Baltic Committee **ICES CM 2000/H:03**
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REPORT OF THE

STUDY GROUP ON THE SCIENTIFIC BASIS FOR ECOSYSTEM ADVICE IN THE BALTIC (SGBEAB)

Gydnia, Poland

19–21 June 2000

International Council for the Exploration of the Sea

Conseil International pour l’Exploration de la Mer

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1 INTRODUCTION

A Study Group on the Scientific Basis for Ecosystem Advice in the Baltic [SGBEAB] was held in Gydnia, Poland from 19–21 June 2000. The meeting was most graciously hosted by the Sea Fisheries Institute. The terms of reference were to:

a) Review Present Understanding of the Baltic Ecosystem and Modelling

Progress in understanding of Baltic ecosystem structures and dynamics:

i) in relation to human impact and driving environmental forces, and
ii) present state of the art of modelling ecosystems and its components.

b) Outline Necessary Actions to Enhance Understanding and Predictive Ability

What are the necessary actions to enhance the understanding and functioning of the Baltic systems as a scientific basis for giving sound ecosystem oriented advice?

What are the necessary actions to establish modelling tools for conducting simulations on the impact of human activities and regulatory enforcements?

c) Identify Advisory Area for ICES

Identify potential key areas for ecosystem advice to be requested from ICES in the future.

Consider the present capability of giving ecosystem oriented advice on various human activities affecting the Baltic systems.

Consider the present and potential role of international organizations and ongoing major international programmes with respect to implementing a framework for ecosystem oriented advice.

d) Workshop

Prepare a recommendation for a workshop on "The Scientific Basis for Ecosystem Advice in the Baltic" to be held in 2001.

e) Report

The Study Group will report to the Baltic and Consultative Committees at the 2000 annual Science Conference.

The Study Group participants were:

Dr. T. Linkowski, Poland;
Prof. J. Thulin, ICES;
Dr. E. Ojaveer, Estonia;
Dr. W. Fennel, Germany;
Dr. T. Raid, Estonia;
Dr. S. Hansson, Sweden;
Mr. J. VanTassell, Sweden;
Mr. Z. Witek, Poland;
Mr. E. Andrulewicz, Poland,
Dr. J. Horbowy, Poland;
Mr. M. Plikshs, Latvia Co-Chair;
Prof..T Osborn, USA Co-Chair

2 REVIEW PRESENT UNDERSTANDING OF THE BALTIC ECOSYSTEM, MODELING AND NECESSARY ACTIONS TO ENHANCE UNDERSTANDING AND PREDICTIVE ABILITY, AND ADVISORY AREA FOR ICES

2.1 Introduction

While no simple review can do justice to the complicated nature of the Baltic and its ecosystem, a few details are worth noting at the very start.

Main Characteristics of the Baltic Sea:

- semi-enclosed brackish water area but a recent development (3500 years) so it has been a changing and developing system
- persistent vertical stratification of the water
- residence time of the water volume ≈ 25-30 years
- large scale renewal of the bottom water is unpredictable – often with long stagnation periods
- plants and animals (mostly marine) in low numbers and stressed
- low water temperature causing low decomposition rate
- large catchment area with land-use activities strongly influencing water quality (85 Million people)
- high load of *nutrients* and *toxic substances* from agriculture, industry, transport, and households

A Major Problem: Nutrient Loading

Due to:

- changes in land use
- loss of wetlands
- fertilizers
- sewage (urban and industrial)
- fossil fuels (from air 1/3)

Present Load:

- Nitrogen = 3 times that of 1940
- Phosphorous = 5 times that of 1940

Result:

- increased biological production = eutrophication
- decreased water transparency
- decrease of brown seaweed, bladderwrack
- change in species composition and abundance of fish and bottom dwelling organisms

