provide training opportunities for interested scientists from BSRP beneficiary countries in processing and interpreting satellite data. Special emphasis should be put on low-cost initiatives, making – as far as possible - use of standard PC equipment and open source software.

4.4 Cost-effective Multi-platform monitoring approach for the Baltic Sea

Experience in cost-effective design of monitoring networks in the Baltic Sea is mainly available from projects dealing with operational oceanographic observation networks. **Jun She** (Danish Meteorological Institute) gave a presentation on cost-effective monitoring network design for the Baltic Sea, based on the results of the EU funded ODON project.

ODON is a fundamental research project on designing basin-scale cost-effective monitoring networks, funded by the EU FP5th program. The aim of the project is to develop quantitative methods for optimal observing system design and apply these methods for optimising the Baltic-North Sea temperature and salinity monitoring networks. The project started from 2003. During the past two years, a multi-indicator approach has been developed for quantitative assessment of monitoring networks and applied to satellite-in situ SST monitoring networks. This includes quantitative assessment of data quality, sampling uncertainty, effective coverage, field reconstruction error by using Optimal Interpolation (OI), Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs), and cost estimation. Other progresses include: historical database, operational gridded daily Sea Surface Temperature (SST) maps, parallelisation of European community model COHERENS, implementing and testing data assimilation schemes (Simplified Kalman Filter, OI and Ensemble Kalman Filter) in operational models POLCOMS, COHERENS, HIROMB and BSHcmod (running at Danish Meteorological Institute), high resolution modelling (1 nautical mile resolution for Baltic and North Sea) and sensitivity studies of SST with different quality of numerical weather forecast. The implications of these achievements on regional operational forecasting are also discussed.

In this presentation, an example is given for how to use the multi-indicator method to quantitatively assess existing satellite-in situ SST monitoring network in the Baltic Sea. This study focuses on 1) overall performance of existing SST observing networks; 2) relative importance of different observing networks (observing networks with 1, 2, 3 satellites, with or without in-situ observations); and 3) impacts of network quality factors, e.g., data coverage, data quality and reconstruction methods, on the assessment results.

In order to assess the overall performance of the existing SST observing networks and relative importance of different observing networks (observing networks with 1, 2, 3 satellites, with or without in-situ observations), a number of SST observing networks were set up. The assessment was then performed for these networks. Firstly data quality from satellite and in-situ measurements (GTS, Ferrybox, CTD cast, undulated profiler and buoys) was evaluated. Then the spatial distribution of the spatial-temporal scales of SST was estimated. Based on the scales estimated, the effective coverage of a variety of observation network configurations was calculated. Finally, spatial-temporal distribution of the field construction error of SST gridded products was estimated for the configured SST monitoring networks.

The results show that the best SST product is generated by assimilating the SST observations, with a yearly mean model bias of 0.07 ^{o}C and RMSE of 0.64 ^{o}C. The effective data coverage rate is 31% by using 3 NOAA AVHRR satellites 12, 14 and 16. The data redundancy increases rapidly with the number of infrared sensors. The difference of the effective coverage, field construction error and the ocean model nowcast error between one satellite (NOAA 12) and 3 satellites (NOAA 12+14+16) are all small. The influence of the in-situ SST observations is negligibly small. It is shown that the data coverage is the most important factor in improving the quality of the SST gridded products. Data quality and the field reconstruction method also contribute to the quality of the final SST products. Recommendations were made for possible further improvements of the existing SST monitoring networks.

SGRPOD further discussed, how the knowledge available from the ODON project could be transferred to Baltic Sea productivity and environmental monitoring. The group suggested forming a working group within the BSRP to study the optimal design for a Baltic Sea environment monitoring network. The objectives of this working group would be to evaluate the **capability of existing networks** in describing indicators used by HELCOM and the BSRP Ecosystem Health and Productivity modules in assessing the state of the Baltic Sea ecosystem, and to give recommendations for cost-effective monitoring strategies.

Work should be focused on:

- **Cost-effective technology** (including cost-function evaluation) for BSRP Phase II monitoring activity and for Baltic environmental monitoring Alternatives and supplements to "traditional" ship-board measurements should be described and the associated costs should be estimated.
- **Effective coverage** of existing Baltic (HELCOM) network for monitoring eutrophication and its effects
  This gives a quantitative estimation of representativeness of the existing network based on local scales. For areas not effectively covered, assessment reports should be used with caution.
- Cost-effective sampling strategy for BSRP Phase II (i.e., where and when to sample?)
  Based on monitoring priority and possible funding scale for the monitoring in the BSRP Phase II, a cost-effective sampling strategy for open sea activities in BSRP Phase II should be designed, addressing sampling location and timing. The designed sampling network aims to reach the maximum effective coverage and the best quality of information products by using giving funding.
- Recommendations for **harmonising existing HELCOM environmental monitoring networks**

SGPROD agreed that a working group on the optimal design of a monitoring network would be an important step to prepare BSRP phase II, as well as an important contribution to improve the ongoing Baltic Sea environmental monitoring and assessment, especially if activities were linked with ongoing HELCOM work on restructuring Baltic Sea monitoring.

4.5 Data handling

HIRIS – A High Resolution Information System for the Baltic Sea Regional Project

A new concept of *High Resolution Information System* HIRIS is currently under development in the GIS Group of the Institute of Ecology (Vilnius University). We suggest a new *Pseudo Raster GIS technology* for accumulation and management of spatial data, which would allow to harmonize, accumulate and analyze spatially referenced digital information from standard GIS/RS data sources, as well as point-based field measurements.

The primary purpose of the HIRIS system is providing data for complex analysis and modelling of state and dynamics of coastal and marine ecosystems, environmental impact assessment (EIA) and regional development studies, management of emergency situations and research on global change processes in the Baltic Sea area.

This unique spatial information management technology, which allows development not only of regional, but also global spatial data coverages, is now being tested on a pilot database called HIRIS-Baltic GIS, covering the Baltic Sea drainage area.

Concept

- *Pseudo-raster GIS data layers* contain automatically generated coverages of regularly spaced and topologically clean rectangular polygon objects in geographic coordinates (WGS84), i.e., not projected into any plain CRS;
- *GIS data processing and analysis routines* automatically produce geometric objects, compute their values and fill in (or update) corresponding fields in *external attribute databases*. Therefore structural harmonizing of spatial information is ensured independently of source, origin and format of the spatial data input;
- *Universal HIRIS Object ID system* ensures direct link between pseudo-raster GIS coverages and external attribute data tables, making it possible to link any selected numeric data records and perform thematic and spatial queries of any level of complexity. Structure of the attribute data remains open and unlimited – both permanent and temporary data fields are stored in the system;
- Numeric data accumulated in external attribute data tables allows complex analysis and modelling procedures to be carried out independently from the GIS component. Therefore HIRIS system is made *independent of any operating system and GIS software restrictions*.

Features

- A universal HIRIS object ID coding system allows identification of single polygon objects from pseudo-raster coverages produced at any standard resolution in any place of the World, linking them to corresponding records in external attribute data bases;
- Open thematic structure of external attribute databases allows unlimited extension of thematic structure and flexible management of accumulated data to satisfy actual information requirements of a certain analysis;
- The HIRIS technology has virtually no limitations on spatial resolution of pseudo-raster coverages and external attribute data bases (within hardware and software capacities, as well as spatial resolution of existing GIS data sets). The HIRIS-Baltic GIS database is now being tested on peak grid resolution of 30”x30” (~5.4 mln. pseudo-raster objects);
- Testing of HIRIS-Baltic system demonstrated, that even complex spatial queries and analysis can be processed in a fairly short time, which allows the system to be used for near-real-time GIS data processing solutions.

Functionality

- Cross-referenced index tables of HIRIS attribute databases will support bi-directional links and complex queries relating processed attribute data and pseudo-raster GIS coverages of different spatial resolutions.
- Any combination of spatially related features will be accessible for display, high-level computations and analysis, providing an excellent background for building complex Decision Support Systems.
- HIRIS databases will be available as structured data sources for any scientific analysis and modelling exercises – from simple descriptive statistics to multi-factor analysis, data mining, neural networks, etc.
- It will be possible to serve information from HIRIS databases on the internet. Clients will not have to search for and download any spatial objects during their queries – they will have indexed pseudo-raster grids on their computers in preferred formats and spatial extents.
- Computing and analytical operations will be performed only on attribute databases – independently of platform and software applications used by the clients. Pseudo-raster coverages will only be necessary for display of the results.

Status

Currently the core pseudo-raster layers of the HIRIS-Baltic system are completed and quality-tested. The HIRIS_ID component is still under development. The main technical problem to solve is finding an appropriate (preferably, an open-source) database management system solution able of handling very large attribute databases linked to GIS coverages and operating at a reasonable speed. Our attention is being concentrated on MySQL and PostgreSQL DBMSs. Another issue is fast and reliable geoprocessing of very large GIS data layers into the HIRIS system. Field testing suggests that ArcGIS version 9, which does geoprocessing operations on ArcInfo Workstation level, seems to be the most appropriate technical solution.

Further discussion on the user requirements within SGPROD resulted in a checklist of issues a Baltic data handling system – i.e., the HIRIS GIS - should address with respect to marine applications.

- Easy access to data
  Database should be easy to use, data access should be fast. The system should handle direct data queries, as well as provide a graphical, map-based user interface.
- Integration of different data sources
  Database should be able to handle point data, vertical profiles (e.g., CTD data), as well as area data (e.g., satellite data). The database should also provide links to other data sources, e.g., to the BOOS data exchange system and to Baltic Sea model data.
- Quality assurance
  Data must be quality controlled and information on data quality must be accessible. This should also include meta-information on the spatial representativeness of the data.
- Data processing tools
  The data handling system should include tools for creating a variety of products, for example geostatistical interpolation features for creation of maps from point data, tools for calculating substance budgets, as well as tools for time integration and creation of time series.
- Link to models
  The data handling system should allow efficient links between database and models, e.g., to foodweb models, spatial ECOPATH models, hydrodynamic models, and biogeochemical models.

References

HELCOM, 2004. Thematic Report on Validation of Algorithms for Chlorophyll *a* Retrieval from Satellite Data of the Baltic Sea Area. BSEP No. 94.

5 BSRP Work program

ToR d) identify gaps in and suggest improvements to the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators.

5.1 BSRP Productivity module activities in 2004

Bärbel Müller-Karulis, as the BSRP local project manager for the Productivity Coordination Center, gave an overview of activities in the BSRP Productivity Module. The BSRP **Project Implementation and Procurement Plan (PIP)** calls for near shore and open sea activities, as well as institutional and technical capacity building. Relevant for the ToRs of SGPROD is mainly the data collection strategy in the planned coastal and open sea surveys work programs, which will be discussed in detail. Other activities within the Productivity module in 2004 were

- Planning for a ship of opportunity (SOOP) line between Gdynia and Karlskrona

The BSRP Lead Laboratory on SOOP initiated a call for expression of interest among organizations in the southern part of the Baltic Sea to establish a SOOP line crossing the southern part of the Baltic Proper, carrying also a continuous plankton recorder (CPR). As a result, the Institute of Meteorology and Water Management (Poland) in cooperation with the Swedish Meteorological and Hydrological Institute and Stena Lines will establish a SOOP line between Gdynia and Karlskrona. Procurement and installation of equipment will be carried out in 2005.

