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Report of the Study Group on Baltic Ecosystem Model Issues in Support of the BSRP (SGBEM)

12–14 January 2004
Warnemünde, Germany

International Council for the Exploration of the Sea

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1 INTRODUCTION

1.1 Opening

The first meeting of the Study Group on Baltic Ecosystem Model Issues in Support of the BSRP (SGBEM) was hosted by the Chair, Wolfgang Fennel, who welcomed all participants. Jan Thulin from ICES gave a short introduction to the BSRP.

1.2 Participants

The meeting was well-visited although five nominated members were unable to participate in the meeting. Jan Thulin from ICES and the Chairs of the Study Group on Baltic Sea Productivity Issues and the Study Group on Baltic Ecosystem Health Issues attended the meeting. The list of participants is attached to the report as Annex 1.

1.3 Terms of Reference

2H03 A **Study Group on Baltic Ecosystem Model Issues in Support of the BSRP** [SGBEM] (Chair: Wolfgang Fennel, Germany) will be established and will meet in Warnemünde, Germany, from 12–14 January 2004 to:

a) analyse the scientific basis of ecosystem and fishery models of the Baltic and explore possible connections of them in future generations of Baltic Sea models, taking into account work already done in ICES;

b) define needs for data to initialise and validate models and identify gaps in process descriptions to stimulate targeted measurements, taking into account work already done in ICES;

c) recommend variables included in the BSRP-monitoring to support future modelling activities;

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

1.4 Agenda

The meeting was structured in talks given by modellers dealing with different parts of the marine foodweb, reports on related activities, BOOS-data management and reports on two of the sister Study Groups of the Baltic Sea Regional Project (BSRP). The remaining part of the time was then used for discussions and drafting of the report.

2 STATE OF THE ART OF THE MODELLING OF THE BALTIC SEA

2.1 Physical chemical and primary production modelling (State variables)

Laws for the conservation of momentum, energy and matter are the foundation of physical ocean models. Consequently, physical models are designed to conserve these properties and to describe their transformation from one form to the other (e.g., for energy, from electromagnetic radiation to internal energy of matter).

Likewise, the chemical and biological models are built on conservation principles of chemical substances that participate in the biogeochemical cycling of matter (carbon, macro- and micronutrients). The models describe their assimilation from dissolved inorganic forms into algal biomass during primary production, subsequent grazing by heterotrophic organisms, assimilation into higher trophic levels by predation, and finally, remineralisation back to the water column or burial into bottom sediments. Biogeochemical models of the Baltic should describe this whole cycle.

The Baltic ecosystem has a high inherent spatial and temporal variability, which is obvious from, e.g., satellite images. The variability is seen in numerical models of sufficiently high resolution, and can be explained by analytical theories. There are two main strategies to tackle such variability in models.

Consistent 3-D models, which obey conservation principles, explicitly resolve the natural degrees of variability to a level that depends on their spatial resolution.

Alternatively, the spatial variability of the system can be parameterised in numerical models of lower dimensions. 1- and 2-D models have the advantage of more rapid integration and these models are therefore attractive for explorative studies, but their parameterisations pose more limits to their predictive capabilities than for consistent 3-D models.

Physics

Several types of physical models are being applied to ecological model research in the Baltic Sea. According to their dimensionality, they can be grouped as follows:

- Consistent 3-D models that are based on open source, international models (IOW: MOM3; IFMK: MOM2; FIMR: MITgcm) or sources with a limited distribution (EMI, DHI: Mike3; FIMR: Andreev model; Ivanov model) are being applied for environmental problems of the Baltic Sea. These models typically have an embedded module for Eulerian tracers (i.e., chemical and biological substances), which is integrated simultaneously with the physical module and can therefore benefit from the conservation properties and turbulence schemes of the physical model.
- Off-line 3-D models, which are frequently used to rapidly produce 3-D fields of environmental variables. The source for these models in this category is typically proprietary not released (EIA Finland model), and the time-series of their fields do not satisfy all physical conservation laws.
- 1- and 2-D models, which are typically used for the analysis of nutrient budgets in limited areas. These models can be integrated rapidly and allow for the exploration of several model options.

Chemistry

Almost all ecosystem models of the Baltic Sea describe the evolution of inorganic nitrogen and phosphorus. The situation with various forms of inorganic nitrogen (nitrite, nitrate, ammonium) varies between the models, whereas the description of dissolved organic and particulate forms is often included, but as a reflection of active international research on DOM dynamics, consistency between the model implementations, as well as their validation, could be better. Silicate is included as a limiting variable for diatoms in a few models.

The redox dynamics has been shown to be important for the nitrogen cycles in particular. Denitrification varies both spatially and temporally, whereas phosphate is mostly released in less variable deep anoxic areas.