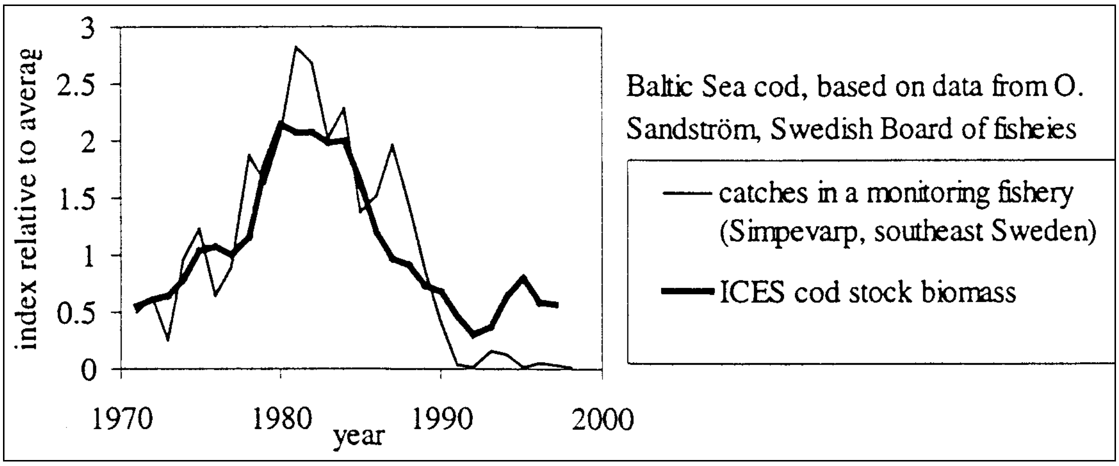
Compared to 1900:

- primary production increased by 30 – 70%
- zooplankton increased by 25%
- sedimentation increased by 70 – 190%

2.2 Baltic Fishery

2.2.1 Review

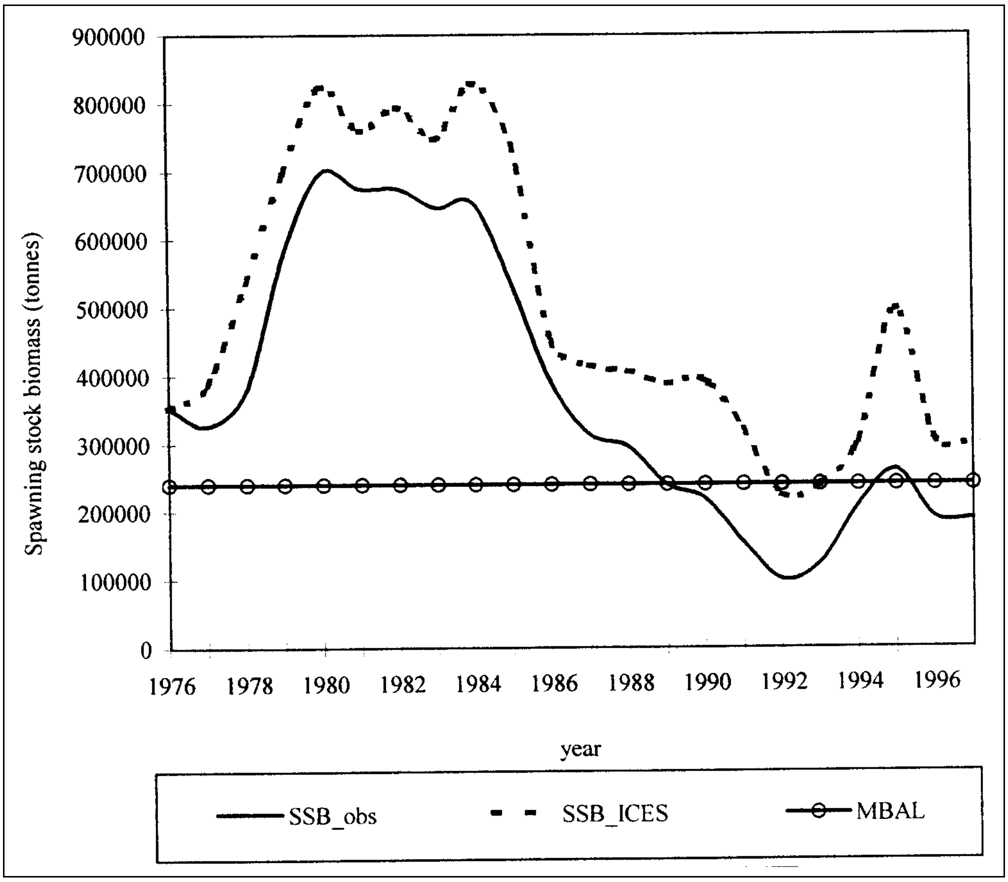
The commercial fishery has significantly influenced the Baltic Sea ecosystem, particularly through the targeting on piscivorous fish. Cod has a special status in this respect, naturally being the dominant piscivore in the Baltic proper. Its reproduction is restricted to few areas with sufficiently high salt and oxygen concentrations (Sparholt 1996). The "spawning volume" of cod is small and rather variable as a result of natural variation in the water exchange with the Kattegat/Skagerrak area. This volume has been further reduced due to an increased deep-water oxygen consumption induced by increased sedimentation caused by eutrophication. Taken together, these factors result in large inter-annual variation in the reproduction success, and the fishery management has failed to account for this and overfishing has reduced the population and caused a dramatic reduction of the area occupied by cod. In these areas, with cod as the key piscivorous species, this more or less means the removal of an entire trophic level. The reduction in the cod stock affects stakeholders beyond the large-scale fishery. In areas where cod has traditionally been caught in coastal fisheries, fisherman and anglers now have problems in catching any cod. This change in the distribution of cod has also been documented in coastal fish monitoring (graph below).