- Equipment upgrades

The Productivity Coordination Center issues a call for expression of interests to institutes involved in HELCOM COMBINE monitoring of eutrophication to assess the need for equipment upgrades. Among the equipment requested were CTD probes, microscopes, spectrophotometers, and water sampling equipment. In total, USD > 328 000 were requested, and procurement will be started for USD 135 000.

- Capacity building

Activities focused on intensifying participation in ICES study and working groups, on promoting the use of remote sensing in productivity monitoring, and on the ECOPATH workshop. A questionnaire was distributed to ICES working and study group chairs to query BSRP beneficiary country representation in the group and to announce BSRP financial support for participants form the BSRP beneficiary countries. Participation in ICES work was considered appropriate in groups dealing with fishery issues and in groups concerned with environmental monitoring and assessment. More research oriented groups complained about low membership from BSRP beneficiary countries (see also http://sea.helcom.fi/dps/docs/folders/Baltic%20Sea%20Regional%20Project%20(BSRP).html). Similarly, a questionnaire was distributed to organizations involved in HELCOM COMBINE monitoring assessing the use of remote sensing and the needs for support and training (see also Section 5.3). Also the ECOPATH workshop (see Section 3) was partially a training and capacity building activity.

5.2 Coastal survey work program

Coastal activities within the BSRP Productivity module were kicked off with a joint BSRP workshop on strategic design of phytobenthos, water quality and productivity monitoring in the coastal zone, organized by the BSRP Lead Laboratory on Phytobenthos monitoring and the BSRP Productivity Coordination Center (http://sea.helcom.fi/dps/docs/folders/Baltic%20Sea%20Regional%20Project%20(BSRP).html).

The workshop discussed the state of phytobenthos monitoring in the BSRP beneficiary countries, presented different indicator systems in use for coastal zone management (e.g., EU Water Framework Directive, US EPA index/classification system), and introduced a workplan for the BSRP Productivity module coastal zone activities.

Coastal activities are planned around a network or pilot study sites. For these sites a suite of tools for ecosystem based coastal zone management should be established, including (Fig. 7)

- Assessment of external forcing;
- Study of ecosystem dynamics, using ECOPATH modelling;
- Development of management tools, indicators and ecological quality classes.

Pilot monitoring surveys to test proposed indicators and classification system are planned during pilot monitoring surveys for phytobenthos and pelagic productivity parameters in summer 2005.

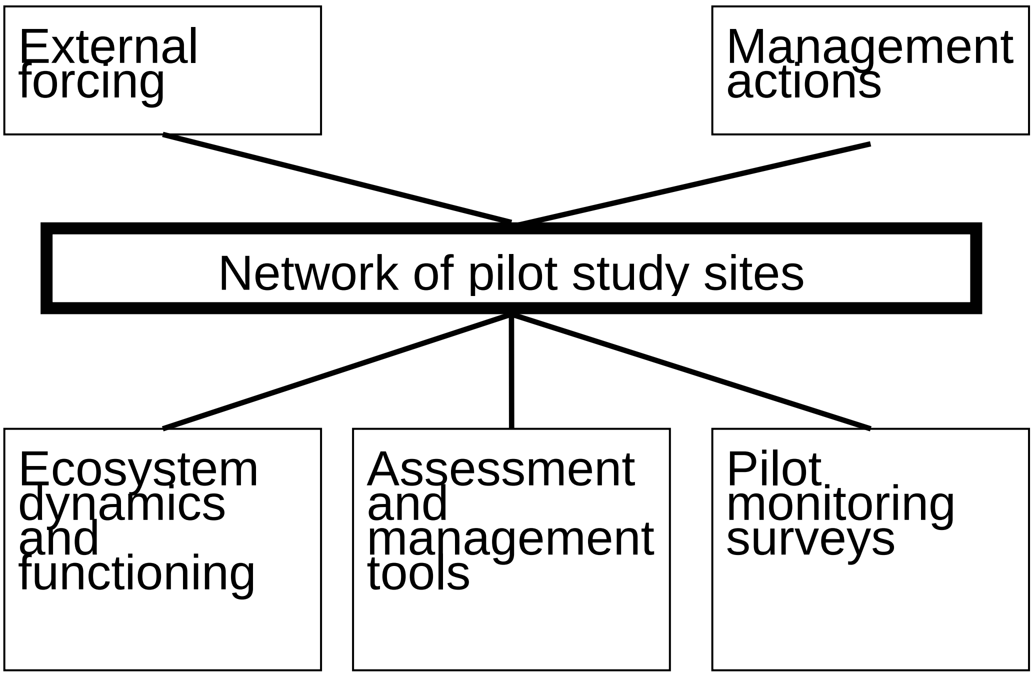


Figure 7: BSRP Productivity module coastal zone work program

According to this workplan, a network of pilot study sites have been established in all BSRP beneficiary countries (Fig. 8). Background information, comprising a description of the study site ecosystem, known anthropogenic pressures, and existing monitoring and assessment programs, including established indicator systems, was collected (http://sea.helcom.fi/dps/docs/folders/Baltic%20Sea%20Regional%20Project%20(BSRP).html). ECOPATH models of all study sites, except the Aleyka/Pionerskij area, were constructed during the BSRP ECOPATH workshop (see also Section 3).

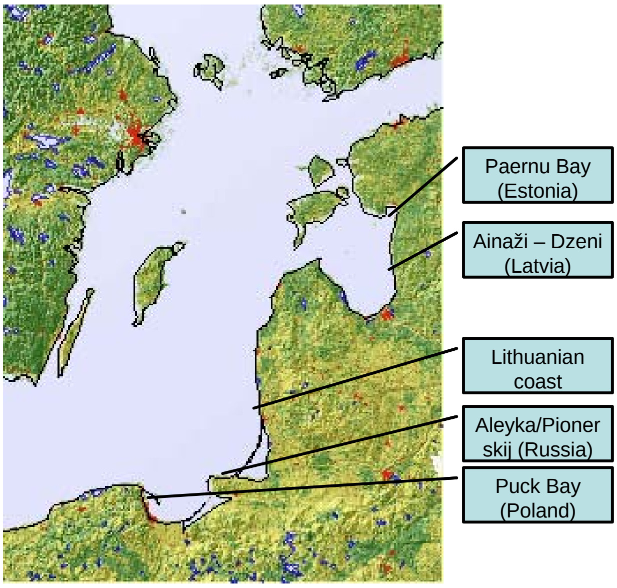


Figure 8: Coastal survey pilot study sites.

The meeting suggested that the Productivity module coastal zone work should focus more in productivity indicators as discussed under ToR b. Field work activities should be designed specifically to test the proposed productivity indicators. Duplication of work, for example with Water Framework Directive activities should be avoided. The meeting also criticized, that the pilot coastal survey program has only been vaguely defined.

5.3 Open sea survey work program

The BSRP joint open sea survey will be integrated into the Latvian/Polish hydroacoustic survey for herring and sprat in the Eastern Gotland basin. Potentially also AtlantNIRO will add a productivity sampling program to their 2005 spring hydroacoustic survey in the Russian economic zone.

The Latvian/Polish survey will be conducted by the Latvian Fisheries Research Institute (LatFRI) in cooperation with the Sea Fisheries Institute in Gdynia (MIR) on board R/V Baltica. Two scientists from the Institute of Aquatic Ecology, University of Latvia (IAE) will be responsible for collecting nutrient and phytoplankton samples, zooplankton sampling will be arranged in cooperation with LatFRI.

The Polish/Latvian survey will cover ICES subdivision 28 and the area north of 56º in ICES subdivision 26 (Figure 9). The area will be covered from north to south in an undulating cruise track from 15–24 May 2005. During the survey, water samples and CTD profiles will be taken at haul stations along the track (marks in Figure 9 a). These stations will be used for nutrient and phytoplankton sampling. Additionally, the following COMBINE stations will be sampled (see Figure 9 b): J 52 (BY9/46), J 39 (BY10), J 38 (43), J 26 (BY11), J 1 (37), J 18 (40A), J 4 (BY20).

Productivity sampling during the survey aims to establish relationships between the distribution of herring/sprat and zooplankton, as well as to assess the state of nutrients and plankton in the area.

Herring/sprat

Distribution of herring and sprat will be available from hydroacoustic survey data. Potentially, analysis of stomach contents could be integrated in the survey program to investigate the fish feeding conditions

Zooplankton

Zooplankton nauplii are the food basis for the developing sprat larvae. Larger zooplankton stages are the food basis for adult sprat and herring. During spring, zooplankton development is mainly limited by temperature and links to phytoplankton are expected to be weak.

Details of the zooplankton sampling program will be elaborated in the work of LL Zooplankton/Ichthyoplankton (LL ZOO). LL ZOO planned to form and expert team to study potential zooplankton indicators based on an analysis of existing data. Lutz Postel, chairman of the HELCOM Zooplankton expert network, offered to make available data from the Baltic Sea Patchiness Experiment (PEX), to show the spatial distribution of zooplankton in the Gotland Basin during spring.

Density of zooplankton sampling is limited by technical constraints. Because net sampling is time-consuming, samples cannot be taken at the haul stations planned along the survey track. Zooplankton samples will have to be collected in the evening, after hydroacoustic work is finished. Possibly, locations for zooplankton sampling can be selected according to fish distribution as shown by the hydroacoustic records.