Primary production

A good and timely strategy for the modelling of the biotic parts of the Baltic ecosystem is given by the Working Group on Modelling of Physical Biological Interactions (WGPBI). The Working Group emphasises the need to search for "biological primitive equations" describing the intrinsic dynamics of individual functional groups or species. Concerns are expressed about the capability of current models to represent, e.g., the diapause, as well as the fundamental problem of whether it is possible to accumulate individual species into functional groups, and what accuracy is lost in this process.

Present models of primary producers in the Baltic Sea often separate between the generalized functional groups of cyanobacteria, flagellates and diatoms. Differences in the responses of these groups to environmental stresses (hydrodynamic conditions, changes in anthropogenic forcing) are seen in model results.

As a result of the WGPBI recommendations, the first steps towards the biological primitive equations (species-specific models) of critical phytoplankton species have been made. These are based on the derivation of phytoplankton growth properties from laboratory experiments, and these model results are therefore independent of observations against which they can be validated.

For species or processes, for which there is not enough experimental knowledge, fuzzy logic tools have been applied. Such tools constitute a way to mathematically formalize educated guesses, and may prove useful for environmental management.

Inverse models are used to create consistent nutrient budgets and networks of material fluxes within the ecosystem using monitoring data of state variables. Although somewhat sensitive to the choices made in the inverse models, they have the potential to provide information of nutrient sources, pathways, and sinks.

Gaps in models

The coastal sea is the primary receiver of nutrients and toxic substances from rivers and land-based points and diffuse sources. The load of nutrients, mineral particles and dissolved organic matter results in higher concentrations of biochemical parameters within the coastal sea as opposed to the open sea. Frequent resuspension of sediments in shallow areas increases the concentration of suspended matter in coastal waters and affects the underwater light environment. This may eventually result in sharp gradients between coastal and open sea phytoplankton production.

The effect of dissolved organic matter and suspended particular matter on light attenuation has not yet been properly resolved in the ecosystem models. Irregularities of coastal upwelling, formation of upwelling filaments and squirts extend far to open sea. Present ecosystem models do not resolve cross-filament spatial scale properly. Thus, to apply improved parameterisation of subgrid-scale transport processes between coastal sea and open sea is recommended.

Phytoplankton growth is limited by different nutrients in different parts of the Baltic Sea. The transport of material between the sub-basins of the Baltic Sea connected via narrow channels and separated by shallow sills is important. The analysis of factors affecting transports of material between basins in the model should be performed. Much of the nutrients and organic matter is deposited in the sediments, while the redox processes in sediments and the release of nutrients from the sediments could be better represented in models.

The explicit simulation of fate of toxins, biological uptake of toxic substances and bioaccumulation of toxins in different trophic levels should be included in models. Also, the biochemical processes of remineralisation have not been satisfactorily resolved. The utility of modelling regarding the influence of the toxic substances on the parameterisation of the biochemical reactions (ecotoxicology models) is not well assessed.

Consistent assimilation schemes should be developed for the biological and chemical parts of the models. Such schemes could be used to establish model-derived time-series of the state of the Baltic, which are consistent with observations. Such analysis schemes allow the calculation of nutrient budgets.

There is a need for a better understanding of the sedimentation, remineralisation, and aggregation processes in the water column (marine snow), and their effect on the nutrient budgets.

Usage examples

New applications of existing and foreseen models are sought in process studies, case studies (the two latest include the development and assessment of development scenarios), operational support of marine activities, support of the decision-making process and training.

At the present state, a bi-directional exchange among monitoring groups in the BSRP is highly encouraged, i.e., while the modelling community assesses the field outputs from the BSRP, the monitoring parties should have the opportunity to use model results—ideally operational forecasts—to assess the expected conditions in a time/space frame of their ongoing field activities.

2.2 Zooplankton Modelling

Stage resolving model of copepods in biogeochemical ecosystem models

Most of the ecosystem models applied to the Baltic Sea include zooplankton, but with differently detailed process resolution. Simple approaches truncate the foodweb at the level of phytoplankton and simulate the top-down effects of zooplankton in terms of phytoplankton mortality. A step towards a more complex approach is an explicit formulation of a zooplankton state variable, the so-called bulk zooplankton, which lumps together all parts of zooplankton. The bulk variable provides a dynamically developing grazing pressure on phytoplankton. These approaches usually are applied in biogeochemical models that aim at descriptions of nutrient cycling in marine environments. Successful applications on eutrophication problems and harmful algae blooms have been made in Sweden, Finland, and Germany.

A more detailed resolution of zooplankton is needed for simulations aiming specifically at the zooplankton and the link to higher trophic levels. In this context, life cycles of zooplankton and size classes become important aspects of the model design. The model types are still in an early phase of development and further theoretical work is required. Some progress has been achieved in the framework of the ongoing German GLOBEC Project. A Eulerian stage resolving zooplankton model component was embedded in biogeochemical models to extend the description of the food chain in a consistent manner, in particular the mass conservation is included. These models are suitable for decadal simulations where interaction between trophic levels is important.

