Baltic Sea 2020

The Baltic Sea fish stocks and fisheries in their ecosystem context

Report from the workshop, Helsinki 3 December, 2007

Heikki Peltonen

20 February 2008

SUMMARY OF THE LECTURES AND DISCUSSIONS

Background

The workshop in Helsinki December 3, 2007 "The Baltic Sea fish stocks and fisheries in their ecosystem context" aimed at highlighting the potential to combat eutrophication of the Baltic Sea and the Gulf of Finland through management of fish stocks and fisheries (possibly combined with other environmental management). The goals in brief were to evaluate the questions:

- *Would it be possible through management of fish stocks and fisheries to enhance the fish stocks and bring about a healthier ecosystem in the Baltic Sea and in particular in the Gulf of Finland ?*
- *Do we already know enough about impacts of fish on ecosystem functioning to generate useful forecasts about Baltic Sea ecosystem dynamics with (probabilistic) modeling?*
- *Will we ever be able to generate useful forecasts of the ecosystem impacts of fisheries management actions?*

The current report summarizes the talks and discussions in the workshop. The 11 keynote speakers and altogether 26 invited scientists represented several research branches to enable competent discussion on the various links through which fish stocks can, in respect to other driving forces, influence the "health" of Baltic Sea and particularly the Gulf of Finland. Knowledge from many other research areas than fish biology is needed if fish stocks are treated as essential components of the ecosystem. Besides, the workshop aimed at including knowledge beyond purely biological processes to discuss the environmental conditions where impacts of fishing could be of importance. Therefore, the keynote talks and discussions also covered hydrodynamics, modeling methods and human impacts such as fishing and anthropogenic nutrient loading. However, societal aspects of fisheries were not included in this one-day workshop, but they will be discussed in another BalticSea2020 workshop during spring 2008.

There are still considerable uncertainties in understanding functioning of marine ecosystems - any uniform theory does not exist. Therefore, we need to link different theories and models to understand and predict functioning of an ecosystem. Uncertainties should not be used as a reason why not to apply scientific information to predict ecosystem function. The large amount of available information has to be combined with modeling to predict ecosystem changes considering various temporal changes in anthropogenic and natural impacts. Appropriate process descriptions, parameter estimates, and access to relevant datasets will be possible only if skilled scientist from various research disciplines incorporate their efforts and apply a suitable set of modeling tools.

One of the aims of the project was to highlight the probabilistic approaches in ecosystem modeling. Probabilistic methods have so far been little applied in process-oriented research in the Baltic Sea. The workshop aimed at bringing together ecologists and modelers in order to enable generation of new useful approaches on modeling the Baltic Sea fish ecology and ecosystem. The following chapters summarize the lectures and discussions in the workshop (The names in parentheses indicate the participant of the workshop who gave such a statement).

Ecological consequences of overfishing predatory fish

Fisheries influence the target species and other caught biota, and also influence the whole ecosystem. Several talks in the workshop addressed the adverse ecosystem impacts of excessive predatory fish exploitation. This kind of overfishing has cascading effects through the food-web both in coastal areas and on open sea (Peltonen, Hjelm, Appelberg). The Baltic Sea ecosystem has shifted from a cod-dominated system in the 1980s to a sprat-dominated one due to overfishing and unfavorable spawning conditions for cod caused by eutrophication and influenced also by climatic changes (Hjelm). Collapses of cod populations have induced from the human point of view unwanted cascading effects through the food chains. Zooplanktivorous fish have increased, zooplankton decreased and phytoplankton increased (Hjelm). The unfavorable changes in the food web have decreased the energy content of e.g. sprat and subsequently, piscivorous sea birds (especially common guillemot) had a decrease in reproduction (Hjelm). Selective removal of sprat may be needed to accelerate recovery of cod, because sprat can feed on young development stages of larval cod and cod eggs thereby prohibiting recovery of cod stocks (Hjelm). However, selective more intensive fishing on sprat can be risky because too many herring from many weak subpopulations would be taken as by-catches (Kaljuste). Besides, drastic reduction in cod catches would allow recovery of cod even without intensified fishing on sprat as the unexploited proportion of the cod stock would rapidly increase the cod abundance (Hansson). Another important issue is that the same mistakes that were made in the Black Sea should not be repeated in the Baltic Sea (Knuuttila). In the Black Sea the predatory fish were first depleted to low levels and subsequently, the fisheries overexploited planktivorous fish (*Daskalov, G.M., Grishin, A.N., Rodionov, S. and Mihneva, V. 2007. Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. Proc. Natl. Acad. Sci. USA. 104(25): 10518–10523)*. Thereby an ecological niche was left open for the alien comb jelly *Mnemiopsis leidyi* which produced even stronger adverse control on lower levels than planktivorous fish, resulting in decreased zooplankton but increased phytoplankton biomass, and deterioration in oxygen concentrations (*Daskalov et al. 2007*).