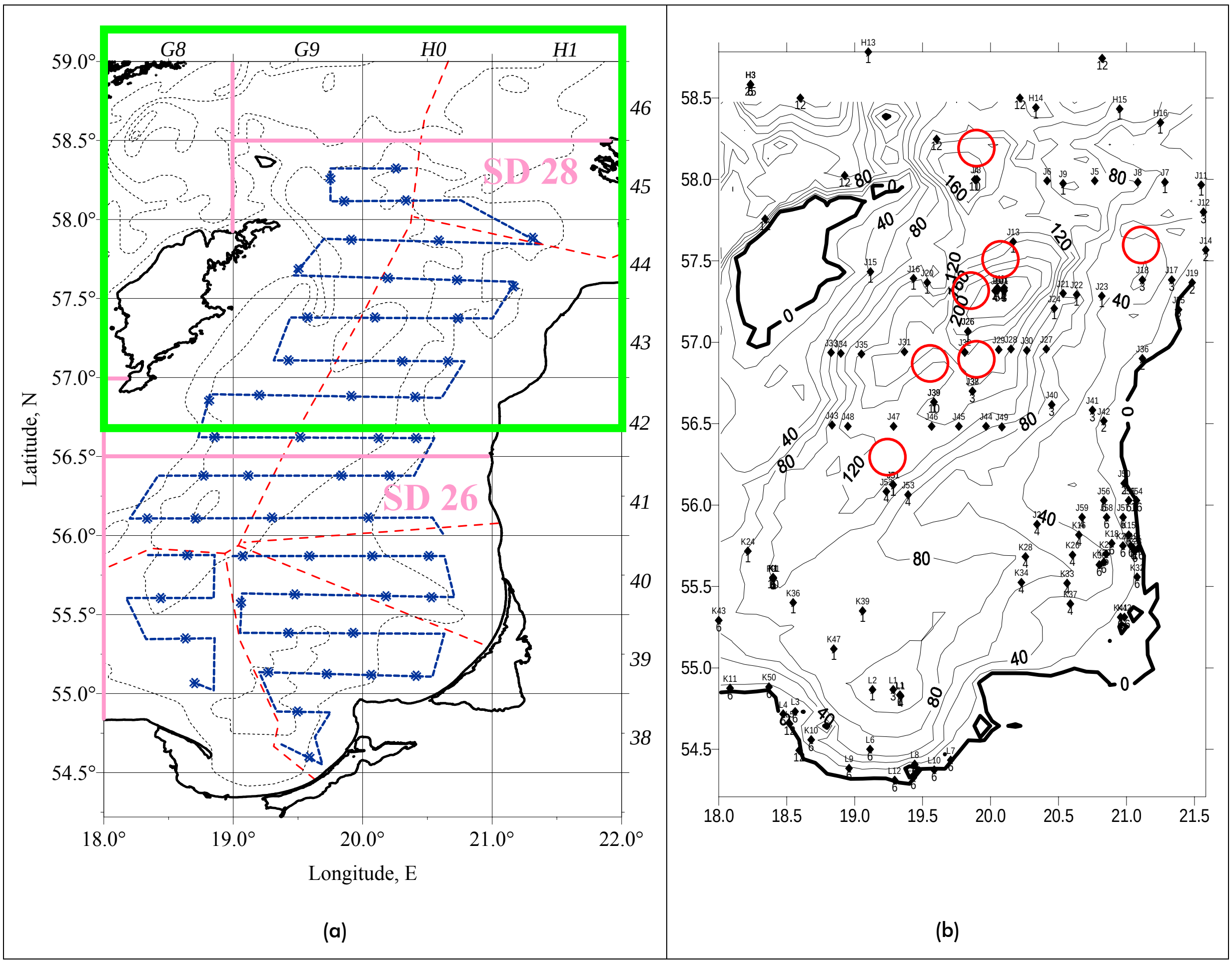


Figure 9: Hydroacoustic survey cruise track, survey area marked in green (a) and HELCOM COMBINE monitoring stations in the survey area (b).

Phytoplankton

Parameters: Chlorophyll *a*, fluorescence profiles (?), species composition, biomass (selected samples)

In the Gotland basin the phytoplankton spring bloom spreads from South to North. During the survey, the spring bloom will most likely be in its final stage. Because of the temperature limitation for zooplankton, only weak links between phyto- and zooplankton are expected.

Nutrients

Parameters: NH_4, NO_3, NO_2, PO_4, SiO_4, N_{tot}, P_{tot}

Nutrients are the chemical basis for phytoplankton development. At the time of the survey, the phytoplankton spring bloom is probably in its final stage. Most likely, nutrient concentrations will be low, especially for nitrogen components. Mixing/diffusion from the Baltic intermediate water will be the source of phytoplankton growth in summer. If the light conditions are sufficient, phytoplankton can also develop in the thermocline. For the further development of the phytoplankton community, nutrient concentrations below the thermocline are essential and nutrient sampling will therefore be designed to give a good assessment of these nutrient pools.

Hydrology

Parameters: temperature, salinity, oxygen, hydrogen sulfide

In mid-May the thermocline in the Gotland Basin is only weakly developed, with surface water temperatures of approximately 8 ºC. Below is the cold intermediate water, followed by the permanent halocline in 60 m (south) - 70 m (north) depth. The depth of the permanent halocline depends on the intensity of vertical mixing in winter and by the frequency of salt water inflows into the Baltic Proper. Oxygen conditions in the deep are mainly determined by frequency of salt water intrusions and oxygen conditions are therefore highly variable. The hydrological conditions to be expected will be known more precisely from data of the winter HELCOM monitoring cruises (February 2005).

Hydrological conditions – especially dissolved oxygen concentrations/hydrogen sulfide - limit the vertical distribution of fish. Temperature conditions influence the growth zooplankton and fish larvae. Some zooplankton species are also sensitive to salinity.

For the euphotic layer, the strength of the density gradient in the thermocline influences the vertical mixing and therefore limits the nutrient pools available to phytoplankton. At the same time, thermocline strength also influences the phytoplankton light regime – deep mixing means low average light intensity.

Statistical analysis of sampling design

Samples represent the true spatial distribution of an environmental variable at unknown precision. The precision can be estimated by analyzing the spatial correlation of the parameter of interest. Vice versa, also the sampling grid can be optimized to improve the precision (minimize the interpolation error) if the statistical properties of the environmental field can be estimated. It is therefore planned to analyze the spatial correlation of nutrients, phytoplankton and zooplankton based on existing data in the survey area during May. Interpolation errors will be calculated for several station grid designs and an optimum sampling density will be selected.

SGPROD added the following suggestions for the BSRP open sea survey:

Zooplankton:

- Juday-net (120µm) vertically after each fishing station
- Important for sampling – into the oxygen deficiency (check with CTD before)
- Important for analysis – identify nauplii to species

Ichthyoplankton:

- IKS-80 vertically after each fishing haul
- Alternatively or **additionally** – Bongo 335 and 500µm during night

Fish:

- length-stratified herring and sprat stomach sampling
- cod stomach sampling ?

Other surveys:

- exchange information with other hydroacoustic surveys, e.g., IOR Rostock

6 Workplan 2005

The final meeting for SGRPOD in spring 2006 coincides with the end of BSRP phase I. Therefore the group suggests to review the results of phase I and to prepare BSRP phase II. In particular, the monitoring and survey strategies applied both in coastal areas and for the open sea, will be assessed and the performance of the productivity indicators will be evaluated. Work has also to be dedicated to interlink productivity assessment with the ongoing Baltic Sea management, especially with HELCOM and ICES fishery assessment activities. To prepare BSRP phase II, a workplan for the productivity module and a productivity monitoring strategy for the second phase of the project will be established. The group also suggested establishing a similar study group in support of the BSPR Productivity module for the second phase of the project.

The proposed Terms of Reference for the final year of SGPROD is attached as Annex 8.

7 Other business

7.1 Theme session on Impact of external forcing on flows in marine trophic networks at ICES 2005 ASC

SGPROD had submitted a theme session proposal on "Material and energy flow in Baltic Sea trophic networks of the Baltic Sea ecosystem" for inclusion into the 2005 ICES Annual Science conference. To attract a wider audience, the proposal was broadened to flows in marine systems under external pressure in general. The ICES Statutory Meeting held in Vigo, Spain in September 2004, accepted the proposal and appointed Bärbel Müller-Karulis (Latvia), together with Villy Christensen (Canada) and Arturas Razinkovas (Lithuania) as conveners. The general Call for Papers and Posters for the 2005 Annual Science Conference will be issued in the beginning of 2005. Participants will be required to send titles and abstracts (up to 200 words) of their contributions before April 25, 2005.

Bärbel Müller-Karulis invited presentations from SGRPOD and interested colleagues.

8 Closing and reporting

Bärbel Müller-Karulis thanked all participants for an interesting and fruitful meeting. The group agreed that the chair will assemble the individual sections of the report and distribute the draft report among the study group members for their comments.

Annex 1: Basic estimates of the modelled networks

Baltic Proper (Sandberg *et al.*, 2000)

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m^{-2})	(g C m^{-2})	(year^{-1})	(year^{-1})			(g C m^{-2})	(g C m^{-2})
Primary prod	1	1	1.07	1.07	150.09	166.77	0.62	0.90	160.00	177.78
Bentic prod	1	1	0.02	0.02	233.65	303.60	0.00	0.77	4.91	6.38
DOM	1	1	280.0	280.0	-	-	0.81	-		
Sed Corg	1	1	404.0	404.0	-	-	0.43	-		
Pel Bacteria	2	1	0.21	0.21	142.86	247.62	1.00	0.58	30.00	52.00
Meiofauna	2.01	1	0.24	0.24	5.70	31.32	1.05	0.18	1.36	7.45
Macrofauna	2.05	1	4.34	4.34	0.84	8.39	0.38	0.10	3.65	36.35
Meso Zoopl	2.45	1	0.20	0.20	73.89	295.57	0.48	0.25	15.00	60.00
Micro Zoopl	2.79	1	0.07	0.07	214.29	542.86	1.00	0.40	15.00	38.00
Invert Carn	3.45	1	0.01	0.01	200.00	660.00	0.82	0.30	1.00	3.30
Pelagic Fish	3.59	1	0.57	0.57	1.31	7.67	1.00	0.17	0.75	4.39
Demersal Fish	3.72	1	0.55	0.55	0.89	3.76	0.45	0.24	0.49	2.05

Baltic Proper 1980s

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m⁻²)	(g C m⁻²)	(year⁻¹)	(year⁻¹)			(g C m⁻²)	(g C m⁻²)
benthic prod	1	1	0.02	0.02	58.9	-	0.545	-	1.178	
Phytoplankton	1	1	4	4	175	-	0.141	-	700	
Detritus	1	1	-	-	-	-	0.153	-		
Meiobenthos	2	1	0.28	0.28	1.025	8.48	0.826	0.121	0.287	2.3744
Bacteria	2	1	0.42	0.42	53.2	88.5	0.49	0.601	22.344	37.17
Cladocerans	2.02	1	0.49	0.49	20	66.667	0.03	0.3	9.8	32.66683
Temora	2.02	1	0.09	0.09	30	100	0.538	0.3	2.7	9
Acartia	2.02	1	0.09	0.09	30	100	0.198	0.3	2.7	9
other copepods	2.02	1	0.03	0.03	30	100	0.457	0.3	0.9	3
other meso	2.02	1	0.24	0.24	30	100	0.029	0.3	7.2	24
Macrobenthos	2.03	1	5.24	5.24	0.35	2.38	0.996	0.147	1.834	12.4712
Mysids	2.05	1	2.7	2.7	1.65	7.15	0.163	0.231	4.455	19.305
Pseudocalanus	2.08	1	0.54	0.54	25	83.333	0.13	0.3	13.5	44.99982
Microzoo	2.36	1	0.14	0.14	150	217.3	0.169	0.69	21	30.422
Sprat Ad	3.03	1	0.172	0.172	1.333	4.118	0.877	0.324	0.229276	0.708296
Sprat Juv	3.03	1	0.103	0.103	0.341	6.433	0.687	0.053	0.035123	0.662599
Herring Juv	3.04	1	0.135	0.135	0.302	6.055	0.425	0.05	0.04077	0.817425
Herring Ad	3.06	1	0.59	0.59	0.89	3.22	0.429	0.276	0.5251	1.8998
Cod Juv	3.08	1	0.364	0.364	0.637	4.668	0.294	0.136	0.231868	1.699152
Cod Ad	3.37	1	0.276	0.276	1.578	2.717	0.287	0.581	0.435528	0.749892
Seal	4.06	1	0.000045	0.000045	0.1	12.77	0	0.008	0.0000045	0.000575