The State Variables models cannot track life histories or trajectories of individual copepods. This can be done with Individual Based Models (IBMs). However, IBM's have their own problems, which limit their usefulness to a subset of studies.

Output for other BSRP Study Groups

All state variables simulated in 3-D models can be made available and accessible. Apart from the physical quantities, these variables include nutrients, phytoplankton, and zooplankton, but also oxygen which is important for the Baltic.

Fluxes between state variables represent processes. Not all of these data are stored as standard output of models and needs for specific data must be formulated to be included in model output data files, i.e., requirements for model data must be known before the simulations take place.

Data needed

Modelling needs data for calibration, validation and initialisation. Consequently, independent data sets with an appropriate resolution in time and space for all simulated variables are required. This cannot be done in a realistic way. A compromise could be data sets with monthly resolution and at least some transects from the coasts to central parts. Most important parameters are nutrients (N,P,Si) and phytoplankton. All data beyond this requirement would be much appreciated.

A stage structured individual-based model of the copepod *Pseudocalanus* sp. coupled to a 3-D hydrodynamics model

Present state

The copepod, *Pseudocalanus* sp., is a key trophic player in the deep basins of the Central Baltic Sea. The calanoid is a major food organism for many fish larvae as well as for juvenile and adult pelagic planktivorous fish. Variations in abundance thus determine fish and fish larvae vital rates such as growth and mortality eventually influencing recruitment success.

Pseudocalanus sp. lives in the study area on the margin of its distribution with respect to salinity, and large interannual fluctuations in the standing stock over the last two decades have been attributed to significant changes in the hydrographic environment. Simultaneously, changes in the atmospheric forcing resulted in changes of the general circulation pattern in the Central Baltic deep basins from retentive in the 1980s to dispersive during the 1990s. The model combines a temperature-dependent simple stage-based Individual-Based Model (IBM) to a General Circulation Model (GCM) of the Baltic Sea to simulate the interaction of *Pseudocalanus* sp. with the physical environment. By performing model runs for years 1979 to 2000, the drift and development of individual copepods with respect to: (i) the exchange of animals between the three major deep basins of the area (Bornholm Basin, Gdansk Deep, and Gotland Basin), and (ii) advection in habitats with unfavourable physical conditions was investigated. Finally, the contribution of individual drift to the observed interannual dynamics of *Pseudocalanus* sp. was evaluated.

Cumulative final distribution of the C5 resting-stages showed a large fraction of the Bornholm Basin population to be advected into basins further to the east, while only a very small percentage of the Gdansk Deep/Gotland Basin population was able to reach the Bornholm Basin. Further, during the 1990s, higher percentages of individuals were advected out of the Bornholm Basin more frequently. This model study thus shows that: (i) circulation patterns may have implications on the standing stock of *Pseudocalanus* sp. in the Bornholm Basin, with (ii) effects on the food availability for especially larval fish, and eventually on recruitment; and (iii) changes in the circulation pattern during the 1990s are clearly visible in the results of our simulations.

Simulated annual percentages of C5 resting-stages in waters with ambient salinities above and below 7 showed an opposite development. While during the 1980s decreasing percentages in salinities <7 were observed, the proportions in low salinity waters increased during the 1980s. From these simulations it can be concluded that: (i) increased advection into unfavourable salinities may have impacted vital rates of *Pseudocalanus* sp. in relation to maturation, egg production or mortality, and thus (ii) contributed to the declining standing stock during the 1990s; and (iii) again the impact of climate-induced changes in the circulation on a marine population is visible in our simulations.

Future developments

Using newly available data on life-cycle and distribution of *Pseudocalanus* sp., the present model will be further developed to include processes such as growth, egg production and mortality. Beside the physical environment derived from the coupling to the 3-D hydrodynamics model, the model forcing will be constituted by prey fields of phyto- and microzooplankton. These may be derived from field campaigns or by coupling to NPDZ-models (see Section 2.2.1).

A more sophisticated, coupled IBM may then have the potential to realistically mimic the population dynamics of *Pseudocalanus* sp. and may feed prey fields in, e.g., fish IBMs (see Section 2.3) or multi-species stock production models (see Section 2.4). Further it may be possible to simulate the impact of climate change on the *Pseudocalanus* sp. population by using outputs from atmospheric circulation models as forcing for the hydrodynamic model.

Output for other BSRP SGs

This modelling approach has the potential to deliver time-series on abundance useful in growth and recruitment models for stock projections of commercially important fish stocks (see Section 2.4; link to SGBFFI).

Moreover, abundance and biomass time-series may serve as indicators of ecosystem health and productivity, especially with respect to climate-induced changes in salinity and circulation in the Baltic Sea (link to SGBEH and SGPROD).