Excessive exploitation of predatory fish (cod, salmon, trout, fresh water predatory species) has produced unbalanced fish communities with few predatory fish but abundant slowly growing low-valued planktivorous and benthivorous fish stocks with unwanted consequences on the functioning of the ecosystem (Peltonen). In the Gulf of Finland, low abundance of predatory fish has contributed to poor growth rates and low condition of clupeid fish, and low value of catches (Peltonen). Increase in predation mortality of small sprat and herring would increase growth rates and also decrease concentrations of persistent organic pollutants in clupeid fishes (Peltonen). Slowly growing individuals have to allocate much of the energy intake to maintenance and consume much food, whereby persistent pollutants accumulate in their tissues (Peltonen). It is hypothesized that in the Gulf of Finland, high abundance of slowly growing small clupeids in comparison to zooplankton production contributed to starvation and collapse of zooplanktivorous fish stocks and catches of clupeids in 2003, which caused severe problems for the fishing industry (Peltonen). This important hypothesis, "wasp-waist control" of ecosystem functioning *(Cury, P., Bakun, A., Crawford, R. J. M., Jarre, A., Quin˜ones, R. A., Shannon, L. J., and Ver-*

heye, H. M. 2000. Small pelagics in upwelling systems: patterns of interaction and structural changes in ''wasp-waist'' ecosystems. – ICES Journal of Marine Science, 57: 603–618), may be important to understand the Baltic Sea ecosystem dynamics (Peltonen). The wasp-waist hypothesis states that the ecosystem is not regulated only by resources (bottom-up control) or predators (top-down control) but at least at certain times by small pelagic planktivorous fish which are highly variable in abundance and which produce bottom-up control on upper trophic levels and top-down on lower levels (*Cury et al. 2000*). It was also pointed out that alien species can bring about unpredicted ecosystem impacts which may complicate ecosystem modeling (M. Viitasalo). The results from stable isotope analysis data (Kiljunen et al., unpublished) indicate that sprat, herring and salmon are on a higher trophic level in the Gulf of Finland than in the Baltic Proper and in the Bothnian Sea. The shift in trophic level may be due to invertebrate predators which consume energy and less is shifted to upper trophic levels. The shift in trophic level could be due the alien predatory water flea *Cercopagis pengoi* which established itself in the Gulf of Finland in the latter half of the 1990s (Peltonen).

Predicting impacts of fish on zooplankton dynamics

In the Baltic Sea there are c. 14 frequently found zooplankton species with many different life stages. However, few species dominate the zooplankton community (Koski). Zooplankton constitute food for many fish species, they are grazers of phytoplankton and microzooplankton, they are producers of fast sinking fecal pellets, and they are recyclers of nutrients and degraders of aggregates (Koski). There are substantial amount of evidence that fish stocks can restructure zooplankton communities and thereby produce cascading effects through the whole food web both in the open sea and in coastal waters (Hjelm, Appelberg). We should be able to model the impacts of fish especially on mesozooplankton and further on to lower trophic levels, if fish stocks are included in modelling the pelagic ecosystem (Pitkänen). The present predictive ecosystem models have substantial weaknesses in this respect (Pitkänen). However, there are many uncertainties when considering the possibilities to predict impacts of fish on zooplankton, although there are also some obvious patterns which may support modeling the impacts of fish predation on zooplankton (Koski). The species composition in the zooplankton community substantially influences the recycling and sedimentation of nutrients (nitrogen, phosphorus, iron) and of organic carbon (Koski). For example, the copepods *Acartia bifilosa*, *Pseudocalanus acuspes and Temora longicornis* release relatively more nitrogen while the cladoceran *Bosmina longispina* release phosphorus. The copepods especially *Pseudocalanus acuspes* and *Temora longicornis* produce large and rapidly sinking fecal pellets, while the cladocerans (dominating species *Bosmina longispina*) recycle nutrients and organic matter in the water column (Koski). There are species-specific seasonal patterns in population dynamics of each species, but interannual differences occur e.g. in dominant species in mesozooplankton (Koski).

Changes in coastal fish stock influence benthic communities

In many sheltered coastal areas in the Baltic Sea piscivorous perch, pike and pikeperch (= zander) are thriving, while in areas exposed to the open sea there are severe recruitment disturbances of e.g. perch and pike (Appelberg). It is hypothesised that these species experience high mortality due to lack of zooplankton when newly hatched larvae start feeding. Zooplankton deficiency may be caused by high abundance of zooplanktivorous fish, especially sprat and stickleback (Appelberg).