Index of the status of the eastern Baltic Sea cod stock (heavy line) and catches on a monitoring site at the eastern Swedish coast (thin line).

The decreased cod population has resulted in a drop in the predation pressure on zooplanktivorous fish and as a consequence, sprat (the main prey of cod) has increased substantially (ICES CM 2000/ACME:02). One could speculate about an ecosystem regime shift, from a cod to a clupeid dominated system. By volume, this has probably been beneficial to the off shore fishery, since this has allowed large catches of sprat. Economically, however, this shift has decreased the value of the fishery (less than 1 SEK/kg for sprat compared to 13.50 SEK/kg for cod). Ecological effects of the removal of predatory fish are not restricted to cod. In the Pärnu Bay in the Gulf of Riga, overfishing of pikeperch has resulted in a drastic increase in one of their prey species, the three-spined stickleback (E. Ojaveer, pers. comm.).

The ecological and economic consequences of the management problems that we have had in the Baltic are not fully understood. The lack of separate management of biologically distinct populations, like the eastern and western cod stock and different herring populations, is problematic. When combined with TACs that exceed management advice (graph below), and catches that exceed TACs, this has probably resulted in long-term economic losses and substantial ecological damage.



The biomass of the spawning stock of eastern Baltic cod as observed (SSB_obs) and as simulated under the assumption that ICES advice on management was followed (SSB_ICES). Biomass levels below MBAL is considered a sign of overfishing (from Radtke 2000).

Not only does the fishery influence the target species. There are by-catches of other fish species, harbour porpoises, seals and seabirds. This is considered as a particular problem for the very small population of the Baltic Sea harbour porpoise. Further details on by-catch issue are in ICES (ICES CM 2000/ACME:02).

It is possible that fishery induced changes have cascaded down the foodweb. The strong increase in sprat was paralleled with a decreased growth in herring (Raid and Lankov 1995). One explanation of this is food competition for their common food (zooplankton). Another explanation is that the deep water stagnation, which caused decreased salinity and recruitment problems for cod, also influenced the zooplankton community structure in such a way that the large and nutritionally important prey decreased in abundance (e.g. Ojaveer et al. 1998; Flinkman et al. 1998). Limited monitoring data and the lack of actual production measurements weaken our understanding of the role of zooplankton, and their changes.

The interaction between the increased adult cod mortality caused by the fishery, and their reduced spawning success due to eutrophication, was described above. Together with other environmental concerns, the latter has initiated actions in Baltic countries to mitigate eutrophication and change the Baltic to a less productive system. A likely effect of this is a generally reduced fish production, which will call for catch reductions that goes beyond those motivated by our ambition to reduce today’s overfishing. Another expected consequence of an oligotrophication of the Baltic is changes in fish species composition (c.f. Hansson 1985; Hansson and Rudstam 1990). It has also been suggested (Hjerne 2000) that the fishery is an important factor in managing the eutrophication problem: by sequestering large quantities of phosphorus from the water column during summer, fish can possibly compete for phosphorus with cyanobacteria and influence the occurrence of bluegreen algal blooms.