Baltic Proper 1990s

	TROPHIC LEVEL	HABITAT AREA	BIOMASS IN HABITAT AREA	BIOMASS	PRODUCTION/ BIOMASS	CONSUMPTION/BIOMASS	ECOTROPHIC EFFICIENCY	PRODUCTION/ CONSUMPTION	PRODUCTION	CONSUMPTION
			(g C m⁻²)	(g C m⁻²)	(year⁻¹)	(year⁻¹)			(g C m⁻²)	(g C m⁻²)
benthic prod	1	1	0.02	0.02	58.9	-	0.535	-	1.178	
Phytoplankton	1	1	4	4	175	-	0.782	-	700	
Detritus	1	1	-	-	-	-	0.673	-		
Meiobenthos	2	1	0.28	0.28	1.025	8.48	0.826	0.121	0.287	2.374
Bacteria	2	1	0.42	0.42	53.2	88.5	0.49	0.601	22.344	37.17
Cladocerans	2.02	1	0.81	0.81	30	100	0.011	0.3	24.3	81
Temora	2.02	1	0.69	0.69	40.15	133.833	0.212	0.3	27.7035	92.34
Acartia	2.02	1	4.13	4.13	47.75	159.167	0.017	0.3	197.2075	657.4
other copepods	2.02	1	0.13	0.13	30	100	0.554	0.3	3.9	13
other meso	2.02	1	0.52	0.52	30	100	0.124	0.3	15.6	52
Macrobenthos	2.04	1	5.24	5.24	0.35	2.38	0.159	0.147	1.834	12.47
Pseudocalanus	2.08	1	0.23	0.23	18.25	60.833	0.562	0.3	4.1975	13.99
Microzoo	2.36	1	0.14	0.14	150	217.3	0.519	0.69	21	30.42
Mysids	2.51	1	2.7	2.7	1.65	7.15	0.128	0.231	4.455	19.31
Sprat Ad	3.02	1	0.745	0.745	0.847	4.118	0.683	0.206	0.631015	3.068
Sprat Juv	3.02	1	0.246	0.246	0.341	6.812	0.776	0.05	0.083886	1.676
Herring Juv	3.05	1	0.1	0.1	0.302	6.015	0.563	0.05	0.0302	0.602
Herring Ad	3.17	1	0.416	0.416	0.917	3.22	0.278	0.285	0.381472	1.34
Cod Juv	3.34	1	0.111	0.111	0.637	4.676	0.071	0.136	0.070707	0.519
Cod Ad	3.88	1	0.0855	0.0855	1.559	2.717	0.302	0.574	0.1332945	0.232
Seal	4.14	1	0.000045	0.000045	0.1	12.77	0	0.008	0.0000045	6E-04

Gulf of Gdansk

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m⁻²)	(g C m⁻²)	(year^{-1})	(year^{-1})			(g C m⁻²)	(g C m⁻²)
Phytoplankton	1	1	1.965	1.965	75.01	-	0.627	-	147.39	
Detritus	1	1	20	20	-	-	0.881	-		
Bacteria	2	1	0.875	0.875	40	90.02	0.932	0.444	35.00	78.77
Macrobenthos nd	2.23	1	1.168	1.168	0.88	4.41	0.668	0.2	1.03	5.15
Mesozooplankton	2.27	1	1.064	1.064	12.58	62.91	0.409	0.2	13.39	66.94
Protozooplankton	2.36	1	0.246	0.246	83.96	292.07	0.648	0.287	20.65	71.85
Macrobenthos dp (detritophags and predatory)	2.4	1	0.335	0.335	1.62	8.12	0.987	0.2	0.54	2.72
Macrozoplankton	2.88	1	0.079	0.079	3.34	16.7	0.545	0.2	0.26	1.32
Meiofauna	2.9	1	0.169	0.169	8.88	44.42	0.557	0.2	1.50	7.51
Herring+spratt	3.28	1	1.451	1.451	0.52	3.09	0.799	0.168	0.75	4.48
Demersal fish	3.38	1	0.066	0.066	0.52	4.21	0.862	0.124	0.03	0.28
Cod	3.72	1	0.257	0.257	0.61	3.81	0.51	0.16	0.16	0.98

Bothnian Sea (Sandberg *et al.*, 2000)

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/Co nsumption	Production	Consumption
			(g C m⁻²)	(g C m⁻²)	(year^{-1})	(year^{-1})			(g C m⁻²)	(g C m⁻²)
Primary prod	1	1	0.733	0.733	150.09	166.77	0.607	0.9	110.02	122.24
Bentic prod	1	1	0.013	0.013	230.77	303.6	0	0.76	3.00	3.95
DOM	1	1	278	278	-	-	0.791	-		
Sed Corg	1	1	309	309	-	-	0.697	-		
Pel Bacteria	2	1	0.14	0.14	142.86	257.14	0.998	0.556	20.00	36.00
Meiofauna	2.01	1	0.315	0.315	4.95	26.78	1.049	0.185	1.56	8.44
Macrofauna	2.04	1	4.795	4.795	1.08	12.44	0.276	0.087	5.18	59.65
Meso Zoopl	2.46	1	0.2	0.2	50	199.5	0.709	0.251	10.00	39.90
Micro Zoopl	2.77	1	0.048	0.048	214.29	540.92	1.001	0.396	10.29	25.96
Invert Carn	3.39	1	0.146	0.146	0.98	3.97	0.583	0.247	0.14	0.58
Pelagic Fish	3.46	1	0.007	0.007	171.429	571.429	0.86	0.3	1.20	4.00
Demersal Fish	3.66	1	0.555	0.555	1.11	7.68	0.152	0.145	0.62	4.26

Bothnian Bay (Sandberg *et al.*, 2000)

	TROPHIC LEVEL	HABITAT AREA	BIOMASS IN HABITAT AREA	BIOMASS	PRODUCTION/ BIOMASS	CONSUMPTION/ BIOMASS	ECOTROPHIC EFFICIENCY	PRODUCTION/ CONSUMPTION	PRODUCTION	CONSUMPTION
			(g C m^{-2})	(g C m^{-2})	(year^{-1})	(year^{-1})			(g C m^{-2})	(g C m^{-2})
Primary prod	1	1	0.167	0.167	150.09	166.77	0.622	0.9	25.07	27.85
Bentic prod	1	1	0.013	0.013	230.77	303.6	0	0.76	3.00	3.95
DOM	1	1	186	186	-	-	0.256	-		
Sed Corg	1	1	288	288	-	-	0.249	-		
Pel Bacteria	2	1	0.035	0.035	142.86	228.57	1	0.625	5.00	8.00
Meiofauna	2.01	1	0.165	0.165	4.76	26.16	1.052	0.182	0.79	4.32
Macrofauna	2.37	1	0.1	0.1	30	120	0.944	0.25	3.00	12.00
Meso Zoopl	2.42	1	0.11	0.11	1.4	18.35	1.841	0.076	0.15	2.02
Micro Zoopl	2.83	1	0.011	0.011	214.29	545.45	1.018	0.393	2.36	6.00
Invert Carn	3.37	1	0.003	0.003	182.82	566.67	0.708	0.323	0.55	1.70
Pelagic Fish	3.49	1	0.052	0.052	1.05	4.22	0.599	0.249	0.05	0.22
Demersal Fish	3.62	1	0.207	0.207	1.07	7.6	0.126	0.141	0.22	1.57

Curonian Lagoon

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m⁻²)	(g C m⁻²)	(year⁻¹)	(year⁻¹)			(g C m⁻²)	(g C m⁻²)
Phytoplankton	1	1	1.27	1.27	196.43	-	0.422	-	249.47	
Detritus	1	1	2.475	2.475	-	-	0.283	-		
Bacteria	2	1	0.11	0.11	189	247.62	0.769	0.763	20.79	27.24
deposit feeders gastropods	2	1	0.153	0.153	8.64	40.5	0.603	0.213	1.32	6.20
Grazing zooplankton	2.1	1	0.37	0.37	37.8	237.6	0.831	0.159	13.99	87.91
Oligochaets	2.14	1	0.396	0.396	5.11	10.4	0.921	0.491	2.02	4.12
Filtrators bivalves	2.15	0.24	10.44	2.506	0.27	10	0.236	0.027	0.68	25.06
Chironomids	2.25	1	0.224	0.224	10.8	59.4	0.778	0.182	2.42	13.31
Mysids	2.35	1	0.0226	0.0226	8	14.5	0.493	0.552	0.18	0.33
Meiobenthos	2.38	1	0.338	0.338	18.9	44.42	0.748	0.425	6.39	15.01
Carnivorous zooplankton	2.96	1	0.08	0.08	37.8	237.6	0.649	0.159	3.02	19.01
Demersal fish	3.18	1	1.777	1.777	0.7	3	0.978	0.233	1.24	5.33
Planktivorous fish	3.27	1	0.014	0.014	0.7	10.13	0	0.069	0.01	0.14
Predatory fish	4.02	1	0.419	0.419	0.76	2.71	0.802	0.28	0.32	1.14
grey heron	4.32	1	0.000858	0.000858	0.3	30.94	0	0.01	0.00	0.03
Larus	4.32	1	0.0159	0.0159	0.3	12.38	0	0.024	0.00	0.20
Goosander	4.32	1	0.00181	0.00181	0.3	45.351	0	0.007	0.00	0.08
Great Crested Grebe	4.32	1	0.00115	0.00115	0.3	56.876	0	0.005	0.00	0.07
Cormorants	4.32	1	0.0137	0.0137	0.3	15.84	0	0.019	0.00	0.22

Pärnu Bay

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m⁻²)	(g C m⁻²)	(year⁻¹)	(year⁻¹)			(g C m⁻²)	(g C m⁻²)
Phytoplankton	1	1	0.18	0.18	2550	-	0.875	-	459.00	
Annual macrophytes	1	1	0.6	0.6	37.717	-	0.061	-	22.63	
Perennial macrophytes	1	1	3	3	3.033	-	0.009	-	9.10	
Detritus	1	1	-	-	-	-	0.968	-		
Mesozooplankton	2	1	0.6	0.6	40	133.333	0.952	0.3	24.00	80.00
Herbivores	2	1	0.014	0.014	33.571	111.905	0.638	0.3	0.47	1.57
Deposit feeders	2	1	13.6	13.6	10	50	0.03	0.2	136.00	680.00
Dreissena polymorpha	2.05	1	1.7	1.7	30.588	203.922	0.058	0.15	52.00	346.67
Neomysis integer	2.76	1	0.32	0.32	6.19	20.633	0.24	0.3	1.98	6.60
Cyprinids	2.99	1	4.5	4.5	0.125	0.625	0.978	0.2	0.56	2.81
Cercopagis pengoi	3	1	0.0015	0.0015	30	100	0.349	0.3	0.05	0.15
Herring larvae	3	1	0.03	0.03	5	16.667	0.088	0.3	0.15	0.50
Pearch	3.21	1	2.5	2.5	0.2	1	0.55	0.2	0.50	2.50
Pikepearch	3.3	1	0.5	0.5	1	5	0	0.2	0.50	2.50

Lithuanian coast

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m^{-2})	(g C m^{-2})	(year^{-1})	(year^{-1})			(g C m^{-2})	(g C m^{-2})
macrophytobenthos	1	0.2	9	1.8	11.9	-	0.1	-	21.42	
Phytoplankton	1	1	1.97	1.97	90	-	0.681	-	177.30	
Detritus	1	1	300	300	-	-	0.561	-		
Bacteria	2	1	0.875	0.875	142	247	0.314	0.575	124.25	216.13
macrozoobenthos filtrators	2.15	0.2	95.53	19.106	0.88	4.41	0.094	0.2	16.81	84.26
macrozoobenthos detritophagous	2.23	0.9	7.87	7.083	1.62	8.12	1.509	0.2	11.47	57.51
Zooplankton	2.31	1	1.4	1.4	40	160	0.42	0.25	56.00	224.00
Mysids	2.79	1	0.029	0.029	3.1	15	4.649	0.207	0.09	0.44
Bird	3.23	0.3	1.65	0.495	0.5	5	0	0.1	0.25	2.48
planktivorous fish	3.4	1	3.3	3.3	0.11	0.68	2.58	0.162	0.36	2.24
benthivorous fish	3.53	1	0.141	0.141	0.12	0.99	0.689	0.121	0.02	0.14
piscivorous fish	4.02	1	0.16	0.16	0.98	6.1	0.431	0.161	0.16	0.98
seal	4.47	1	0.00047	0.00047	0.1	12.77	0	0.008	0.00	0.01

