



SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

BONUS

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briefing

IBAM

Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland

IBAM demonstrates that the ecosystem risks are underestimated if the impact of only one driver is estimated at a time. Baltic herring and common eider are used as key example species. The project provides an estimate of degree of overfishing for the Baltic Main Basin herring and the impacts of overfishing on the total catches. The spread of reed has been analysed and a model describing the future spread of reed has been developed. The results highlight the importance of focusing the management actions on those drivers where human intervention is most effective. It is also important to take into account the uncertainty due to partly unpredictable response of humans to management actions. The developed methodology can be extended to new areas and new species in the Baltic Sea.

OVERVIEW

The main objective of the project was to produce an integrative environmental decision model for the Gulf of Finland. As the ecosystem of the Gulf of Finland is highly stressed, the area can be considered a good example representing also other areas within the Baltic Sea facing human induced threats. The model will integrate the probabilistic risk estimates caused by three drivers: harvesting (fisheries/hunting), eutrophication and oil spills. The model ranks the available alternatives for management, and it can be used to

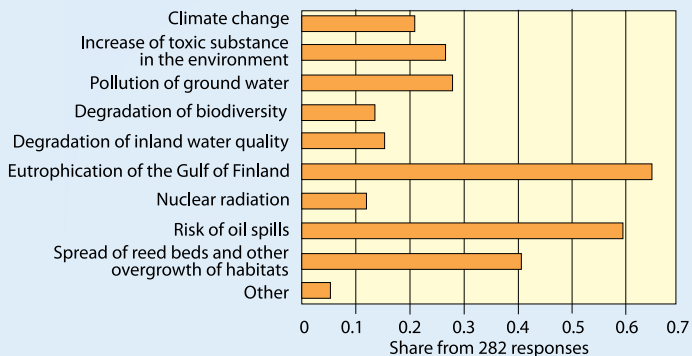
plan future information collection activities to support management. The developed methodology can be applied worldwide to model several co-occurring risks impacting at the same time on the same species.

The project applies interdisciplinary methodology and combines knowledge from several types of models: oil spill risk models, 3D ecosystem models, and fisheries models. Decision models are applied to improve the applicability of the scientific findings to the practical management problems. Risks are estimated for common eider (*Somateria mollissima*), Baltic herring (*Clupea harengus membras*) and the spread of the common reed (*Phragmites australis*). There are separate models for all species included. An integrative model is used to summarise these results and to evaluate the likely impacts of alternative risk management actions.

Bayesian models are applied to risk analysis in order to provide justified uncertainty estimates and to utilise the existing scientific literature in addition to data. The use of prior information in parameter estimates is important to enhance effective learning in science: the information content of previous publications can be used to decrease the uncertainty in future analyses by including this knowledge to prior probabilities of model parameters.

IBAM has also developed a new way to manage the Baltic herring stocks. A Bayesian quota is based on the updating of the stock estimates during the quota year, and the quota can be a combination of catch and total effort. This enables more "on line

A) WHAT ARE THE MOST IMPORTANT ENVIRONMENTAL CONCERNS THAT SHOULD BE SOLVED AS SOON AS POSSIBLE?



B) HOW HAS THE QUANTITY OF REED CHANGED IN THE WATER AREAS NEAR TO YOUR RESIDENCE FROM 1990 TO 2010?

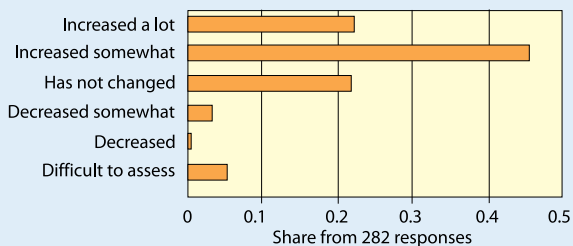


Figure 2. The share of answers concerning the different environmental concerns of the Gulf of Finland among people living close to the coast (A) and the change in the quantity of reed near to the residences of the interviewed people (B).

management” of the fish stocks. A more detailed analysis has been carried out to analyse the productivity of the Baltic main basin herring stock. The aim has been to take into account the impact of environmental factors on the productivity of the stocks.