The use of coupled biophysical models for habitat identification and recruitment prediction of Baltic fish stocks

Present state

A coupled hydrodynamic/trophodynamic individual-based model (IBM) of drift and feeding has been used to examine growth and survival of Baltic larval cod at the level of individuals. This coupled model allows an examination of feeding success, growth and starvation mortality of larval cod in the Bornholm Basin, which is presently the most important spawning area, in the context of their transports by utilizing trophodynamic relationships along their potential drift routes. Implementation of the coupled model required zooplankton abundance as well as turbulence and temperature fields as inputs to the larval feeding, metabolic and growth components. The results of the model runs showed the dependence of Baltic cod larvae growth and survival success on climatic forcing conditions both directly in terms of transport and temperature and indirectly due to the impact on prey population development.

From the simulations a general change in circulation patterns from retention during a first decade (1979–1988) to dispersion in the following decade (1989–1998) was obtained. This increase in dispersion was related to an increase in the variability of the local wind forcing conditions over the Baltic. The more frequent occurrence of dispersion in spring of the second decade was accompanied by a strong decay in biomass of one of the main larval fish feeding components in the central basin, the calanoid copepod *Pseudocalanus elongatus*. Larger dispersion of this prey organism affected the spatial overlap and thus the contact rates between predator and prey. Hence, this may have resulted in a food limitation for early life stages of Baltic cod and potentially contributed to the pronounced shift in their peak spawning time from spring to late summer. Early life stages of cod originating from late-spawning fish, benefited from a stronger dispersion in late summer and autumn, into shallow coastal areas with higher calanoid abundance.

As a second modelling task, the circulation model has been used to provide information on the physical environment within the Baltic Sea to be compared with measured variables obtained from Data Storage Tag (DST)-equipped adult cod. The methodology in use allows the identification of the most proper migration routes (geolocation) by utilization of commonly used ‘least-square’ techniques.

Future developments

Future IBM approaches have to simulate the full life cycle of fish early life history stages. For example, there is a need to incorporate the egg stage and, consequently, to address the impact of predation on egg survival considering spatially resolved predator fields.

Another task will be the coupling to lower trophic models, i.e., input of zooplankton prey fields from, e.g., copepod population models or more complex NPZD-models which incorporate zooplankton stage-structure (see Section 2.2).

Output for other BSRP SGs

These modelling approaches have the potential to deliver recruitment indices time-series useful in stock projections of commercially important fish stocks (see Section 2.4; link to SGBFFI).

Additional time-series on recruitment indices may serve as indicators of ecosystem health and productivity (link to SGBEH and SGPROD).

2.3 State of the art of fish-modelling

2.3.1 Fish stock assessment models taking into account species interactions in the Baltic Sea

Multispecies stock assessment models are the only fishery models applied in the Baltic Sea which take into account elements of the ecosystem approach. Elements of ecosystem approach in this context refer to simulation of interactions between species: usually predator–prey interactions. These may be interactions of two types:

a) impact of predator fish or other animals on survival of smaller fish;

b) impact of food resources on growth rate of fish.

Three multispecies models have been applied to the Baltic:

- Andersen–Ursin model;
- The multispecies VPA: MSVPA;
- The multispecies production model.

Of those three, only the MSVPA—after several years of testing and implementation—has in recent years been routinely used by ICES working and study groups.

The Andersen–Ursin model

The Andersen–Ursin model (Andersen and Ursin, 1977) is a very comprehensive, age-structured model of the ecosystem, simulating interactions of type a) and b). The model in its entire form covers all trophic levels: from primary production, through zooplankton to fish and top predators. Its fishery part is a multispecies extension of the single species model of Beverton and Holt (1957). This part of the model is formed by the system of differential equations for numbers (N), weight (w), and yield (Y)

$$dN_{as}/dt = -(F_{as} + M2_{as} + M1_{as})\, N_{as}$$

$$dw_{as}/dt = v_s h_s f_{as} w_{as}^{2/3} - k_s w_{as},$$

$$dY_{as}/dt = F_{as}\, N_{as}\, w_{as}$$

where

F, $M2$, $M1$ = fishing, predation, and residual natural mortality,

f = feeding level,

v, h, k =growth parameters (v - fraction of eaten food assimilated for growth),

and a and s are indexes for age and species.

In this model, two quantities are new compared to the single species Beverton and Holt model: feeding level and predation mortality. These quantities add the multispecies dimension to a single species model. The feeding level takes values between 0 and 1 and determines feeding conditions for fish. It is zero when fish is fully starving while it is close to 1 when feeding is optimal. In the Andersen and Ursin model, the feeding level is presented as hyperbolic function of available food, P

$$f_{as} = P_{as} / (P_{as} + Q_{as}) ,$$

where Q is the search rate.

The predation mortality increases with predator numbers and its weights, and decreases with available food for the predators

$$M2_{as} = \sum_{predator} \ldots \sum_{ages} h_r\, G_{br}^{as}\, N_{br}\, w_{br}^{2/3} / (Q_r + P_{br})$$

It is also dependent on suitability coefficients G_{br}^{as} which measure how given prey (age a of species s) is suitable as food for given predator (age b of species r). The suitabilities are normalised so that they assume values between 0 and 1. They may be further separated into vulnerability (ro) and size selection (g)

$$G_{br}^{as} = ro_r^{s}\, g_{br}^{as}$$

Andersen and Ursin (1977) assumed lognormal size selection in their model.