Ainaži – Dzeņi

	Trophic level	Habitat area	Biomass in habitat area	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic efficiency	Production/ Consumption	Production	Consumption
			(g C m^{-2})	(g C m^{-2})	(year^{-1})	(year^{-1})			(g C m^{-2})	(g C m^{-2})
Phytobenthos	1	1	43.731	43.731	40	-	0.033	-	1749.24	
Phytoplankton	1	1	0.25	0.25	200	-	0.448	-	50.00	
Detritus	1	1	300	300	-	-	0.134	-		
Zooplankton	2	1	0.2	0.2	40	160	0.431	0.25	8.00	32.00
Bentos	2	1	21.6	21.6	0.32	13	0.379	0.025	6.91	280.80
Mysids	2.2	1	0.288	0.288	7.5	25	0.599	0.3	2.16	7.20
Benthivorous fish	2.6	1	0.4	0.4	1	5	0.895	0.2	0.40	2.00
Planctivorous fish	3.06	1	0.421	0.421	0.4	7.96	0.95	0.05	0.17	3.35
Birds	3.12	1	0.24	0.24	0.3	5	0.035	0.06	0.07	1.20
Piscivores	3.41	1	0.32	0.32	1.06	2	0.236	0.53	0.34	0.64

Diet matrices of the modelled networks

Baltic proper 1980s

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Seal																					
2	Cod Ad	0.05																				
3	Cod Juv								0													
4	Sprat Ad	0.38	0.66	0.3																		
5	Sprat Juv		0.16	0.01					0													
6	Herring Ad	0.51	0.02	0.01																		
7	Herring Juv	0.07	0.02	0.01																		
8	Macrobenthos		0.15	0.49																		
9	Mysids						0.3	0.07	0.01													
10	Meiobenthos								0.02													
11	Cladocerans			0.01	0.04	0.08																
12	Temora			0.03	0.6	0.6	0.48	0.72		0.1												
13	Acartia			0.04	0.25	0.25	0.11	0.16		0.1												
14	Pseudocalanus			0.03	0.08	0.03	0.08	0.02		0.1												
15	other copepods			0.03	0.03	0.04	0.03	0.03		0.1												
16	other meso			0.01						0.1												
17	Microzoo			0.01								0.01	0.01	0.01	0.06	0.01	0.01					
18	Bacteria																	0.36				
19	Benthic prod			0.01					0.05													
20	Phytoplankton			0.01					0.15	0.5		0.57	0.57	0.57	0.35	0.57	0.57	0.59				
21	Detritus								0.77		1	0.42	0.42	0.42	0.59	0.42	0.42	0.05	1			
22	Import																					

Baltic Proper 1990s

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Seal																					
2	Cod Ad	0.04																				
3	Cod Juv		0.072	0.0001					0.0001													
4	Sprat Ad	0.29	0.1	0.05																		
5	Sprat Juv		0.01	0.0009					0.0009													
6	Herring Ad	0.39	0.1	0.01																		
7	Herring Juv	0.28	0.01																			
8	Macrobenthos		0.6	0.7																		
9	mysids						0.3	0.04	0.01													
10	Meiobenthos								0.019													
11	Cladocerans			0.01	0.2	0.2																
12	Temora			0.01	0.43	0.43	0.17	0.4		0.01												
13	Acartia			0.019	0.11	0.11	0.03	0.12		0.01												
14	Pseudocalanus			0.05	0.25	0.25	0.45	0.33		0.01												
15	other copepods			0.01	0.01	0.01	0.05	0.11		0.01												
16	other meso			0.01						0.01												
17	microzoo			0.01								0.01	0.01	0.01	0.05	0.01	0.01					
18	bacteria																	0.36				
19	benthic prod			0.01					0.05													
20	Phytoplankton			0.01					0.15	0.95		0.51	0.51	0.51	0.3	0.51	0.51	0.59				
21	Detritus								0.77		1	0.37	0.37	0.37	0.5	0.37	0.37	0.05	1			
22	Import																					

Pärnu Bay

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Phytoplankton		0.9		0.2									0.95		
2	Mesozooplankton			1	0.6	1								0.05		
3	Cercopagis pengoi								0.01							
4	Neomysis integer						0.07		0.12							
5	Herring larvae						0.01									
6	Pikepearch															
7	Cyprinids						0.11		0.11							
8	Pearch						0.11									
9	Annual macrophytes							0.05				0.8				
10	Perennial macrophytes											0.05				
11	Herbivores								0.12							
12	Deposit feeders						0.7	0.24	0.64							
13	Dreissena polymorpha				0.15			0.71								
14	Detritus		0.1		0.05							0.15	1			
15	Import															

Ainazi - Dzeni

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11
1	Birds											
2	Piscivore											
3	Planctivore fish	0.08	0.1									
4	Benthivore fish	0.08	0.35									
5	Mysids		0.45	0.3								
6	Zooplankton			0.6		0.2						
7	Bentos	0.85	0.1	0.1	0.6							
8	Phytobentos				0.4			0.2				
9	Phytoplancton						0.7					
10	Detritus					0.8	0.3	0.8				
11	Import											

Gulf of Gdansk

	PREY \ PREDATOR	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Cod													
2	Demersal fish	0.02												
3	Herring+spratt	0.34												
4	Meiofauna						0.08			0.12				
5	Macrozoplankton	0.05	0.18	0.01										
6	Macrobenthos dp (predatory)	0.45	0.18	0.01										
7	Protozooplankton								0.2					
8	Mesozooplankton			0.97		0.69	0.08							
9	Macrobenthos nd (non predatory)	0.14	0.64	0.01			0.12							
10	Bacteria				0.9			0.36						
11	Phytoplankton							0.54	0.8					
12	Detritus				0.1	0.31	0.72	0.1		0.88	1			
13	Import													

Curonian lagoon

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Fitoplankton		0.9	0.2		1	0.3	0.15								0	0.1	0.2			
2	Bacteria		0.1	0.1												0	0.1	0.1			
3	Grazing zooplankton			0.6	0.8				0.01									0.1			
4	Carnivorous zooplankton			0.1	0.2				0.01												
5	Planktivorous fish																				
6	deposit feeders gastropods								0.15												
7	Chironomids								0.35						0.01						
8	Oligochets						0.1		0.1												
9	Demersal fish									0.66	0.66	0.66	0.66	0.66	0.5						
10	grey heron																				
11	Larus																				
12	Goosander																				
13	Great Crested Grebe																				
14	Cormorants																				
15	Predatory fish									0.14	0.14	0.14	0.14	0.14	0.13						
16	Filtrators bivalves								0.03												
17	Meiobenthos						0.1	0.1									0.2	0.1			
18	Mysids								0.01						0.06						
19	Detritus	1					0.5	0.75								0	0.6	0.5			
20	Import								0.35	0.2	0.2	0.2	0.2	0.2	0.31						

Lithuanian coast

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	seal														
2	bird														
3	piscivore fish	0.1	0	0.07											
4	planktivore fish	0.86	0.12	0.57		0.24									
5	benthivore fish	0.04	0.02												
6	mysids		0	0		0.11									
7	zooplankton			0	0.99	0.06	0.68	0.1		0.01					
8	macrozoobenthos detritofagos		0.44	0.36	0.01	0.06			0.07						
9	macrozoobenthos filtrators		0.42			0.53									
10	macrophytobenthos		0						0						
11	phytoplankton						0.3	0.67	0.23	0.98					
12	Detritus						0.02	0.05	0.7	0.01					
13	Import														
14	Bacteria							0.18							

Annex 2: Working document on zooplankton indicators, Lutz Postel (IOW Warnemünde)

- zooplankton as productivity indicator

which parameters are useful (e.g., biomass, abundance, secondary production, ..)

Biomass and abundance are useful to describe the relative surplus at a given time and place (standing stock). It is an indication for long term eutrophication processes. For example the Baltic Sea was known as an oligotrophic area until the middle of the last century. Then nutrient inputs from land increased drastically. It resulted in a significant increase of all stock parameter starting with nutrients, via phytoplankton, zooplankton, including pelagic fish.

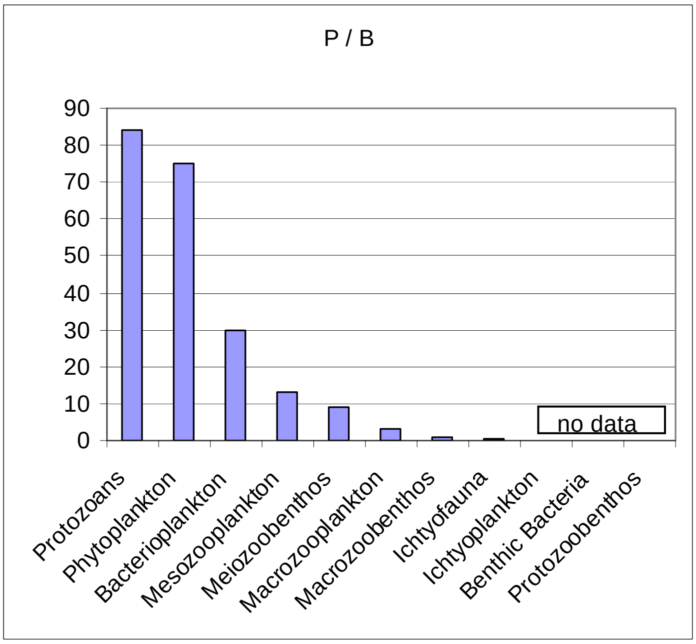
However, this information is unsuitable for the evaluation of "master factors" governing the system, i.e., is the system top down or bottom up controlled.

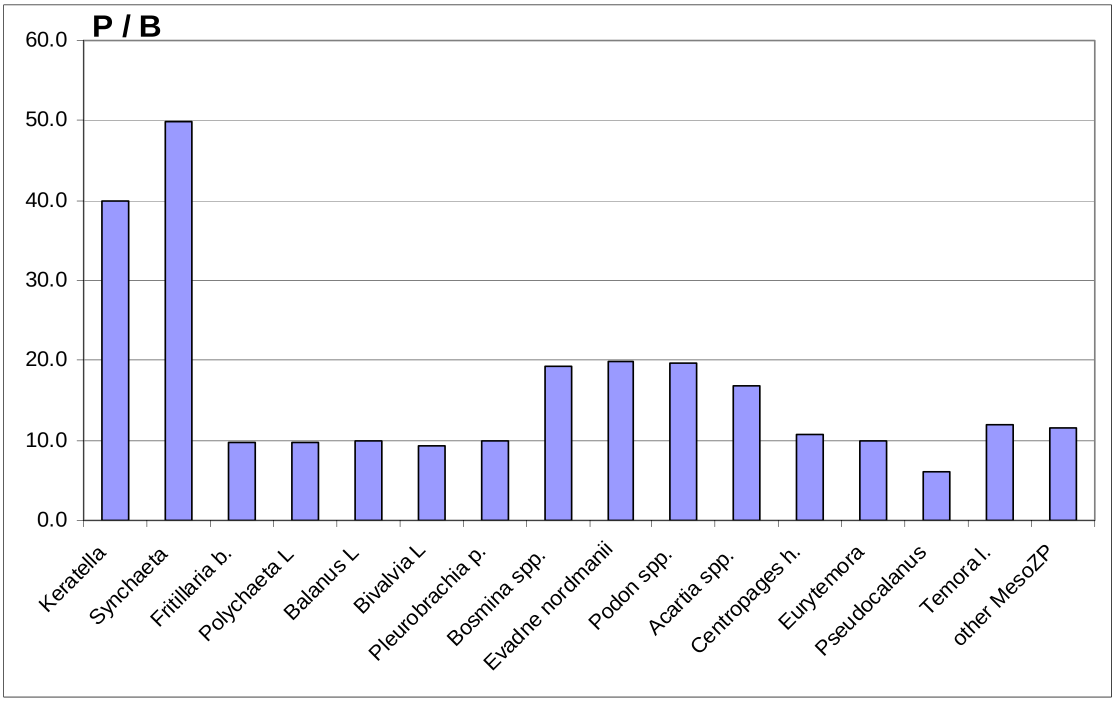
Individual body mass would be an important initial information for the calculation of ***production*** (P), respiration (R), and consumption (C) by individual specific P/B -, P/R- and R/C- ratios.