Field studies and ongoing experimental studies in the Baltic Sea indicate that the lack of piscivorous fish in exposed coastal areas causes cascading effects at lower trophic levels, enhancing growth of epiphytic algae (Appelberg). Decrease of predatory fish has enabled increases of e.g. stickleback, whereby feeding on amphipods, crustaceans and snails has increased. Decreased in the invertebrates which would feed on filamentous epiphytic algae has enabled proliferation of such algae (Appelberg). The increase of algae living on rocks or other stony matter may prevent colonisation of these surfaces by e.g. blue mussel. Decrease of the blue mussel may have unwanted impacts on functioning of the coastal ecosystems (see below). Supporting evidence about the cascading effects of excessive exploitation of predatory fish is also accumulating in other open sea and coastal areas (*e.g. Scheffer, M., Carpenter, S. and de Young, B. 2006. Cascading effects of overfishing marine systems. TRENDS in Ecology and Evolution 20: 579-561*) (Appelberg). Due to the observed interactions between fish community development and cascading effects in the open sea and in exposed coastal areas, we need ecosystem based fishery management which would consider ecosystem function both in the open sea and in coastal areas (Appelberg).

In the Archipelago Sea and at the northern coast of the Gulf of Finland, substantial changes have occurred in fish stocks during the last two decades (Lappalainen). Especially, the substantial increase in roach abundance may have important consequences for functioning of the coastal ecosystem (see below) (Lappalainen, Westerbom). Roach has plentiful spawning areas in eutrophied coastal macrophyte-covered areas. However, they can only reproduce in areas with <3.5 PSU salinity. Therefore the roach of the outer archipelago reproduce in low salinity in coastal areas (Lappalainen).

As roach is an important predator of mussels in the Gulf of Finland, and especially blue mussels may greatly contribute to organic matter decomposition, depletion of mussels may increase the flow of organic substances to deeper bottoms (see below, Westerbom, Peltonen). Increased quantity of organic matter provides more energy for decomposing benthic bacteria, whereby more nutrients are released and oxygen reserves are depleted (Lehtoranta, see below). In the north-western Gulf of Finland, the blue mussel is a very important species in the diet of roach (Westerbom). The predation pressure is hardest in marginal areas for blue mussel distribution (Westerbom). Disappearance of the blue mussel also decreases the abundance of e.g. many other detrivorous benthic species, because blue mussel colonies provide shelter for diverse communities of zoobenthos (Westerbom).

In addition to increased predation, eutrophication and decrease in salinity may have contributed to the decreased abundance of blue mussels in their easternmost distribution areas in the Gulf of Finland (Westerbom). However, it was pointed out that during the last 15 years there has hardly been any decrease in salinity in the Gulf of Finland, whereby salinity may not be the ultimate reason for the decrease of blue mussel (Pitkänen). However, as pointed out above, eutrophication-induced increase in sedimentation and filamentous algae on rocky surfaces can prevent blue mussel colonisation of the sites.

Benthic fauna, especially mussels are long-lived and also active in cold water, which emphasize their importance as decomposers of organic material (Kotta). While there are few zooplankton in spring to consume the spring phytoplankton bloom, in areas where at present existing, benthic fauna can decompose the settling organic material even in spring. Even if the size of blue mussel decreases towards less saline areas, they can anyhow be important consumers of organic matter because the filtering capacity of small mussels for each biomass unit is higher than the capacity of large mussels (Kotta). Control of roach abundance (especially via predatory fish stocks management) could enable recovery of blue mussel which would bring about positive changes in water quality via efficient decomposition of settling organic material (Peltonen). Some kind of "artificial reefs" could be an option to increase suitable areas for mussel larvae colonization (Kotta).

Focus on settling organic material

Currently, in the Baltic Sea excessive amount of settling organic material on the bottom provides plentiful energy for benthic micro-organisms. Increased microbial activity at the sediment surface induces nutrient (nitrogen and phosphorus) release from sediments (Lehtoranta). The biological activity can deplete oxygen reserves and cause hypoxia at the bottom, in deep water and in coastal deeps (Lehtoranta). It is important to note that oxygen deficiency is not the ultimate cause for internal loading, but it is the consequence of biological oxygen demanding decomposition processes (Lehtoranta, Pitkänen). Changing focus from oxygen deficiency to organic material decomposition is of utmost importance when modelling the ecosystem function (Lehtoranta). As decomposition of organic material has direct links to biotic production, it is possible with suitable modelling to evaluate the contribution of food web structure on the settling of organic material (Lehtoranta, Peltonen). This change in focus also enables to evaluate if food-web manipulations (e.g. trough fisheries) can decrease organic material flow to the bottom, and thereby decrease internal nutrient loading (Peltonen). New findings concerning several biogeochemical processes which induce nutrient release from sediment should be considered in ecosystem modelling (Lehtoranta).