The available food is the sum of all biomasses in the model with suitabilities as weights

$$P_{br} = \sum_{prey} \ldots \sum_{ages} G_{br}^{as}\, N_{as}\, w_{as}$$

The multispecies VPA

The MSVPA (Helgason and Gislason, 1979) is an age-structured model, now routinely used in the Baltic by ICES Working and Study Groups. The method is constrained to simulation of impacts of predatory species on prey fish. The weight-at-age is not modeled; for calculation of biomass the observed weights are used. The MSVPA is a backward calculation recursive method, iterations are used to find its final solution. Basic equations are presented below:

$$N_{as}(y) = N_{a+1,s}(y+1)\; exp[F_{as}(y)+M2_{as}(y)+M1_{as}]$$

$$C_{as}(y) = F_{as}(y)\; avN_{as}(y)$$

$$M2_{as}(y) = \sum_{predator} \ldots \sum_{ages} R_r\, G_{br}^{as}\, avN_{br}(y) / [OT+P_{br}(y)]$$

where R is the feeding ration, $avN_{br}(y)$ the average number at age group b of species r at year y, C is the catch in numbers, OT refers to other food. These equations relate fish numbers at the beginning of year, y, with numbers at the beginning of following year, y+1, and the present catch and predation mortality in year, y.

The multispecies production model

This multispecies production model (Horbowy, 1996) is a synthetic model which needs the time-series of age structures of the simulated stocks. The model in its original form was constrained to simulate impacts of predatory species on prey fish. However, an extension of the model to reflect the dynamic of fish growth rates is possible. The model has been derived from the multispecies model of Andersen and Ursin and may to some extent be regarded as its synthetic simplification. The derivation was based on taking derivatives $dB_{as}/dt = w_{as}dN_{as}/dt + N_{as}dw_{as}/dt$ of the biomass $B_{as}(t) = N_{as}(t)\; w_{as}(t)$, and replacing dN_{as}/dt and dw_{as}/dt by formulae from the Andersen and Ursin (1977) model. Next, dB_{as}/dt were summed over ages, some terms and quantities were averaged and approximated, which led to the model:

$$dB_s/dt = (v_s h_s w_s^{-1/3} - k_s - F_s - M1_s - \sum_r h_r w_r^{-1/3} \frac{G_r^s B_r}{\sum G_r^i B_i + OT})\; B_s \qquad (*)$$

where

G_r^S = suitability of prey s to predator r,

w = observed average weight in the stock.

Denoting the term in brackets in (*) by $a_s(t)$ and assuming that it is constant in interval <t,$t+dt$> equation (*) may be solved for B

$$B_s(t+dt) = B_s(t)\; \exp[a_s(t)dt]$$

Next, taking dt=1 and assuming that recruitment enters the stock at time $y + 1$:

$B_s(y+1) = B_s(y) \exp[a_s(y)] + R(y+1)_s$.

One can use shorter time step to solve (*) if needed. Recruitment in the model may be treated as external variable and presented as

$R(t)_s = bR(y)_{s,\ \mathrm{index}}$

where $R_{s,\ \mathrm{index}}$ = index of year class strength from *YFS*, and b is the parameter to be determined or, alternatively, a recruitment sub-model may be developed, relating year class strength with parent stock biomass and some other environmental variables if necessary.

2.3.2 Spatial distribution data from acoustic and demersal trawl surveys Baltic

Data obtained from fishery research surveys play an important role in age-structured stock assessment models. These data are also used for ecosystem studies. There are two fishery research surveys conducted regulary in the Baltic area: pelagic trawl surveys mainly for sprat and herring (in October, sometimes in May) and demersal trawl surveys mainly for cod and flounder (in February/March and November). These surveys are internationally coordinated in time and area, and for the demersal trawl surveys a common standard fishing gear (TV3-trawl) is used. The biological, cpue and acoustic data obtained from the surveys are used for stock assessments and for estimating year class abundance used later for predictions. The survey data are stored in a standard exchange database format: The demersal survey data are recorded in a BITS (Baltic International Trawl Survey) database and pelagic survey data in a BAD (Baltic Acoustic Database) database. Apart from detailed haul information and biological data (length distribution, maturity, age, etc.) of species, valuable environmental data, such as hydrographic data (temperature, salinity, and oxygen), are recorded in 10 m depth intervals, but at least near the surface and the bottom. The database also allows for recording meteorological parameters (wind direction and speed) and also for physical aspects of the water like swell direction and height surface and bottom current and speed.

The present use of the environmental data is rather limited but can be useful in studies with ecosystem models.