2.2.2 Fishery Conclusions

Fisheries management has traditionally been focused on commercially important species and how to optimize catches. Species of limited or only local economic interest, like non-commercial by-catch species, are generally not considered in the management. This single minded focus on overall catch optimization has resulted in the negligence of other aspects, like geographical distributions and the availability of the species concerned to different categories of stakeholders (e.g. off-shore and coastal commercial fisheries, coastal fisheries for recreation and food, marine mammals and birds). Furthermore, traditional single- or multispecies management does not acknowledge that fish populations constitute integrated ecosystem components. Heavily exploited fish species were often originally very abundant and had important ecological roles as both predators and prey, while many have now been seriously reduced by fishing. There are numerous examples of cases in which changes in fish populations have cascaded through the food web, influencing the ecosystem down to the level of phytoplankton (e.g. Carpenter and Kitchell 1993).

By applying an ecosystem analysis in the fishery management, more parameters than stock sizes of target species will be considered and the shortcomings described above will be better visualized. It will also highlight the need for relevant data, for example on the zooplankton production and the factors that determines this. Zooplankton constitute the food-base for many fish species and control their production potential. In a similar manner, ecosystem models will allow for incorporation of climate variation/changes and changes in nutrient loads.

Ecosystem analysis can be seen as a strategic approach which also allows different stakeholders to assign values to different parts of the ecosystem, in contrast to the more tactical approach of short term TACs. It should be acknowledged, however, that we do not today have ecosystem models that can replace the management tools presently used by ICES. There are, however, numerous ecosystem modelling approaches that can be developed to address fisheries/ecosystem management questions and some of these are discussed later. A summary of various models is also given in sections 3 and 7 of ICES (ICES CM 2000/ACME:02).

As described above, the fishery has had a strong impact on the Baltic Sea ecosystem. Thus, an ecosystem management approach has to include a combination of a sustainable and properly managed fishery and effective measures to reduce eutrophication and concentrations of toxic substances. Healthy populations of ecologically and economically important fish stocks will increase our possibility to maintain commercial fisheries, at the same time as new fisheries can be developed (e.g. tourism with fishing possibilities as an important component). With the central role that fish have in the food web, dominating two of the five trophic levels from phytoplankton to mammals and birds, the fishery management is also likely to influence other ecosystem components (e.g. algal blooms, see above and experiences from lakes (Carpenter and Kitchell 1993). Our management goals are not only an issue for the fishery but should be determined through a political process involving different stakeholders. The critical questions to be asked are: **What would we like the Baltic Sea ecosystem to look like, and to what extent can the fishery manager influence this?**

2.3 Modelling

Models are mathematical tools by which we synthesize and test our understanding of the dynamics of the system through retrospective and predictive calculations and comparison to data. Suitable prediction models can then be used for management purposes. Mathematical models are usually presented by a set of differential equations. Models are being used in the Baltic for both fisheries management (Anon. 1999) and ecological analysis (Stigebrandt and Wulff, 1987).

Modelling needs a balanced dialogue between biologists and modellers. Model development needs a well addressed focus with clear objectives and a methodological concept that ensures that the goals can be reached.

Ecosystem models can be roughly characterised by their spatial dimension, from 0D to 3D-models. Box models (0-D) have reduced physics but can be very complex with regard to chemical/biological process resolution and species interactions and can be expanded to 1D water column models. In order to couple the biological models to full circulation models, it is necessary to reduce the complexity of the biological representations as far as is reasonable. Extreme cases of reduced biology in a coupled model are simulations of trajectories of cells or animal, which are considered as passively drifting particles.

We can distinguish two broad classes of models, one which models the food-chain from nutrients to the zooplankton and the other which describes the fish stock dynamics with only weak linkages to the lower part of the food web.