Importance of spatial scales and variations

There are observations from lakes that fisheries management can induce a desired regime shift towards a less eutrophied ecosystem, when decrease of anthropogenic nutrient loading had not alone induced such a shift (Peltonen). Even if fisheries manipulation would not help to restore the ecosystem everywhere, in certain areas the impacts of fish stocks can be of crucial importance (Peltonen). The substantial spatial variability in marine habitats specific to many areas in the Baltic Sea should be considered when evaluating the potential for ecosystem impacts through fish stock manipulations and possibilities to link fish stock manipulation with various other environmental management actions, e.g. decrease of nutrient loading (Kotta, Peltonen). It would be important to link results from increasing marine habitat mapping activity (aiming at determining the habitat characteristics from the biodiversity point of view) with evaluation of functioning of the habitats to facilitate e.g. modelling of the impacts of fish stock manipulations (Kotta, Peltonen). There is a need to develop approaches for habitat-specific modelling, but this could also support substantial benefits when making decisions about ecosystem management (Kotta, Peltonen).

Hydrodynamics

Hydrodynamics should be consider when evaluating the impacts of fish stocks on an ecosystem level. The Gulf of Finland is an elongated estuary with a mean depth of 37 meters only, in which physical processes ranging over scales from small vortices to the overall circulation take place (Myrberg). A strong east-west salinity gradient is formed as the western end of the Gulf is directly connected with the Baltic Proper, and the eastern end receives freshwater especially from the River Neva, which is the largest river in the catchment area of the Baltic Sea (Myrberg). The Gulf of Finland ecosystem function is also influenced by the general circulation patterns, water residence time and upwelling events (Myrberg). The water age in the GoF with respect to water exchange with the Baltic Proper is at most two years. Such small values confirm very intense water exchange between the Gulf and the Baltic. The overall water residence time of the Baltic Sea with respect to the North Sea is up to 40 years. There are characteristic large-scale spatial patterns in the "water age structure" in the Gulf of Finland which influence the chemical features, as well as biotic communities and processes (Myrberg). Most typically upwellings take place at the Finnish coast due to the prevailing westerly winds. The upwellings lead to strong vertical mixing and affect the phytoplankton dynamics. This mechanism is of special importance for the late-summer cyanobacterial blooms. The circulation in the Gulf is cyclonic from its origin. A relatively persistent flow exists along the whole gulf towards the Baltic Proper about 30 km offshore from the Finnish coast. In addition to the external loading especially from St. Petersburg area, local sources also contribute to the high nutrient concentrations in the Finnish coastal waters.

Nutrient loading scenarios with ecosystem implications

Gulf of Finland is the most eutrophied of the large basins of the Baltic Sea (Pitkänen). There are substantial nutrient reserves in the Baltic Proper and decreases in external nutrient loading can slowly influence the ecosystem. While local changes in algal biomass can occur rapidly near e.g. point sources where drastic nutrient load reductions are made, it will take many years and even decades to achieve significant decreases in algal biomass in the Baltic Proper through reductions in external nutrient loading (Pitkänen). Recent studies on large scale nutrient cycling in the Baltic Sea demonstrate that on time scales of a few years, internal processes play a much more important role in the control of eutrophication than even strong changes in external loading (Pitkänen). However, it is of utmost importance to substantially decrease the nutrient loading entering the sea. The nutrient loading reductions taking place in the Gulf of Finland area will relatively soon enable some recovery, especially regarding cyanobacterial blooms in the Gulf of Finland (Pitkänen). HELCOM has estimated that the good ecological status of the Baltic Sea defined in the Baltic Sea Action Plan (HELCOM 2007, http://www.helcom.fi/stc/files/BSAP/BSAP_Final.pdf) will require reductions of 40% of phosphorus and 15% of nitrogen from the present level (Pitkänen, Knuuttila).

Why probabilistic (Bayesian) modeling

Probabilistic or Bayesian modeling has substantial virtues compared to traditional deterministic methods for example when linking science with decision making, e.g. to select the most promising environmental management actions (Kuikka, Peltonen). Probabilistic methods are rapidly becoming increasingly popular in scientific research linked e.g. with ecosystem modeling (Peltonen). Probabilistic models consider uncertainties in every step and thus, also the predictions provide estimates of uncertainties (Kuikka). Probabilistic modeling tools enable flexible applications in very many different modeling tasks, and provide straightforward methods to link many different data sources, such as published scientific data, various measurement data sets and expert knowledge in the same predictive model (Peltonen).