3 LINKS TO OTHER ACTIVITIES

3.1 Data management in BOOS and PAPA

Thomas Badewien reported on the advance of data management in BOOS and PAPA (Baltic Operational Oceanographic System and Programme for a bAltic network to assess and upgrade an oPerational observing and forecAsting System in the region). The work is mainly focused on fast availability of physical, operational real-time data, including derived products such as transports through the transition area of the Baltic. The project provides invaluable experience in building up basin-wide networks and fast data distribution, which is a prerequisite for good forecast systems.

Chemical and biological data are so far not part of the system. One reason, among others, is the problem with working up biological measurements. There is still a substantial delay, and real-time data are not so easy to obtain as physical data (e.g., sea-level, temperature, and salinity).

Due to the operational aspect of the data management in BOOS and PAPA, there is still a need to define ways for a coherent long-term management and banking of data sets.

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

Bärbel Müller-Karulis, Chair of the Study Group on Baltic Sea Productivity Issues in Support of the BSRP (SGPROD) reported on the first meeting of SGPROD and explained the goals of the productivity module in the BSRP. In the BSRP, productivity serves both as an eutrophication indicator, as well as a descriptor of trophic interactions. The project aims to introduce productivity information into fish stock assessment, establishing an ecosystem-based approach to fishery management, as well as to improve the indicator systems used to describe eutrophication.

With respect to productivity issues, the BSRP aims to upgrade the current productivity monitoring system by expanding the use of automated data collection strategies (buoys, ships of opportunity, satellite information). Shipboard productivity monitoring will be integrated into fishery data collection, generating a unified dataset of productivity (phyto- and zooplankton), and supporting data (nutrient concentrations, hydrographic variables). In the coastal zone, which is regarded both as the recipient area for eutrophying substances as well as the nursery grounds for many fish species, phytobenthos monitoring will be intensified and combined with the collection of other productivity information (nutrients, phyto- and zooplankton). Coastal zone monitoring will be coordinated with land and coastal management activities under Component 2 of the BSRP. The project aims to establish a tested set of indicators that traces the effects of land-based nutrient load reductions in the coastal ecosystem.

The Chair of SGPROD explained that the Group was established to provide scientific advice to the productivity module in the BSRP. She reviewed the conclusions of the Group which are elaborated in CM 2004/H:03.

3.3 Study Group on Baltic Ecosystem Health Issues in support of the BSRP (SGEH)

The Chair of the Study Group on Baltic Ecosystem Health Issues in Support of the BSRP (SGEH), Eugene Andrulewicz, presented a brief overview on the first SGEH meeting in Gdynia, which took place from 9–12 November 2003. He stressed that the participation at the meeting was not limited to the ICES community experts. This meeting was attended by university lecturers, experts from academy of sciences, NGOs as well as representatives from HELCOM and Baltic 21. An expert from the US had been invited and attended the meeting. His aim was to present and introduce new approaches (Multiple Marine Disturbances (MMED)) relevant to the health of the Large Marine Ecosystems. The main aim of inviting such a diverse group of experts was to share different experiences and approaches to the ecosystem health and ecosystem-based management, recognising that this is a relatively new and a very complex issue.

Further, the SGEH Chair presented past developments of HELCOM Periodical Environmental Assessments and recent developments aiming to improve environmental assessments by introducing an ecosystem-based management strategy to the Baltic Sea. He described issues related to P-S-R and D-P-S-I-R framework of indicators, the concept of Ecological Quality Objectives (EcoQOs) and reference levels. The discussion was focused on common understanding on what should be an ecosystem-based approach to management in case of the Baltic Sea.

In addition, the SGEH Chair stressed the need for modelling in relation to the Baltic ecosystem health developments. He expressed his hope that modelling will help not only in creating a better understanding of the physical, chemical, and biological functioning of the Baltic ecosystem, but also lead to better management. As an example of expected developments he mentioned:

- Models aiming to distinguish anthropogenic effects from natural changes in the marine ecosystems (e.g., in case of eutrophication and/or anoxia);
- Operational models establishing relationship between fishing activities and changes in the marine environment;
- Preparing scenarios of effects of different management measures.

Finally, he expressed his hopes that the SGEH workplan, including a schedule for deliverables to ICES and HELCOM and, in a wider context, to the management of human activities in relation to the Baltic will be prepared in cooperation with SGBEM.

3.4 Working Group on Modelling of Physical/Biological Interactions (WGPBI)

Several member of the study group are also members of the parent ICES Working Group on Physical Biological Interaction. This opens the possibility to interact with a wider community outside the Baltic.

4 RESULTS AND RECOMMENDATIONS

An important aspect of the meeting was to provide an opportunity for modellers working at different trophic levels of the marine foodweb to discuss their approaches.

Three classes of models were considered:

- Coupled physical-chemical-biological models, which provide consistent descriptions of bottom-up effects and included nutrient and oxygen dynamics. These models see fish only through mortality rates.