Average individual body mass is to calculate by the quotient between biomass concentration and abundance within a certain size category in a first order of approximation on one hand and by individual specific biomass factors on the other.

Models to calculate production base on classical approaches to study zooplankton production, i.e., incubation methods. The data basis produced by the latter techniques is remarkable and was considered by Banse and Mosher (1980) and Huntley and Lopez (1992). The allometric approach by Banse and Mosher (1980) with P/B = 0,64 body mass$^{-0.37}$ ±2% (temperature range: 5 to 20°C) produces more realistic specific production rates (especially in deeper waters) in comparison to the temperature approach of Huntley and Lopez (1992). It could be used as a first step. The results of computations needs to be compared with those of actual direct measurements (egg production, cohort analysis, enzymatic approaches).

Another allometric approach is that of Witek, Z. (1995) performed in Gdansk Basin (Baltic Sea). The following two Figures shows the average P/B ratios according to Witek (1995):





References:

Banse, K. and Mosher, S. 1980. Adult body mass and annual production biomass relationship of field populations. Ecol. Monogr. 50: 355–379

Huntley, M.E. and Lopez, M.D.G., 1992. Temperature dependent production of marine copepods: A global Synthesis, The American Naturalist, 140: 201–242

Witek, Z. 1995. Biological production and its utilization within a marine ecosystem in the western Gdansk Basin. Morski Institut Rybacki, Gdynia: 145 pp.

What kind of information is contained in zooplankton data

(energy transfer phytoplankton - fish, temperature/salinity signals, eutrophication, ...)

Concerning temperature salinity signal, there are some **indicator species**, for example *Pseudocalanus* spp. was substituded by *Arcatia* spp. in the longer period of lower salinity in the central Baltic Sea before 1993 (Kononen *et al.*, 1996), *Acartia tonsa* is a typical warm water species mostly abundant during warm summer month (e.g., Arndt and Heidecke, 1973), *Bosmina* spp. indicates also warm summer seasons (Hernroth and Ackefors, 1979), and *Oithona similis* indicates effective renewal of deep water in Gotland Basin (Postel in Wasmund *et al.* 2004).

Reference

Arndt, A.E. and Heidecke, D. 1973. Investigations on zooplankton in the coastal areas of the Bay of Mecklenburg. Wiss. Z. Univ. Rostock, Math. Naturwiss. Reihe. 22 (6-7): 599-616

Hernroth, L., Ackefors, H. (1979) The zooplankton of the Baltic proper. Inst. Mar. Res. Report 2: 1 - 60

Kononen, K., H. Kuosa, J.-M. Leppänen, R. Olsonen, J. Kuparinen, L. Postel and G. Behrends 1996. Overall assessment: Pelagic biology. Third periodic assessment of the state of the marine environment of the Baltic Sea, 1989-93: background document. Helsinki: Helsinki Commission - Baltic Marine Environment Protection Commission. (Baltic Sea Environment Proceedings; 64B): 215-222

Wasmund, N., F. Pollehne, L. Postel, H. Siegel and M. L. Zettler 2004. Biologische Zustandseinschätzung der Ostsee im Jahre 2003. Meereswiss.Ber., Warnemünde 60: 1-78

How is zooplankton information useful in the context of ecosystem based management?

Experimental work and complex ecosystem conditions

Results of experimental laboratory work do not always mirror the complex ecosystem conditions. Consequently multivariate statistical approaches of existing time series should be used in order to check laboratory outcomes and in combination of them.

Top down or bottom up?

Evaluating the seasonal production / consumption ratios (P/C) could be helpful to evaluate changes in the control of the system. For example the question whether diatoms regulate copepod production would require to ask for diatom production (availability) and consumption rate by copepods feeding on diatoms at the same time and place.

Key processes

In order to know what questions need to be solved a sensitivity analysis concerning various single influences on complex ecosystem level is needed.

- available information

how is the current zooplankton monitoring carried out,

German mesozooplankton times series partly exiting since 1979 are going to continue at 9 stations from Kiel Bay to the eastern Gotland Sea according to the HELCOM manual (WP2 net, 100 µm mesh size) mainly at three depth levels related to the hydrographical vertical structure (surface to thermocline or 25 m, 25 m or thermocline to halocline, halocline to bottom or the level of anoxia).

Station	°Lat	`Lat	°Long	`Long	Depth [m]	BMP	IBY	H	C	P	Zp	Be
TF0360	54	36,00	10	27,00	20	N3		x	x		x	
TF0012	54	18,90	11	33,00	25	M2		x	x	x	x	x
TF0046	54	28,00	12	13,00	27	M1		x	x	x	x	
TF0030	54	43,40	12	47,00	22	K8		x	x	x	x	x
TF0113	54	55,50	13	30,00	47	K5		x	x	x	x	
TF0213	55	15,00	15	59,00	91	K2	5A	x	x	x	x	x
TF0259	55	33,00	18	24,00	90	K1		x	x	x	x	
TF0271	57	19,20	20	3,00	249	J1	15A	x	x	x	x	
TFOBB	54	4,60	14	9,60	13			x	x		x	

German zooplankton stations collected on 5 cruises per year (month 2,3,5,8,10) some of them twice per cruise. H=hydrography, C=nutrients, P=phytoplankton abundance, biomass, taxonomy, Zp =zooplankton abundance, taxonomy, Be= benthos abundance, biomass, taxonomy

We report abundance and requested taxomical information including such on developmental stages and sex. We avoid to report biomass concentrations because of the current lack of reliable biomass factors. Currently we are working on improvements.

All zooplankton monitoring stations are included in the following map provided by HELCOM. Information on actual sampling frequency will be collected during a HELCOM MONAS zooplankton workshop in Warnemünde announced for March 2005.

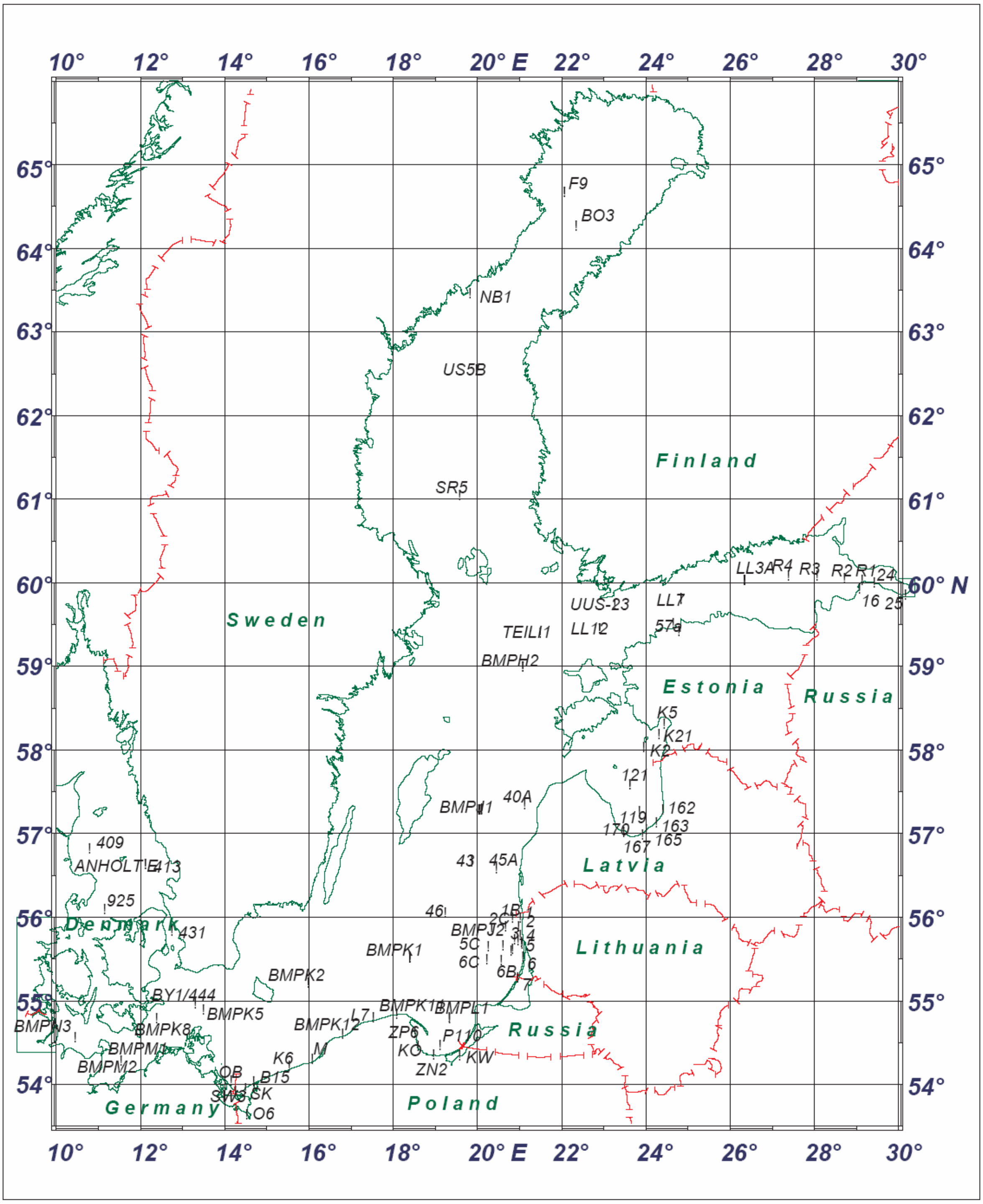


Figure A.7. Zooplankton stations.

Is the available information sufficient?