Consideration of uncertainties may significantly change our ideas about optimal environmental management actions (Kuikka). For example, a management action giving greatest benefit when evaluated with a deterministic model may not be optimal anymore if probabilistic modeling indicates that this specific choice would contain substantial uncertainty, risk of failure or possibilities for negative influence (Kuikka). The currently rapidly developing spatial Bayesian models are an interesting avenue for further consideration allowing useful applications in ecosystem modeling and management (Kotta, Mäntyniemi).

In the case of considering the "top - down" and "bottom - up" mechanisms in the Baltic Sea, it is important to develop models that take into account both of these possible causal nets as alternative hypothesis, as we can not be sure which one is correct now, and in the future (Kuikka). A decision model that includes these two alternatives should be used to test whether the alternative hypotheses about causal mechanisms favor some management alternatives independently of the probabilities given to each hypothesis (Kuikka). In an optimal case, the same model would summarize the empirical evidence related to the two alternative hypotheses and thus utilize both the theories and large existing data sets from the Baltic Sea (Kuikka).

Fisheries management options

(The whole chapter from the talk of Heikki Peltonen)

Fisheries management generally aims at sustainable exploitation of a fish stock. Usually fisheries management focuses on restrictions of fishing mortality in order to maximize catches or economic profit from fishing. However, the history of fisheries management includes many failures and often the goals have not been met. Commercially important fish stocks have collapsed, sometimes beyond recovery. It has been noted that detrimental environmental changes have followed some collapses. However, fisheries management could also serve environmental goals. It has been shown that fisheries can remove substantial amounts of nutrients and harmful pollutants from the Baltic Sea. And there may be substantial potential to enforce a healthier ecosystem as the fishery-induced trophic interactions are considered.

Fisheries management can include a wide range of methods depending e.g. on the goal of management, ecology, legislation, governance of fish resources etc. Some of the management alternatives are directly linked to fishing such as landing size limits (minimum, maximum, intermediate), catch quotas, closed areas, closed seasons, restrictions or obligations on catching techniques, fishing licenses and fishing effort restrictions. Besides, the fisheries management can include release of hatchery-reared fish, control of predators or competitors, enhancement of reproduction areas (e.g. of river-spawning migratory species) and establishment of marine protected areas. And ultimately, fisheries can be enhanced through enhancement of environmental quality in the sea (control of eutrophication, pollution, physical habitat loss etc.). The management decisions have to be set in action and the fisheries have to be efficiently controlled to combat illegal fishing. Many of the above-mentioned management methods are already in action in the Baltic Sea, though the principal marine stocks are mainly managed through catch quotas. The management is in principle based on advice from ICES, agreed in decision making within EU, and negotiations between EU and Russia. So far the management has hardly focused on the ecosystem impacts of fisheries.