OUTLINE OF KEY RESULTS

INTEGRATION – THE WORD OF TODAY

The project has used the Gulf of Finland as the study area, as it is the most stressed area in the Baltic Sea and therefore the best example of future risks for other areas. The new methodology for the ecosystem approach to management is based mainly on Bayesian statistics, which offers a flexible approach to integrate knowledge from several sources of different types. The methodology can be used to learn from the large existing national and international databases and literature related to the Baltic Sea.

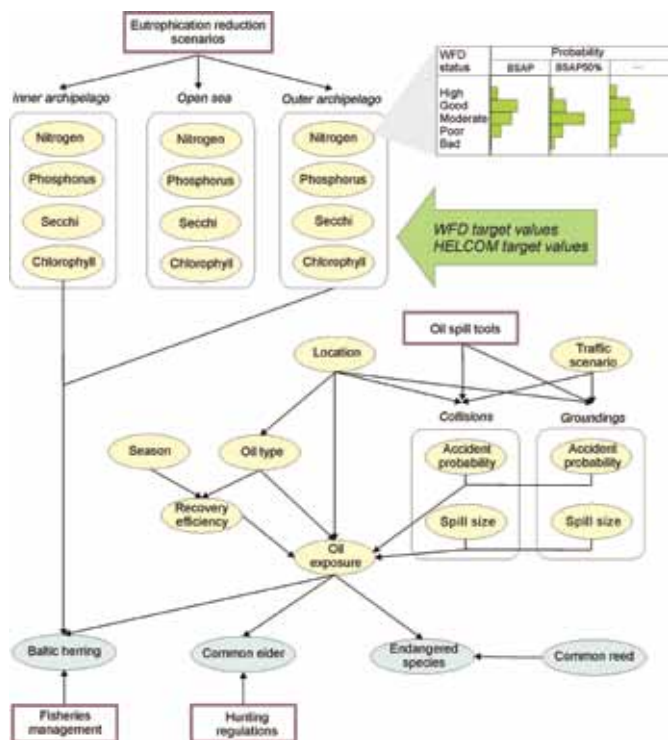


Figure 1. A simplified structure of the integrative risk analysis. The rectangles represent management options, the rounded rectangles separate submodels and the ellipses random variables. For example the eutrophication part of the model produces estimates describing the probability to reach a certain water quality class with different nutrient loading reduction scenarios in a certain area of the Gulf of Finland.

The decision model developed in the project integrates knowledge from several separate models and considers three potential risk factors: eutrophication, oil spills and harvesting (fisheries/hunting) (Figure 1). The decision options related to eutrophication reflect different nutrient loading reduction schemes (e.g. according to the HELCOM Baltic Sea Action Plan), the options related to oil spills include measures to decrease the probability of tanker accidents (e.g. implementation of Visual Tag System alarm), and with regard to harvesting, different fishing/hunting mortality levels.

There is a common need to utilise various existing models to provide estimates for probabilistic decision models. Also, a deterministic 3D ecosystem simulator is applied to provide estimates on the likely water quality changes under different nutrient loading scenarios. However, as the main aim is to estimate the probability of reaching the water quality targets of the EU Water Framework Directive and Baltic Sea Action Plan in the Gulf of Finland, the project developed new ways to estimate uncertainties for large ecosystem models. The model outcomes and the data are compared by applying a hierarchical model which provides an uncertainty estimate for model outcomes. Same approach can be applied, for example, in the uncertainty analysis of climatic models.