2.3.1 Ecological Models

Ecological models may cover the food chain starting from nutrients and phytoplankton and include zooplankton. They can be embedded in ocean circulation models in order to cover the physical control of the chemical/biological processes. While phytoplankton can be described quite well as a bulk-biomass variable, the treatment of zooplankton requires a stage resolving approach in order to describe growth, development and reproduction in a consistent manner. In stage resolving population models, the development is prescribed by observed stage duration. This approach neglects the feedback to the low trophic levels. More advanced, but also more complex models, include the lower food chain. Then the inclusion of biomass concentration and numbers of individuals per unit volume for each stage is required.

Ecological models coupled to circulation models are now in a state that they can be used to make experimental simulation or to hindcast observed scenarios, e.g., Fennel and Neumann (1996) look at the control of the phytoplankton distribution by mesoscale variability in circulation and nutrients. From the scientific point of view, the "model-experiments" are a way to explore relationship and 'what-happens-when' scenarios. By this work, the models are subject to further development and acquire an enhanced predictive potential, which is important to provide products such as tools for management, e.g., maps of blue-green algal distributions.

Usually the food web models are truncated at a certain level by parameterization, e.g. by including predation by fish through an extra mortality term. One of the few exceptions is the ERSEM (Baretta, *et al*., 1995) where a fish module is explicitly included. However, implementation of these models becomes problematic when behaviour plays a role because this requires modelling on the individual level.

Multi-box and 1D biogeochemical models have been developed for studying eutrophication processes in the Baltic Sea (Stigebrandt and Wulff, 1987 and Savchuk and Wulff in press). They have demonstrated explanatory potential for temporal trends analysis, as well as for regional differences of the nutrient states in the Baltic Sea.

2.3.2 Fish Stock Assessment Models

These may be classified into analytical models and production models. In analytical models, the elements of stock dynamics, such as growth, mortality and recruitment, are described by separate equations which, when coupled together, lead to the model of stock dynamics. An example of such approach is the Beverton and Holt (1957) model. In production models, the change in biomass is a function of biomass and fishing effort. The well known logistic equation (Verhulst, 1838) is a simple example of a production model.

Another classification of fish stock assessment models is to separate between single species and multi-species models. In the single species models, the stock is treated as a unit isolated from the ecosystem, not being influenced by other species or the environment. In the multispecies models, trophic interactions are taken into account. In management applications the predator-prey relationship is most often limited to the impact of predators on the survival of the prey species. Usually only fish trophic levels are modelled and the linkages with other levels are neglected.

Probably the most comprehensive multispecies model is the one developed by Andersen and Ursin (1977), in which the ecosystem is modelled from primary production level to apex predators. This model, however, is quite complex and, in case of the Baltic (with relatively simple trophic relations), is represented by hundreds of differential equations. Such a complex model with many variables and hundreds of parameters is difficult to handle and this complexity is one reason why it is not used as a standard tool of stock assessment.

To apply any model one needs the data characterising the stock and some external information to tune the model. In the case of assessment of Baltic fish stocks, the external information comes from surveys (acoustic survey of pelagic species, bottom trawl survey for demersal fish, young fish survey) and catch per unit of effort from commercial fishery.

There are possibilities to further develop the existing models in such a way that information on the state of the environment could be taken into account. For instance one could model the growth of fish as dependent on food resources by parameterization of the growth equation as a function of food quality and quantity. Similarly, in production models intrinsic rate of growth and/or carrying capacity could be a function of food resources. At present, however, the only interaction with the environment is modelled when assessing the state of herring and sprat stocks. The natural mortality of these species is decomposed into predation mortality (dependent on the state of cod stock) and residual natural mortality. There are attempts to develop the model of cod recruitment in relation to cannibalism and the environment (STORE Project).

2.3.3 Modelling Conclusions

Fishery models are based on statistics and knowledge of fish-biology in conjunction with data from landings, surveys, etc. Though the models truncate the lower part of the food chain, they carry a lot of implicit information by the use of observed data. Those models apply in particular to those cases where variations in the prey field play a minor role and where physical or chemical forcing, e.g. oxygen deficiencies, act directly on the trophic level of the fish.