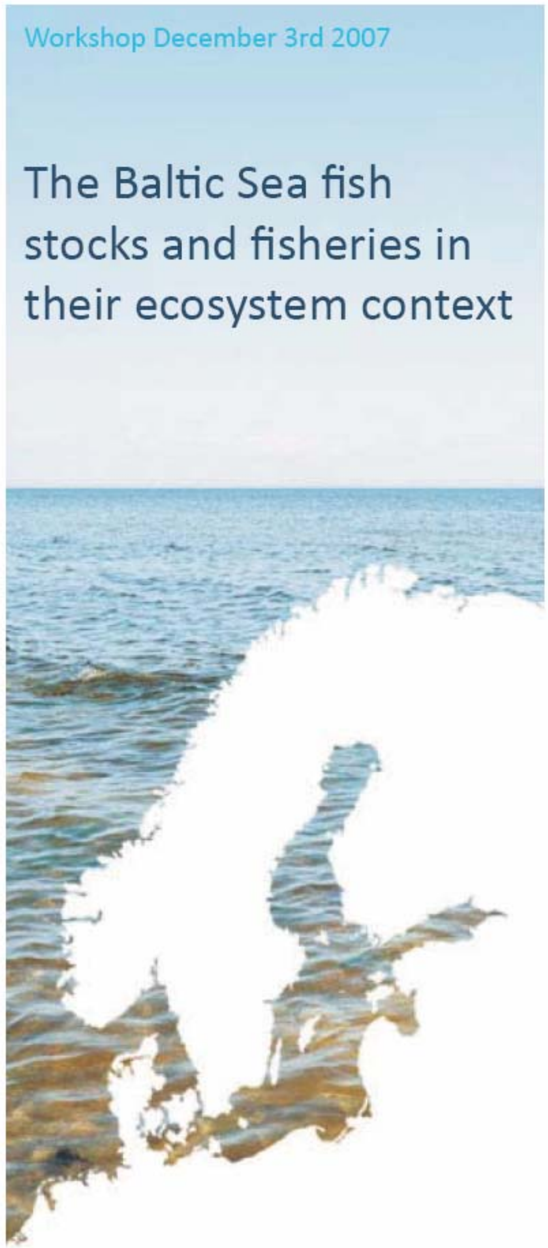
The currently widely debated ecosystem approach in fisheries aims at establishing the context for the assessment and criteria with which to determine environmentally sound TACs (total allowable catches). The principal issue is to protect the commercially exploited fish resources. In contrast, in food-web management or biomanipulation of lakes, fishing and fisheries management are applied to enforce certain desired changes in the ecosystem. In the Baltic Sea, the economic value of the fisheries is relatively low, but not negligible. But above all, the sea supports numerous even more important "ecosystem services", for example recreation, and there are many critical issues from the conservation point of view. Therefore, it is natural that fisheries are not only considered as producers of nutritious food, but they are also evaluated as a potential toolset when working toward a healthier Baltic Sea. However, in the Baltic Sea e.g. the biotic communities, abiotic environment and biogeochemical processes are different from those in lakes and in other seas. Thus, the experiences from for example biomanipulation experiments in lakes cannot be directly applied in the Baltic Sea, but the ecosystem impacts of fish have to be evaluated specifically considering the characteristics of the Baltic Sea.

In the Baltic Sea, fisheries and fisheries management constitute a very attractive alternative for ecosystem restoration. In contrast to some other ecosystem management methods, it is likely that a suitable set of fisheries management tools would have no negative side-effects to the environment. Besides, cost effectiveness is likely to be very good because over-exploitation of fish stocks not only endangers existence of the stocks (weakest populations are first endangered), it is likely to produce unrecoverable damage to the genetic structure of the stocks and leads to waste of economic resources in commercial fishing. For example, smaller intensity in fishing of cod and of other predatory species would enable recovery of the stocks. Besides, catches even with the lower fishing effort could soon surpass the current levels.

Acknowledgements: *The organization of the workshop "The Baltic Sea fish stocks and fisheries in their ecosystem context" was financially supported by the BalticSea2020 foundation. Discussions with Prof. Erik Bonsdorff and Prof. Sture Hansson were useful when planning the workshop. Finnish Environment Institute (SYKE) provided the premises and the contribution of Ms Heta Rousi was valuable in practical arrangements of the workshop. And finally, the wide knowledgebase and enthusiasm of the participants enabled the fruitful discussions in the workshop.*

APPENDIX 1. The workshop program.

Baltic Sea 2020



Björn Carlsons Östersjöstiftelse Baltic Sea 2020
Kungl. Vetenskapsakademien
Box 50005, S-104 05 Stockholm, Sweden
Tel: +46 (0)8 673 97 64, Fax: +46 (0)8 673 97 60
info@balticsea2020.com - www.balticsea2020.com

The aim of Baltic Sea 2020 is to stimulate creative interdisciplinary and international collaboration in a variety of areas, resulting in political, economical and physical measures taken to improve the environment of the Baltic Sea in the coming 10-15 years.
Baltic Sea 2020 was established as a foundation through a private donation made by Björn Carlson in the autumn 2005.

Baltic Sea 2020

Program

09.00 - 09.30	Arrival and breakfast
09.30 - 09.40	Opening of the workshop *Erik Bonsdorff, Åbo Akademi & Baltic Sea 2020*
09.40 - 10.10	Introduction to the propsed project *Heikki Peltonen, Finnish Environment Institute*
10.10 - 10.40	Coastal and offshore trophic cascades in the Baltic - implications for management? *Joakim Hjelm, Institute of Marine Research, Lysekil, Sweden*
10.40 - 11.10	Do offshore fisheries shape the coastal food web? *Magnus Appelberg, Institute of Coastal Research, Öregrund, Sweden*
11.10 - 11.40	The pelagic system functioning - will it be possible to predict impacts of fish? *Marja Koski, Danish Fisheries Research Institute*
11.40 - 12.10	Re-evaluation of the fundamental biogeochemical processes *Jouni Lehtoranta, Finnish Environment Institute*
12.10 - 12.35	Gulf of Finland coastal fish communities *Antti Lappalainen, Finnish Game and Fisheries Research Institute*
12.35 - 13.00	Hard-bottom communities - potential impacts on ecosystem functioning *Mats Westerbom, Yrkeshögskolan Sydväst, Finland*
13.00 - 14.00	Lunch
14.00 - 14.25	Ecopath, Bayes and Grasp modeling - experience from the Estonian coastal sea *Jonne Kotta, Estonian Marine Research Institute*
14.25 - 14.50	Why probabilistic modeling when considering environmental management? *Sakari Kuikka, University of Helsinki, Finland*
14.50 - 15.15	Hydrodynamic modeling of the Gulf of Finland with ecosystem implications *Kai Myrberg, Finnish Institute of Marine Research*
15.15 - 15.40	Scenarios on external nutrient loading and ecosystem dynamics *Heikki Pitkänen, Finnish Environment Institute*
15.40 - 16.00	Coffee
16.00 - 19.00	Discussion