The integrated risk assessment for individual species is performed using separate probabilistic population dynamics models and expert knowledge. For example, the common eider model developed in the project encompasses the life stages of eiders both in Finland and Denmark, i.e. in their nesting and wintering grounds, respectively. A separate model describing the total Baltic Sea eider population wintering in Danish waters is first used to estimate hunting mortality in Denmark, after which the eider population nesting in the Gulf of Finland is modelled with a more sophisticated state-structured population model. The assessment of risks is done by exposing the population to different level of harvesting and oil spills of different sizes occurring in different locations within the Gulf of Finland. The results suggest that the estimated impact of oil spills on the population risks of common eider seems to be low compared to hunting. An accident in spring time would have more severe impacts than spills in other times of the year.

THE REED NUISANCE

The common reed has in many places overtaken the Finnish coast of the Gulf of Finland causing substantial nuisance to real estate owners. The reed invasion is thought to be an important factor

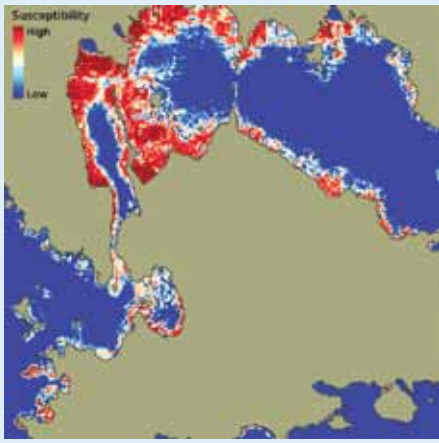


Figure 3. Susceptibility for reed colonisation in an example area, estimated by the cellular automata model.

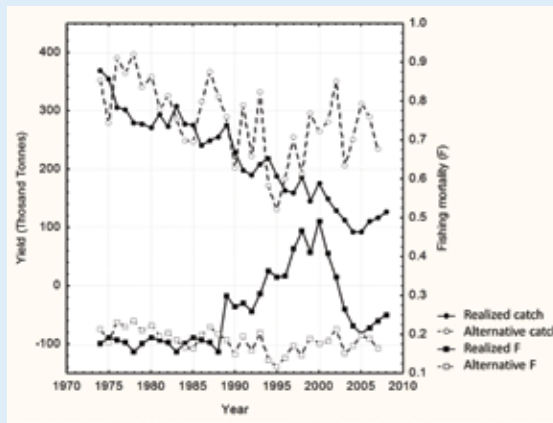


Figure 4. Yield (circles) in relation to fishing mortality (squares) according to historical records estimated by ICES (filled symbols) and if FMSY, like now estimated by IBAM project, would had been applied (alternative yields and fishing mortalities, open symbols).

influencing the reproduction success of both birds and fish. For example, by spreading to sandy beaches, it potentially creates risks for many threatened species. Moreover, reed expansion can alter habitats by favouring certain species and influencing negatively the abundance of others. During the past decades, the common reed has spread extensively in the inner and middle archipelago areas of Finland covering now up to 8 % of the area of some coastal municipalities in the Southern Finland.

The IBAM project carried out an interview study among people living by or the near the coastline of the Gulf of Finland. The spread of reed beds and other overgrowth of habitats are seen by the locals as the third biggest environmental concern that should be addressed after eutrophication and the risk of oil spills (Figure 2A). Moreover, it was a common view that the amount of reed has increased in their nearby areas (Figure 2B).

The spread of the reed can be explained by the high tolerance of reed to different environmental conditions, making it a robust competitor in several ways. It prefers nutrient-rich habitats; hence, eutrophication may offer an explanation for the reed expansion. In our analysis, we found a dependency between the distance to river mouths and reed existence that is likely related to nutrient loads from rivers.

In order to predict the possible future extension of the reed to new areas, a cellular automata model incorporating the aforementioned factors has been developed. The estimates of the probability of reed expanding into the habitats of an endangered species provide input to the integrative model making it possible to assess the risk on those species. Figure 3 shows a susceptibility map where free areas with potential for reed colonization are defined.

DO FISH STOCKS BENEFIT FROM EUTROPHICATION?