- Coupled physical and individual-based models which look at one trophic level (e.g., copepods or fish larvae) with considerable detail, but with uni-directional interaction to other trophic levels (e.g., prey field are prescribed).
- Fish stock models without spatial resolution that see lower trophic levels indirectly through data from surveys or landing reports.

The development of model systems which cover substantial parts of the foodweb (nutrients to fish) is a challenge, but seems to be feasible in the coming years. The Group encourages modellers dealing with different trophic levels to combine and integrate their knowledge. Such models can be very complex and will probably be more important for theoretical studies than for short-terms applications. However, such model system can be up-scaled for practical applications.

It is obvious that such models could play a key role in providing a theoretical basis for ecosystem-based advice.

Complex models can also provide data sets for focussed IBM studies which have a great potential to understand migration patterns of target species during their life cycles.

Experimental simulations with numerical model systems provide the potential for the exploration of scenarios, which cannot be done with natural systems. Exploring the response of the Baltic to changing nutrient loads is a successful example. Similar studies can become feasible for fishery scenarios on the basis of new generations of models.

Scenario studies require well-calibrated standard runs to provide reference cases. Concerning forcing fields, meteorological data are available, while there are problems to obtain river discharges and nutrient loads.

There is an urgent need for data sets to initialise and validate models on several trophic levels. Errors in the initialisation may propagate through the models at several time scales.

4.1 Data needs for modelling

There is, in principle, a need for two types of data, on the species level and on the level of the system.

Dynamical signatures of the model species, e.g., growth rates for key species and functional groups as functions of environmental parameters are necessary to improve the mechanistic description in individual-based and state variable models.

Data sets for initialising models—gridded data of physical parameters as well as chemical and biological data, in particular at higher trophic levels—are required for high quality simulation. Spatially resolved data on fish distribution, both zooplanktivores and piscivores, by integrating acoustic surveys with other measurements.

4.2 Specific data needs

A continuous flow of monitoring data is an important requirement for model updates and validations. Currently monitoring datasets are available for the open sea area, but consistent data sets from the coastal sea area are largely missing. Availability of river load data that has passed quality check should be improved.

Apart from bulk chlorophyll data, species-specific and trophic biomass data can provide the information needed for model validation.

Experimental studies to quantify the parameters of vital rates needed in models are similarly important as hydrographical data and spatio-temporal resolved prey fields (e.g., phyto- and microzooplankton). Spatial distribution of fish in conjunction studies of stomach contents is important to describe and quantify the predator fields and prey selectivity. Information on the responses to abiotic factors such as light and behaviour patterns, i.e., ontogenetic and diurnal vertical migration, can be derived from spatially and temporally resolved fields of specific zooplankton stages.

Time-depth series of physical and biological data at fixed locations should be combined with highly resolved sections using towed, undulating instruments complementary to the regular monitoring.

Time-series of gridded ecological fields in the Baltic may be extremely helpful to initialise and check models and to provide boundary values for regional models. Operationally running Baltic Sea ecosystem models with reasonable spatial resolution can become increasingly able to provide analysed datasets to be used as initial and boundary conditions for specific model experiments. For such model data sets, data assimilation will be an important issue.

Toxic substances, which influence the growth, mortality and life cycle of algae, and/or are subject to bioaccumulation and might influence the higher levels of the foodweb, have to be identified and corresponding data acquired.

4.3 Data management

Building on the BOOS and PAPA experience, guidelines for data management and long-term banking should be developed or existing successful systems should be applied. An import aspect is the choice of formats to ensure interoperability of data sets, i.e., seamless use of different sets.

One integrated BSRP product could be a comprehensive ‘BSRP Data Set’, which could be used as a standard to support modelling. This would imply a close cooperation with other programmes, such as the HELCOM Monitoring and the German GLOBEC Project.

5 WORKPLAN

The future work of the Study Group in the next two years will focus on:

a) Review existing community models for the Baltic ecosystems and new developments also in other areas through cooperation with and active participation in the WGPBI.
b) Identify data sets of high priority for modelling issues and ensure a bi-directional exchange of information with the monitoring group of the BSRP.
c) Review the knowledge of the effects of fish acting down the foodweb to nutrients, and to which extend variations in nutrients may act up the foodweb to fish.
d) Discuss and initiate attempts to bridge the gap between fish stock models and ecosystem models for the Baltic.
e) Establish contacts to relevant projects, such as the German GLOBEC, BECAUSE, etc.
f) Provide input and specific contributions to the Theme Session on Regional Integrated Assessments in 2006.

Justification:

(a) There are several model systems used in the Baltic or in parts of the Baltic, e.g. Gulf of Finland. A general comparison of the structure and properties of the models, including new developments outside the Baltic is important to ensure that best knowledge and most advanced systems are applied.