Ecological models are better able to deal with slow changes that propagate up from below. An ecosystem approach will require further model development and data collection (monitoring and research data) to support the decision making process. **The transition from the 'bottom-up' modelling to the models used in fishery management and stock assessment is still difficult to implement and is an important field of future research.**

2.4 Socio-Economic Impacts Of The Health Of Marine Ecosystems

2.4.1 Introduction

The commercial fish catch may not be the most important benefit from a marine ecosystem. Healthy and balanced marine ecosystems, both unpolluted water and natural communities of marine invertebrates, fish, birds, and mammals are desirable for they:

- constitute the everyday surroundings of the coastal population,
- have impacts upon tourists and tourism.

These activities closely depend on the state of the beaches and the coastal waters which suffer from toxic phytoplankton blooms, the concentration of dangerous and harmful compounds in the seawater, organisms, and marine food.

2.4.2 Baltic Fish And Contaminants

The concentration of contaminants in marine waters and the foodweb have potential impacts on:

- the health of marine organisms (including fish) influencing their health, external appearance and survivability (indirectly their abundance and biomass).
- the health of people consuming marine products.

After many years of declining concentrations of classical organic contaminants (DDT, PCB_s, HCH, HCB) in fish tissues (documented in the HELCOM Third Periodic Assessment), concentrations have ceased to decline. There is little knowledge about concentrations of other organic contaminants in Baltic fish. The same applies to research on the biological effects of contaminants in the Baltic Sea. It is worth noting that some techniques for measuring biological effects are well developed and are already applied in monitoring other seas (e.g., in the North Sea).

The Study group notes differences in capabilities to measure biological effects on fish and other species and the expanding range of chemical analyses of fish (dioxin, furans, co-planar CB_s and TBT compounds) in the more developed countries. These compounds are of concern due to their input into the marine environment, their persistence, and their toxic effects.

2.5 General Comments

2.5.1 The Need to Manage Stocks Separately

The unique large marine ecosystem of the comparatively young Baltic Sea has evolved under the influence of its brackish water which imposes a strong osmotic pressure upon both marine and freshwater organisms, complicating their adaptation process. Bottom topography of the sea and the existence of a number of basins has given rise to a complicated hydrologic regime and has created the variety of environmental conditions in different areas. These effects have resulted in the development of a number of rather autonomous ecological subsystems (Bothnian Bay, Bothnian Sea, Gulf of Finland, Gulf of Riga, Northern Baltic proper, Southern Baltic Proper, etc., and within these systems, coastal and open seas environments). In these subsystems, commercial fishes have developed populations differing in their dynamics and other parameters from those in neighbouring subsystems. Therefore, one can argue on ecological grounds that these populations (stocks) should be managed separately.

2.5.2 Time Scales For Ecosystem Response, For Detection and Remedial Action

Fisheries has two sides: economic and environmental. Economic viability is based on preserving sustainability of commercial resources in order that it can be continuously exploited. The environment has absorbed past damage but we are continually hoping it will recover to a satisfactory state. For the following discussion we can use a simplified picture as follows.

The Pressures on the ecosystem due to fishing are:

- removal of target species
- by-catches (non-target species, birds, and mammals)
- dumping of fish discards and fish offal

- pressure on invertebrate species and benthic habitats

The State of the environment is modified and we see:

- evidence of anthropogenic change of community/foodweb structure/diversity
- evidence of changes in populations of keystone/dominating species
- evidence of changes in species richness/abundance
- evidence of changes in seabird and mammal community structure
- evidence of bottom habitat destruction

The Regulatory Response can be

- technical regulations on fishing gear, fishing practices, etc.
- regulation on dumping of fish remnants and discards
- areas excluded from fishery

The regulatory response is due to the perceived changes in the state and not due to the pressures applied to the ecosystem. Hence, the regulatory response is delayed from the time at which the pressures are applied until the changes are detected and there is agreement as to the need for change and what that change should be. Clearly the detection of change and the development of consensus can (and often have) taken considerable time. Changing to an ecosystem form of advice may make regulators more sensitive to the pressures (rather than waiting for detectable change) and hence, speed up the response process. However, some might argue that there may not be much timing in the response as there is less willingness to respond to perceived threats.