Large environmental and fisheries data sets were analysed as part of the efforts of aiming to find the key environmental factors influencing the productivity of fish stocks along the Finnish coast. The coastline of Finland offers a unique natural experimental setting that can be used to assess the relative importance of various environmental factors for the species occupying it. The area represents significant variability in several crucial environmental factors: salinity, temperature, including winter ice duration, coastline characteristics, and trophic status. The analysis showed that the morphology of the coastal areas is the main environmental factor explaining the fish

productivity and species composition in Finnish coastal waters. This factor cannot be manipulated with any management actions. However, the analysis also demonstrated that the impact of nutrients and climate change is increasing the overall risks of future development of fish populations.

HOW IS THE HERRING DOING?

In the analysis of the productivity of the Baltic Main basin herring stocks, the influences of cod, sprat, and salinity were included to explain the changes. The created model incorporates uncertainty both in the herring population parameters and in the parameters describing the environment. Equations were constructed to produce fishing mortalities leading to a maximum sustainable yield (FMSY) and the associated yield.

Applying the modelling outcomes retrospectively indicates that the herring was overfished in the 1990s and early 2000s, resulting in a net loss in yields with a landing value of approximately EUR 440 million (Figure 4). The catches of the latest years are very likely low due to the over-exploitation in the 1990s.

The management objective in the EU is changing from a precautionary approach towards maximum sustainable yield. The IBAM project collaborated with the International Council for the Exploration of the Seas (ICES) which adopted the IBAM model and used it when recommending the quotas for the herring and sprat in the central Baltic Sea (excluding the Gulf of Riga). If this new scientific advice is adopted by managers and politicians, it is likely that the long term catches will increase and the fishery will provide higher incomes for the herring industry.

THE IMPORTANT HUMAN FACTOR

In the socio-economic part of IBAM, the project has demonstrated the importance of implementation of uncertainty in fisheries management by using salmon fisheries management as an example. If the chance that humans do not always react to management actions as anticipated is not taken into account, the chance to control the fisheries and to decrease environmental risks can be seriously overestimated. These findings help in taking into account the human behaviour in planning environmental risk management actions. It is especially important to compare the likely implementation success of alternative management strategies.

NEXT STEPS AND FUTURE PLANS

There is a need to apply the methods developed in the IBAM project to other areas of the Baltic Sea and to new species of interest and to wider ecosystem aspects. At the same time, there is a need to further develop the models so that the large existing data sets and models, including the new ones produced by the BONUS+ programme, can be utilised more effectively in risk analysis and

risk management. The impact of climate change must be considered more explicitly in the analysis of existing data sets and, most urgently, in the future predictions produced by different type of models in order to describe the uncertainties in a realistic way. Also, the human behaviour must be included in the management analysis in order to achieve a complete understanding of risks.

IN BRIEF

IBAM Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland

IBAM focuses on modelling of several environmental risk factors impacting at the same time. IBAM has developed new ways to manage the Baltic Sea fish stocks, and provides probabilistic estimates of reaching some of the management aims agreed by the society. Baltic herring and common eider are used as key example species in the integrated risk analysis. An extensive analysis of the expansion of reed has been carried out. The developed methodology can be extended to new areas and new species in the Baltic Sea.

KEY RESULTS

- Interactive Bayesian decision models demonstrate that the exclusion of some risk factors underestimates the total risks.
- According to an interview study, the expansion of common reed is the third biggest environmental concern for the people living by the sea.
- The reed very likely continues to spread to new areas, which may result in further changes in the ecosystem.
- Baltic Main basin herring has been overfished, and if the recommendations produced in this project concerning the fishing effort would have been available and applied earlier, a loss of approximately EUR 440 million would have been avoided.
- The uncertainty due to the reactions of stakeholders must be taken into account when management actions are planned.
- There is a need to further expand the use of modern risk analysis to Baltic Sea science and management.

WHO NEEDS THE INFORMATION

The information is important for the policymakers and managers who are responsible for the management actions of the Baltic Sea. The findings also help the citizens of the Baltic Sea region to understand the nature of risks present in the Baltic Sea. Moreover, the other scientists can use the outcomes of the IBAM project in their own risk analyses.

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