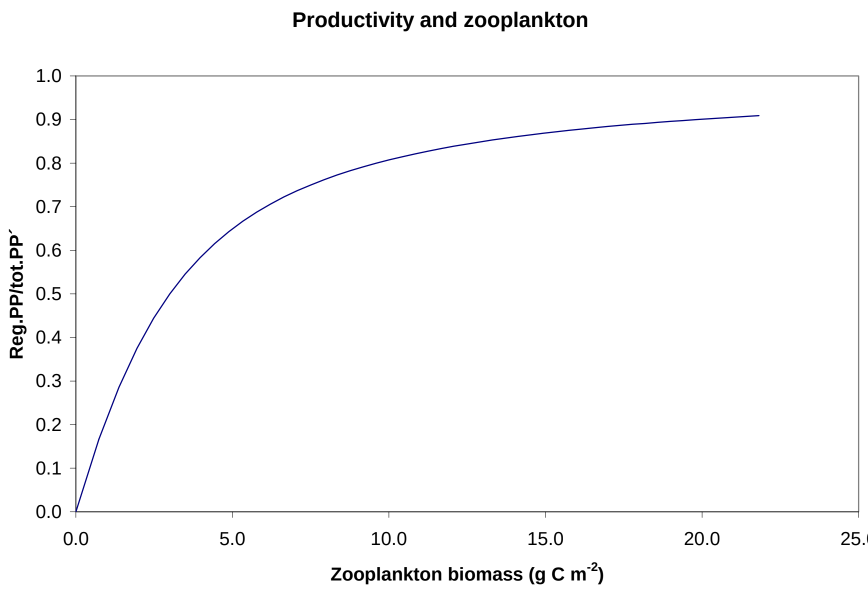
We miss infos on macroplankton. Mysids and especially jellies and ctenophores are seldom sufficiently quantified.

Quality assurance of existing data sets is needed. Sometimes the gear changed also the reporting format, depth levels, etc. Now, we are ready with it for two sets (Arkona Basin, central Gotland Basin).

Annex 3: Working document on productivity indicators, Michael Olesen, Copenhagen University

Whenever measured, it can be demonstrated that the major part of the primary production in the Baltic Sea is based on recycled nutrient. By comparing primary production data for the whole Baltic compiled by Elmgren (1984) with figures of new production for different region of the Baltic measured by Stigebrandt (1991), it can be demonstrated that regenerated production makes up between 50 and 75 % of total production. In the Gulf of Riga regenerated production during the productive season was stipulated to 80-90% (Lundsgaard et al 1999).

Since copepods are the most important grazers on phytoplankton in the Baltic (c.f. Kiwi 1993), the magnitude of regenerated production is likely to be tightly coupled to the presence of copepods. Based on figures on zooplankton biomass and primary production, following relationship between productivity and zooplankton abundance can be outlined:



Primary production is basically determined by the external supply of limiting nutrient (i.e., nitrogen and phosphorus). The outcome in terms of total fixed carbon is however largely depending on the numbers of time these nutrients are made available for primary production before they leaves the euphotic zone. This recycling is a result of two principal features of the pelagic system: on one hand the retention time and on the other hand on the remineralization rate of the limiting nutrients within the euphotic zone. Copepods are likely to play a crucial role for as well the retention as the remineralization of nutrients in the mixed layer. So far no clear evidence for these relationships exists. Therefore this should be considered as a very challenging and top prioritized scientific field for the nearest future.

Important field for further work on this topic:

- Studies of the interaction between copepods and primary production
- Studies of the retention and degradation of matter processed by copepods.
- Compilation of data for comparing the magnitude of regenerated production and the presence of zooplankton in stratified systems
- Studies of copepod regulating mechanisms

Annex 4: Working document on Towed Undulating Samplers, Siegfried Krüger, IOW Warnemünde

Understanding the interaction between biological and physical processes requires high resolution horizontal and vertical sampling made over timescales that are short compared to the evolution of the parameter fields. Traditional methods rely on discrete stations using CTD-probes with Rosette samplers. Fine-mesh plankton nets provide biological samples. Using this methods takes days to weeks to cover a region of interest and delivers a comparatively coarse resolution. Further, over such a period the physical and biological fields may have evolved such that the beginning of the surveybears little relevance to the end. The application of new technology helps to overcome many of these difficulties enabling high resolution measurements from the running ship. One such new technology are ship-mounted or towed ADCP arrangements. Another is the undulating towed body technology. One example of such a towed body with integrated sensors is the ScanFish Mk II. The ScanFish Mk II is a second generation flying underwater wing with flap control of the EIVA A/S in Denmark. It is towed a few hundred meters behind the vessel, undulating self-controlled downwards and upwards according top re-programmed and from the deck unit transmitted tow parameters. In addition to the electronic and mechanical controls the ScanFish can carry standard sensors and probes of different producers in the body. Data are transferred on-line via the tow cable. The complete system consists of the ScanFish Body, the Tow Cable, a computer controlled Cable Winch, a deck-mounted Power and Communication unit and a Control-PC, connected via a serial interfaces (RS-232C). For different instrumentation an extra data collection PC can be necessary (f.e. if a Seabird-CTD is integrated). The fish can be towed with up to 9 knots providing the basic oceanographic parameters (C, T, D, O2) and additional data (depending on the configuration: Chl a, Yellow substances, Turbidity, plankton composition). It produces saw tooth profiles down to 400 m surfacing every 300 to 500m. So areas with complicated structures and high variability can be screened in a short time. There is no alternative with ordinary CTD-measurements for such areas from the point of view of horizontal resolution. A disadvantage is, that now water samples can be taken from the instrument until today, but there are undertaken developments to use a special cable and to pump water from the fish through the cable. The system shouldn't be used without a computer controlled winch and shoud be operated by an experienced engineer. For nutrient and plankton sampling also an ordinary vertical CTD- and Rosette-System should be available for single point measurements and quality assurance.

Annex 5: SGPROD Terms of Reference 2004

The **Study Group on Baltic Sea Productivity Issues in Support of the BSRP [SGPROD]** (Chair: Bärbel Müller-Karulis, Latvia) will meet in Juodkrante, Lithuania, from 2–4 December 2004 to:

a) describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;

b) continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;

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

d) identify gaps in and suggest improvements to the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators.

e) organize a BSRP training workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;

f) plan its meeting in 2006 as a joint or overlapping meeting with at least one other Baltic SG (e. g., SGGIB, SGEH) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups.

SGPROD will report by 15 January 2005 for the attention of the Baltic Committee.

Supporting Information

Priority:	ICES is managing component 1 of the BSRP, Baltic Sea Large Marine Ecosystem Activities. SGPROD provides scientific advice to the productivity module of BSRP component 1. The current activities of the group will address important parts of the BSRP project implementation plan (productivity indicator development, institutional and technological capacity building). Supporting the BSRP, the work of the group also contributes to implementing the ecosystem approach to the management of marine resources and should therefore have a high priority.
Scientific Justification and relation to Action Plan:	a) – 1.2.1 b) – 2.2 c,d) – 1.10 e) – 2.9, 4.10, 4.11.1 all) - 5.6, a and e) Trophic networks will be described for typical subsystems of the Baltic Sea. Trophic networks will be used to analyze the sensitivity of the system to disturbances and to identify suitable productivity indicators. Results will contribute to the indicator system applied in the BSRP. Furthermore, it is planned to present the analysis of the trophic networks at the proposed theme session on “Material and energy flows in trophic networks of the Baltic Sea ecosystem” at the 2005 ICES Annual Science Conference and to publish the results as a scientific paper. The following test cases were suggested for constructing trophic networks: Curonian lagoon Pärnu Bay Askö area Pommeranian Bight Gulf of Riga Experts on the foodwebs of each of these systems will be contacted by March 2004, and invited to contribute. Data should be prepared by October 2004 and the analysis of trophic networks will be started at the November Study Group meeting.

	b) The Study Group will contribute to the development of productivity indicators in the Baltic Sea. During the first half of 2004, the Chair of the Group will intensify contacts to other groups working on indicator development in the Baltic, especially with HELCOM and with the ICES Study Group on Baltic Ecosystem Health Issues in support of the BSRP [SGEH]. The coastal zone management demonstration sites of the BSRP will serve as test cases for indicator development and the Study Group will participate in indicator development and testing. By July 2004, the Chair of the Group will distribute a description of current indicator initiatives in the Baltic Sea as well as background information about the BSRP demonstration sites, available data, and preliminary suggestions for indicator variables, based on the indicator set laid out in this report. By October 2004, the Chair of the group will update the information on the proposed indicators. At this meeting, the Study Group will review the indicator set for the demonstration sites. c) Feasibility and efficiency of automated productivity data collection methods will be discussed intersessionally among SGPROD members with relevant expertise. So far members of the group have expertise with unattended stations and ships of opportunities and the group has established links with BOOS and Alg@line. During 2004, the Group will establish contacts to users of satellite data for productivity monitoring in the Baltic. Intersession consultations will provide the BSRP with the necessary expertise to design the technical upgrading of the productivity monitoring system in the Eastern Baltic. The Chair of SGPROD will distribute a report of the intersession activities to all members in July 2004 and October 2004. Activities will be presented and reviewed at this meeting. d) The Chair will distribute a description of the productivity data collection strategy in the BSRP by July 2004, with an update in October 2004, and invite the Study Group members for their comments and suggestions. The data collection strategy will be discussed and reviewed at this meeting. e) See above under a). f) A joint or partially overlapping meeting with another study group will allow faster exchange of results and ideas and further cooperation among study groups. This will promote develoment of integrated ecosystem assessments.
Resource Requirements:	None
Participants:	The group was attended by 14 participants in 2003. It is planned to expand the group by inviting scientists involved with foodweb analysis in the Baltic Proper and the Swedish archipelago.
Secretariat Facilities:	None
Financial:	BSRP covers participation costs of 2 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 the other groups established in support of the BSRP (SGBFF, SGEH, SGBEM). Contacts have been also established to WGPE.
Linkages to other Organisations:	HELCOM
Secretariat Marginal Cost Share:	BSRP 100%

Annex 6: Meeting Agenda

SGPROD, 2–4 December 2004, Klaipeda, Lithuania

December 2

Plenary

9:00 Welcome

9:15 Introduction of participants

9:30 BSRP Productivity module activities in 2004

Bärbel Müller-Karulis, BSRP Productivity Coordination Center

10:15 ECOPATH modelling of Baltic Sea foodwebs

Arturas Razinkovas, CORPI

11:00 Coffee break

Working groups

Comparative analysis of Baltic Sea foodwebs

ToR a) describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;

The subgroup should discuss the results of the ECOPATH workshop and Baltic Sea foodweb models published in the literatures. The foodwebs should be compared with respect to their productivity and functioning (important trophic transfers, important components). Missing information should be identified. The subgroup should also analyze, whether the foodweb models provide information for the design of productivity indicators.

Productivity indicators

ToR b) continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;

For the lower trophic levels, systematic data collection in the Baltic Sea is driven by the HELCOM COMBINE monitoring program and the requirements of the Water Framework Directive (WFD). Both programs do not aim to describe productivity, but are geared towards the assessment of eutrophication (HELCOM COMBINE part C) or, more general, the evaluation of ecological status (WFD).

The subgroup should discuss, which type of information/indicators is required, to describe the productivity of Baltic Sea coastal and open sea ecosystems, focusing on the lower trophic levels. Expert knowledge and publications on the functioning of Baltic Sea ecosystems, supported by results from the ECOPATH modelling, should be used to identify components of the foodweb that should be covered by a productivity monitoring program. The group should identify how productivity indicators should be evaluated and presented to mangers and decision makers. Further, the subgroup should discuss, to which extend the suggested indicators are covered by HELCOM COMBINE and WFD monitoring programs and how productivity and eutrophication focused indicators and monitoring programs can be linked to each other.