APPENDIX 2. Participants in the workshop "The Baltic Sea fish stocks and fisheries in their ecosystem context", December 3 2007.

Magnus Appelberg, (PhD, professor) Fiskeriverket/Swedish Board of Fisheries Avd. f Forskning och Utveckling/Dept of Research and Development, Kustlaboratoriet/Institute of Coastal Research, SE-740 71 Öregrund, Sweden. Director of the Institute of Coastal Research, Swedish Board of Fisheries, associated professor at the Department of Systems Ecology at Stockholm University. Research interests: monitoring and management of the Baltic fish fauna, with special reference to the coastal zone, development of indicators for EBFM at national and international levels (INDECO and HELCOM FISH), as well as the ecological effects of alien species in marine and freshwater habitats (AquAliens).

Robert Aps (PhD, Ecology, Senior Scientist, Head of Marine Systems Department), Estonian Marine Institute, University of Tartu, Mäealuse 10A, 12618 Tallinn, Estonia. Research interests: Allocation and re-allocation of fisheries/natural resources incl. spatial allocation; transformation of science based advice into management decisions (negotiation process related uncertainty, Bayesian modeling); disturbance related ecosystem's resilience, sensitivity and recovery potential (oil spills, sand and gravel extraction and dumping etc.)

Kirsten Engell-Sørensen, (Fish biologist), Hangovej 2, 8200 Århus N, Denmark. Research interests: Population dynamics, predator-prey interactions, biomanipulation, bottle necks in early stages of marine fish, marine fry production, effects of eutrophication.

Sture Hansson, (Professor), Dept. Systems Ecology, Stockholm University, SE-106 91 Stockholm, Sweden. Research interests: Baltic Sea ecology, primarily pelagic food web interactions. Eutrophication and fisheries has made humans important actors in this ecosystem and Hansson's research addresses effects of both these anthropogenic factors. He has also been a member of the Scientific Council of the foundation Baltic Sea 2020.

Joakim Hjelm (PhD, Laboratoriechef) Swedish Board of Fisheries, Institute of Marine Research, P.O. Box 4, SE 453 21, Lysekil, Sweden.

Mikael Hildén, (Professor), Finnish Environment Institute Research Department, PO Box 140, FIN-00251 Helsinki, Finland. Research interest: environmental and resource policy analysis and evaluation.

Britt-Marie Jakobsson, (Researcher), Åbo Akademi, Miljö- och marinbiologi, Akademigatan 1 , FIN-20500 Åbo, Finland . Research interests: eutrophication, Gulf of Bothnia, long time trends.

Olavi Kaljuste, (Researcher), Estonian Marine Institute, University of Tartu 10a, Mäealuse Str., EE-12618 Tallinn, Estonia. Research interests: biology of Baltic Sea pelagic fishes. Specific interests: hydroacoustic assessment of pelagic fish stocks.

Mikko Kiljunen, (PhD, researcher), department of Biological and Environmental Science, P. O. Box 35, FI-40014 University of Jyväskylä, Finland. Research interests: Bioenergetics-based organochlorine accumulation models and natural abundant stable isotopes used as accumulation markers.

Seppo Knuuttila, (Senior researcher), Finnish Environment Institute, P.O.Box 140, FIN-00251 Helsinki, Finland. Research interests: Monitoring of Finnish coastal waters, especially the state of the Gulf of Finland, preparation of state assessments of the marine environment and calculation of nutrient loading into the Baltic Sea, managing of the Fifth Baltic Sea Pollution Load Compilation (PLC-5) for HELCOM.

Marja Koski (PhD, researcher), Danish Institute for Fisheries Research, Tevhnical University of Denmark Kavalergården 6, DK-2920 Charlottenlund, Denmark.
Research interests: marine and brackish water copepods and their role as consumers in aquatic food webs and in degradation of marine snow particles. Combination of experimental work with cruises / field sampling.