2.5.3 Possible Deleterious Effects Of A Shift To Ecosystem Advice

2.5.3.1 Resource demands

As ICES transitions to giving ecosystem based advice the scope of the process will increase. Future ICES advice in the Baltic will need to be based on a wide range of background information:

- Background information on meteorological and hydrological conditions (exchange processes, input to the Baltic)
- Nutrient, productivity,and toxic blooms
- Contaminants (anthropogenic substances)
- Evaluation of the biomass and the production of the main prey used by intensively exploited fish stocks
- Assessment of fish stocks (herring, cod, sprat) by their natural populations
- Evaluation of the condition of seabirds and marine mammals
- Evaluation of the state of the Baltic Sea ecosystem

The consequences for ICES and National resources due to the shift to an ecosystem approach to advice are significant. The need for additional data and information will be substantial. While the necessary data will be specified by the relevant working groups, the data may not be forthcoming due to limited National resources. Both ICES and the Baltic Coastal Countries will feel the pressure of increasing demands on personnel and their time.

2.5.3.2 Structural Problems

At the national levels, fisheries and environmental ministries are often separated. When only one of the ministries interfaces with ICES, this can serve to limit the expertise and information available to working groups. As well, at the International level, HELCOM and IBSFC are separate entities. These factors may limit the range of clients available to ICES for truly integrated advice. If the effort to generate the advice exceeds the value to the available clients, then the overall effect on ICES and participating member states may be negative. A gradual shift, over time, may be the best approach; where improvements in the scope and type of advice are implemented as the ability of Working Groups increases due to additional data and scientific understanding.

3 WORKSHOP PROPOSAL

The Study Group considered what should be the goals for the Workshop in 2001. Given the large number of groups active in the Baltic and the many meetings, it is desirable to focus the meeting. The Study group felt that only part of the proposal could be written in June and that further details should be added at the ASC in Brugge in September 2000. By that time, several aspects of the Baltic GEF program will be further developed and J. Thulin from ICES can offer some advice on including further environmental consideration. The proposal is as follows:

Part 1

Four talks to describe the needs for ecosystem advice. The speakers would be expected to present the needs for, and the uses of, ecosystem advice. The speakers should represent a variety of perspectives of the need for advice on an ecosystem level.

1) ICES – to speak from the basis of needs expressed by client to ICES at the dialog meetings and other venues.
2) Local governments – to give examples of problems associated with the specific venue of the meeting.
3) HELCOM – to give an environmental perspective
4) IBSFC – to give a fisheries perspective.

Part 2

Two talks to demonstrate examples of scientific analysis and advice based on ecosystem basis. J. Horbowy will present a retrospective analysis for cod in the southern Baltic comparing ICES advice to actual implementation. S. Hansson will present an analysis of the Baltic food web.

Part 3

The Workshop will then consider specific topics from an ecosystem perspective looking at the present state of the knowledge, future work needed and the ability to give advice that will meet the managerial needs.

i) Sampling quality, Monitoring, and Modelling
ii) Interfacing different types of models, specifically fisheries and oceanography models, with some consideration of the potential for ecological models.
iii) Structure of the ecosystem, knowledge of fish stocks and their distribution.
iv) It is anticipated that this list will be modified and enhanced at Brugge. As well, a steering committee, venue, and dates should be recommended.
v) Consider how to use an ecosystem approach for advice in view of the limited available data that is presently collected and likely to be collected in the future. What should be the future content of ICES advice on marine ecosystems, where are the greatest needs for advice or improved advice from the multinational structure of ICES.

4 BACKGROUND DOCUMENTS AND REFERENCES

The Study Group used many documents, besides the references cited, for background material including;

Third Periodic Assessment of the State of the Marine Baltic Environment of the Baltic Sea, 1989-1993.

ICES Working Group Report: Ecosystem effects of Fishing Activities ICES CM 2000/ACME:02

Report of the ICES working group on Ecosystem Effects of Fishing Activities. ICES CM 2000/ACME:02

ICES Study Group Report: Ecosystem Assessment and monitoring ICES 2000/E:09

ACME Consideration on Ecosystem Approach, Ecosystem Assessment, and Ecosystem Advice.

GEF Background Documents (from ICES)

NMFS: Ecosystem-based fishery management. Report to Congress.

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