(b) The Baltic is known as one of the most intensely observed seas of the world. Nevertheless, the observational undersampling both in space and time and in relation to chemical biological state variables is not resolved. The new opportunities provided by the BSRP help to improve the data base. A close relation to the data needs of modelling activities is important to make best use of the data. On the other hand, models can provide a lot of simulated data, which can be made available as, e.g., gridded data sets or animated pictures. The bi-directional exchange of data and information is valuable to optimise observational monitoring programmes.

(c) Attempts to quantify bottom up and top down fluxes of nutrients through the foodweb up to the trophic level of fish were published in recent year. A discussion of the current knowledge and indication of gaps is important to better understand the whole system.

(d) An important challenge in the modelling of the marine foodweb is to bridge the gap between lower and higher trophic levels. A well-established attempt is the work on ‘particle-tracking’ models, which follow trajectories of zooplankter or fish larvae and include some bio-energetic modules. This approach ignores, however, the bi-directional feedback to the upper and lower trophic levels. Future generations of models should also include fish in terms of state variables. The discussion of general approaches and an initiation of first attempts by a subgroup is important to start this kind of work, although the SG is aware that this is a risky endeavour.

(e) The SG is aware of relevant research activities, in particular the German GLOBEC and EU project BECAUSE. A close cooperation will be ensured by the members of the SG which are involved in the relevant projects.

(f) An important final product of the SG is a significant contribution to the ‘Theme Session on Regional Integrated Assessments’ which is planned in 2006.

Deliverables

2005

Reports:

Review of the state of the art of existing and new community models for the Baltic ecosystems.

Discussion paper of data requirements for models and model products to support data acquisition

Discussion paper on the quantification of nutrient flux up- and down the food web

2006

Contributions to the 'Theme Session on Regional Integrated Assessments'

Talks/paper (tentative):

The state of the art of modelling the Baltic ecosystems.

Integration of data set and model products

Approaches to connect lower and higher trophic levels in three dimensional ecosystem models

6 ANY OTHER BUSSINESS

Membership

Membership issues were briefly discussed. There was a general agreement that the group covers well the trophic levels of the Baltic ecosystem that are relevant and important to the tasks of the SG.

Next meeting

The Polish participants offered their help to organise the next meeting in Gdynia, Poland. The meeting will be in January or February 2005. The exact date will be fixed in cooperation with the other groups of the BSRP. A back-to-back meeting of two or more groups may be helpful to strengthen the interaction among the groups.

7 CLOSING

The Chair closed the meeting on 14 January at 12.00.

References

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8 ANNEXES

Annex 1 List of participants

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Annex 2 Draft resolutions

Proposed Terms of Reference for the 2005 SGBEM Meeting:

The **Study Group on Baltic Ecosystem Model Issues in Support of the BSRP** [SGBEM] (Chair: W. Fennel, Germany) will meet in Gdansk, Poland, from 14–16 February 2005 to:

a) Review existing community models for the Baltic ecosystems and new developments also in other areas through cooperation with and active participation in the WGPBI.

b) Identify data sets of high priority for modelling issues and ensure a bi-directional exchange of information with the monitoring group of the BSRP.

c) Review the knowledge of the effects of fish acting down the foodweb to nutrients, and to which extend variations in nutrients may act up the foodweb to fish.

d) Discuss and initiate attempts to bridge the gap between fish stock models and ecosystem models for the Baltic.

e) Establish contacts to relevant projects, such as the German GLOBEC, BECAUSE, etc.

f) Provide input and specific contributions to the Theme Session on Regional Integrated Assessments in 2006.

Supporting Information

Priority:	The current activities is part of the BSRP under the umbrella of ICES into issues related to the ecosystem affects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently these activities are considered to have a very high priority.
Scientific Justification and relation to Action Plan:	1.2 –a 1.3 - b 1.5 - all 1.12 - b 5.6 - all Ecosystem models of the Baltic covering the food web from nutrients to zooplankton while the top down control is truncated and parameterised in terms of mortality. Fishery models ignore widely the bottom up effects and spatial distribution. Future generation of models can be envisaged which bridge the upper and lower trophic levels. Such approaches need to be encouraged by quantitative studies of bottom up and top down controls in the food web and by discussion of possible modelling approaches. This will also help to identifies data types needed for the interaction of observation and modelling.
Resource Requirements:	The BSRP will provide all necessary resources so far as the eastern Baltic countries are concerned.
Participants:	Participants should be scientists primarily but not exclusively from the Baltic area, with experience in modelling ecosystems or fish stock dynamics, and scientists with strong interest to interact with modelling. All Baltic Countries must be represented Members of WGPBI who overview similar issues in a more global framework should be involved where appropriate. The Group is normally attended by some 20-25 members and guests
Secretariat facilities:	N/a
Financial:	BSRP covers costs of 5 member/eastern Baltic country
Linkages To Advisory Committees:	ACE

Linkages To other Committees or Groups:	Strong linkage to the WGPBI SG for implementation of the Baltic GEOHAB, the other BSRP Study Groups
Linkages to other Organisations:	BOOS
Secretariat Marginal Cost Share:	BSRP: 100%