15:30 Coffee Break

17:30 Plenary, short reports from working group discussions

December 3

Plenary

9:00 Report from working groups

9:30 Design of a monitoring program for the lower trophic levels

Mark Berman, US NOAA

10:15 Cost-effective monitoring approach for the Baltic Sea

Jun She, Danish Meteorological Institute

11:00 Coffee Break

Working groups

Cost effective productivity monitoring

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

The subgroup should outline a strategy for cost effective productivity monitoring in the Baltic Sea. The subgroup should also develop suggestions for training and technical upgrades necessary to improve productivity monitoring in the BSRP beneficiary countries.

BSRP workprogramme

ToR d) identify gaps in and suggest improvements to the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators.

The subgroup should review the BSRP coastal study site workprogramme. According to the workplan outlined in the Minutes from the BSRP workshop on strategic design of phytobenthos, water quality and productivity monitoring in the coastal zone, nutrient and phytoplankton indicators will be discussed during dedicated workshops in the first half of 2005. The subgroup should compare the proposed workprogramme to the productivity indicator set proposed under ToR (b) and suggest additions/modifications. The detailed study site descriptions, together with the ECOPATH model results, give a supporting overview of the ecosystem characteristics of each study site.

The subgroup should also discuss elements that should be covered in the 2005 open sea survey in the Eastern Gotland Sea.

For both coastal and open sea surveys, the subgroup should make suggestions, how results of study site data analysis and field surveys should be presented to the scientific community, managers, and decision makers.

15:30 Coffee break

December 4

9:00 **Plenary**

Report from working groups

Discussion of new terms of references, back-to-back meeting with ICES SG/WG in 2005

Theme session **Impact of external forcing on flows in marine trophic networks** at ICES 2005 ASC

ICES SGRPOD Action Plan template

Any other business

11:00 Coffee break

Continue work on draft report

13:00 Closure

Annex 7: Participant List

NAME	INSTITUTE	E-MAIL
Andris Andrušaitis	Institute of Aquatic Ecology, University of Latvia	andris@hydro.edu.lv
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Annex 8: SGPROD Draft Terms of Reference 2005

The **Study Group on Baltic Sea Productivity Issues in Support of the BSRP [SGPROD]** (Chair: Bärbel Müller-Karulis, Latvia) will meet in early spring 2006:

a) review the results of the work of the BSRP lead laboratories on Zooplankton and Phytobenthos, incl. monitoring and survey strategies developed within the BSRP;

b) analyse the technical functioning as well as the results of the coastal and open-sea surveys conducted during 2005, and develop a proposal for a combined ecosystem-fisheries survey;

c) test the performance of the developed system of indicators in characterizing the productivity state of different areas of the Baltic Sea based on existing long-term data, the results of coastal and open-sea surveys conducted during 2005 and the results of trophic network modelling;

d) characterize the productivity state of selected parts of the Baltic Sea ecosystem in 2005 based on the results of coastal and open-sea surveys using identified suitable productivity indicators as a support for the work of fisheries related groups (e.g. WGBFAS, SGBFFI, SGMAB);

e) develop a strategy for ecosystem monitoring in BSRP Phase II, based on analysis of available technologies, sampling design, and cost-benefit considerations.

f) discuss and develop the work plan in the BSRP Phase II and suggest a follow-up Study Group of SGPROD to support the work of the productivity module, and plan its meeting in 2007 as a joint or overlapping meeting with at least one other Baltic SG (e.g., SGGIB, SGEH) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups.

SGPROD will report by xxx 2006 for the attention of the Baltic Committee.

Supporting Information

Priority:	ICES manages Component 1 of the BSRP, Baltic Sea Large Marine Ecosystem Activities and SGPROD provides scientific advice to the productivity module of BSRP Component 1. The current activities of the Group address important parts of the BSRP project implementation plan (productivity indicator development, open sea and coastal surveys) and will serve to review the results of BSRP phase I. Supporting the BSRP, the work of the group also contributes to implementing the ecosystem approach to the management of marine resources and should therefore have a high priority.
Scientific Justification and relation to Action Plan:	a) – 1.10, 2.2 b) – 1.7, 4.11.1 c) – 2.2 d) – 4.11.1, 4.11.2, 4.11.4, 2.2 e) 1.7, 1.10 f) 1.7 a) Work of the BSRP lead laboratories on Zooplankton and Phytobenthos aims to provide better tools for assessing biological properties, including productivity, of the zooplankton and phytobenthos components of marine ecosystems. SGPROD will review the monitoring and survey strategies applied within BSRP Phase I, to strengthen the scientific basis for zooplankton and phytobenthos monitoring in the Baltic Sea. Both lead laboratories will also contribute substantially to the development of productivity indicators. The performance of the developed indicators will be reviewed under ToR c. b) The BSRP open sea survey is based on integrating productivity monitoring with an ICES fisheries survey, providing both productivity (nutrients, phytoplankton, zooplankton) and fisheries data collected within a coherent framework. Technically, integration of both surveys could lead to cost reductions for productivity monitoring. More important, cooperation between the scientists involved encourages holistic ecosystem assessment, addressing interactions between lower and upper trophic levels which are so far widely analyzed separately in the Baltic Sea. SGPROD will review the results of the pilot open sea survey and will develop a proposal for future combined ecosystem-fisheries surveys.

	c) SGPROD has summarized the theoretical background for a system of indicators addressing lower trophic level productivity in the Baltic Sea, developed criteria for productivity indicator performance, and proposed a set of potential indicators. Within the work of the BSRP Productivity Coordination Center and its associated lead laboratories the developed indicator system will now be tested against field data and the performance of individual indicators will be evaluated. d) SGPROD will evaluate the productivity of the lower trophic levels (nutrients -> zooplankton) in selected parts of the Baltic Sea, that were covered by previous work in the framework of ECOPATH models or that were included into coastal and open sea surveys. The information will be made available to fisheries working groups to encourage the use of environmental information in fisheries assessments. e) A sampling strategy for productivity monitoring in BSRP Phase II will be drafted, considering the statistical properties of observed variable fields in sampling network design, as well as cost-benefit considerations, especially with respect to the implementation of modern monitoring technologies (e.g. towed undulators, satellite information). Close cooperation with Baltic Sea monitoring bodies (HELCOM, BOOS) will establish the basis for efficient strategies to improve productivity monitoring in the Baltic Sea. f) Productivity assessment is currently not explicitly addressed in existing Baltic Sea monitoring programmes, though parameters characterizing the lower part of the food web are an integral part of e.g. HELCOM monitoring programmes. During BSRP Phase II productivity assessment has to be anchored within the existing environmental and fisheries assessment programmes and its added value has to be demonstrated. Scientific input from SGPROD to the workplan of BSRP Phase II will be essential to reach this goal.
Resource Requirements:	None
Participants:	The Group was attended by 22 participants in 2004. It is planned to increase cooperation with other groups concerned with the lower trophic levels, e.g., WGZE, WGPE.
Secretariat Facilities:	None
Financial:	BSRP covers participation costs of 2 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 the other groups established in support of the BSRP (SGBFF, SGEH, SGBEM). Contacts have been also established to WGPE.
Linkages to other Organisations:	HELCOM
Secretariat Marginal Cost Share:	BSRP 100%

Annex 9: Action Plan Progress Review 2005

Year	Committee Acronym	Committee name	Expert Group	Reference to other committees	Expert Group report (ICES Code)	Resolution No.		
2004/2005	BCC	Baltic Committee	SGPROD		2004:\E:02	2H02		
Action Plan	Action Required	ToR's	ToR	Satisfactory Progress	No Progress	Unsatisfactory Progress	Output (link to relevant report)	Comments (e.g., delays, problems, other types of progress, needs, etc.
No.	Text	Text	Ref. (a, b, c)	S	0	U	Report code and section	Text
1.2.1	Quantify the changes in spatio-temporal distribution of the stocks of important species in relation to environmental change, using survey and commercial data.	Describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;	a)	+			chapter 3	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop	Describe networks of trophic transfers for the Baltic Sea Ecosystem in selected areas and analyse the importance of individual compartments and flows for the functioning of the ecosystem;	a)	+			chapter 3	
2.2	Develop a process for conducting holistic assessments of the impact of human activities, and identify a suite of indicators or variables that will facilitate the monitoring of ecosystem status and evaluating whether ecosystem quality objectives (EcoQOs) are being met. This will be achieved by the following activities:	Continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;	b)	+			chapter 4	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop integrated approaches for specific sea areas. [BCC]	Continue the development of a system of indicators that characterize productivity at different trophic levels in the Baltic Sea taking into account the work already undertaken by ACE and the EEA, the importance of individual trophic transfers for the functioning of the Baltic Sea ecosystem, as well as the evidence for links between land-based nutrient inputs and long-term changes of productivity and biodiversity in eutrophied areas of the Baltic Sea;	b)	+			chapter 4	
1.10	Develop better tools and training opportunities for monitoring and observation of physical, chemical and biological properties of marine ecosystems. [FTC]* [Other Science Committees]	Continue to study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms, etc.), in collaboration with BOOS;	c)	+			chapter 5	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop integrated approaches for specific sea areas. [BCC]	Continue to study the feasibility and efficiency of automated methods for productivity data collection (e.g., satellite imagery, ships of opportunity, profiling instrument platforms, etc.), in collaboration with BOOS;	c)	+			chapter 5	

Action Plan Progress Review 2005 (continued)

1.10	Develop better tools and training opportunities for monitoring and observation of physical, chemical and biological properties of marine ecosystems. [FTC]* [Other Science Committees]	Identify gaps in and suggest improvements to the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators;	d)	+			chapter 6	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop integrated approaches for specific sea areas. [BCC]	Identify gaps in and suggest improvements to the data collection strategy in the productivity module of the BSRP with respect to addressing relevant trophic transfers and with regard to providing suitable information on productivity indicators;	d)	+			chapter 6	
2.9	Determine the biological response to eutrophication taking into account oceanographic conditions. [OCC/MHC/LRC]*	Organize a BSRP Training Workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;	e)	+			chapter 3	
4.10	Promote, through workshops, study groups, and training courses, the development and better application of methods for resource enumeration, status evaluations, and forecasts. [RMC/FTC/DFC]	Organize a BSRP Training Workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;	e)	+			chapter 3	
4.11.1	Continue and expand the development of tools, possibly ecosystem models, that facilitate the assessment of monitoring and scientific knowledge of ecosystem functions in a holistic manner. [MHC/OCC/RMC/BCC]*	Organize a BSRP Training Workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;	e)	+			chapter 3	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop integrated approaches for specific sea areas. [BCC]	Organize a BSRP Training Workshop together with US NOAA on application of Ecopath modelling methods for the Baltic Sea;	e)	+			chapter 3	
5.6	Collaborate with and support the Baltic Global Environmental Fund Project for the Baltic Large Marine Ecosystem, and related projects from other areas such as NATO, IMO, etc. to develop integrated approaches for specific sea areas. [BCC]	plan its meeting in 2006 as a joint or overlapping meeting with at least one other Baltic SG (e. g., SGGIB, SGEH) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups.	f)		0			logistic difficulties, proposed meeting dates did not fit
8.1	Identify scientific communities in each Member Country that are candidates for increased participation in ICES, and develop a plan for attracting them. [Bureau/Delegates]	plan its meeting in 2006 as a joint or overlapping meeting with at least one other Baltic SG (e. g., SGGIB, SGEH) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups.	f)		0			logistic difficulties, proposed meeting dates did not fit