Jonne Kotta, (PhD, researcher), Estonian Marine Institute, University of Tartu; Mäealuse 10a, Tallinn, Estonia. Research interests: benthic habitat modelling, functional relationships between different ecosystem elements.

Sakari Kuikka, (Professor), Head of FEM research group, University of Helsinki P.O. Box 65, FI 00014 Helsinki, Finland. Research interests: multidisciplinary analysis of fisheries systems, decision analysis in fisheries and environmental management problems, technical measures in fisheries management, fisheries management of both large international systems and small scale fisheries systems, risk and uncertainty analysis in fisheries and environmental management problems, environmental impact analysis.

Antti Lappalainen (PhD, Senior researcher) , Finnish Game and Fisheries Research Institute, P.O. Box 2, FI-00791 Helsinki Finland. Research interests: coastal fish communities and reproduction areas of coastal fish species.

Maiju Lehtiniemi, (PhD , Researcher, Docent), Finnish Institute of Marine Research, P.O. Box 2, FI-00561 Helsinki, Finland. Research interests: Predator-prey interactions on the higher trophic levels of the northern Baltic Sea, especially zooplankton-mysid-fish interactions, distribution, abundance and effects of pelagic alien invasive species in the Baltic Sea.

Jouni Lehtoranta (PhD, Senior researcher), Finnish Environment Institute, P.O.Box 140, FI-00251 Helsinki, Finland. Research interests: sediment nutrient processes and especially iron and phosphorus coupling related to microbial processes in brackish and lacustrine sediments.

Samu Mäntyniemi, (PhD, researcher), FEM research group, P.O. Box 65, FIN-00014 University of Helsinki. Research interests: Bayesian inference, decision analysis, population dynamics.

Kai Myrberg, (Dr., Senior Scientist), Finnish Institute of Marine Research
Adjunct Professor in Geophysics, University of Helsinki, Finnish Institute of Marine Research, P.O. Box 2, FI-00561, Finland. Research interest: hydrodynamics of the Baltic Sea, numerical modelling and process studies with a specific focus on the eutrophication. Specific interest upwelling studies and regionally the Gulf of Finland.

Heikki Peltonen, (PhD, Senior researcher), Finnish Environment Institute, P.O. Box 140, FI-00251 Helsinki, Finland. Research interests**:** Modeling the impacts of fishing and of environmental changes on spatial and temporal dynamics of fish populations. Modeling on bioaccumulation of pollutants. Application of hydroacoustics in assessment of aquatic biota and of marine habitats.

Heikki Pitkänen (PhD, chief scientist), Finnish Environment Institute, P.O. Box 140, FI-00251 Helsinki, Finland. Research interests**: B**ehavior and budgets of nutrients in river catchments and in the Baltic coastal and open sea waters, integrated use of experimental and modelling tools.

Jari-Pekka Pääkkönen (PhD, Head of Environmental Research), Environment Centre, Environmental Protection and Research, City of Helsinki, P.O. Box 500 (street address: Helsinginkatu 24), FIN-00099 CITY OF HELSINKI. Research interest: trophic interactions, ecosystem modelling, eutrophication of coastal waters.

Heta Rousi, Finnish Environment Institute,(Researcher) P.O. Box 140, FI-00251 Helsinki, Finland. Research interests: zoobenthos communities and population dynamics of benthic fauna.

Kristian Spilling (PhD, researcher), Finnish Environment Institute, P.O. Box 140, FI-00251 Helsinki, Finland. Research interests: phytoplankton ecology and spring bloom dynamics in the Baltic Sea.

Markku Viitasalo,(Professor, Director – Baltic Sea Processes), Finnish Institute of Marine Research, P.O. Box 2, FI-00561 Helsinki, Finland. Research interests: pelagic and benthic ecology, eutrophication, effects of cyanobacteria in the aquatic ecosystem.

Satu Viitasalo, (PhD, scientist), Finnish Institute of Marine Research, P.O. Box 2
FIN-00561 Helsinki. Research interests: bioturbation and its effects on benthic nutrient dynamics and on plankton population dynamics.

Mats Westerbom (PhD, Head of Programme in ICZM), Novia University of Applied Sciences, Raseborgsvägen 9, 10600 Ekenäs, Finland. Research interests: ecology of hard bottom key species and associated fauna, dynamics of blue mussel (*Mytilus edulis*) in a Baltic Sea, links with bottom-up and top-down effects on the trophic chain, fish communities in coastal lagoons, and coastal management questions from a socio-ecological and economical standpoint.