Executive summary
- International evaluation of the Danish marine models

To be published after the hearing of the evaluation report

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10. oktober 2017

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1. Introduction

This report presents a scientific review of the Danish management approach regarding coastal waters in relation to the implementation of the European Water Framework Directive (WFD) in Denmark. The parties to the Agreement on Food and Agriculture Package (22 December 2015) have decided to evaluate the modelling tools (pressure-impact models) used to calculate the mitigation demands for nitrogen (N) runoff from land in the Danish River Basin Management Plans. The results of the evaluation will be utilised towards the development and application of models in the 3rd generation water plans valid for 2021-2027.

Task description by the Ministry of Food and Agriculture

The task of the evaluation panel is to perform a thorough evaluation of the marine modelling tools that form the basis for the mitigation demands for land-based nitrogen (N) runoff in the Danish River Basin Management Plans with regards to the importance of N as well as other relevant pressures such as phosphorous, fisheries etc. In particular, the evaluation panel has to:

i. Evaluate the use of models for determination of type-specific reference values (according to the Water Framework Directive, Annex 2) for the water quality element phytoplankton (chlorophyll).

ii. Evaluate the use of models to determine environmental targets (Maximum Allowable Inputs (MAI) of nitrogen)) and mitigation needs to achieve good environmental status and evaluate differences and similarities between the use of different methods and model types for coastal waters with different typology.

iii. Evaluate the estimated nitrogen target loads and mitigation needs in the Danish River Basin Management Plans and evaluate the method for determining the Danish proportion of total mitigation needs. How is the current environmental status in Danish coastal waters determined by N runoff from Danish land areas in relation to other pressures such as N released from sediments and N loads from catchments in neighbouring countries and airborne N deposition (the Danish share of the total mitigation needs related N)?

Further, the Panel is expected to address the technical questions and comments from the stakeholders.

Recruitment of experts

The Danish Ministry of Environment and Food has been responsible for the recruitment of an international panel of five experts to carry out the evaluation. The recruitment of experts has been conducted by a nomination process where the Danish Ministry of Environment and Food has requested water management authorities in other countries (Sweden, Finland, Poland, Germany, The Netherlands and England) and the European Environment Agency, Joint Research Centre (JRC) and the European Commission (DG Environment) to nominate experts to conduct the evaluation. It has been stated in the request that the nominees should have expert knowledge in the following areas: marine ecology, marine ecosystem models, statistical methods and experience in marine water management in relation to the Water Framework Directive.

The request by the Ministry resulted in the nomination of 14 experts of which 9 experts subsequently indicated that they were interested in being part of an expert panel. Of these, the Ministry has selected the following five experts to conduct the evaluation:

- Professor Peter Herman, Deltares, Institute for applied research in the field of water and subsurface, the Netherlands.
- Professor Alice Newton, NILU – Norwegian Institute for Air Research
- Professor Gerald Schernewski, Leibniz Institute for Baltic Sea Research, Warnemunde
- Director Bo Gustafsson, Baltic Nest Institute (BNI), Stockholm University, Sweden
- Senior Researcher Olli Malve, Finnish Environment Institute SYKE
- Professor Peter Herman was chosen as chairman of the Panel

The five experts were chosen according to an assessment of their qualifications with regards to experience with and competences in the following fields of study: *marine ecology/coastal ecology*, c*oastal ecosystem modelling*, *use of statistics in environmental science* and *marine management experience related to the implementation of the Water Framework Directive*.

Aim and focus of the evaluation

This section presents the aim and focus of the evaluation according to the international panel (hereafter referred to as the Panel) and should therefore be seen as the Panel's further operationalisation of the task description.

The evaluation will answer questions related to points (i)-(iii) in the task description above and is therefore focused on the scientific underpinning of the plans, in particular the modelling tools. The evaluation must take into account the internationally agreed goals of achieving Good Ecological Status in the Water Framework Directive.

The main aim of the evaluation

The main aim of the evaluation is to review whether the marine models – as presented in the Scientific Documentation Report and as commented by the researches and stakeholders – *provide solid and robust scientific evidence that the proposed reductions in land-based N runoff will be both necessary and sufficient to reach Good Ecological Status as defined in the Water Framework Directive*.

- By "solid", the Panel means well based in international scientific literature, well performed, credible
- By "robust", the Panel means not unduly dependent on arbitrary details, reliable with acceptable precision
- By "necessary", the Panel means that by doing less the goals would not be reached
- By "sufficient", the Panel means that by executing the plans, there is a high probability of reaching the goals

The scope of the evaluation does not include other models than the marine model and other environmental targets than those applying to coastal areas. The scope of the evaluation does not include the societal costs and benefits of the measures that would be needed to fulfil the environmental targets.

The basis for the evaluation

The basis on which the Panel has made the final evaluation consists of the following materials:

- The Scientific Documentation Report written by Aarhus University (DCE) and DHI in June 2017, which documents the model tools and calculated MAI that were developed for the Ministry over the period 2013-2015.
- Questions and comments from the stakeholders to the Scientific Documentation Report (see Annex 1 of the evaluation report)
- Answers from the researchers to questions and comments which were formulated by the Panel after the members of the Panel read and considered the report as well as the questions and comments from the stakeholders (see Annex 2a and 2b of the evaluation report).
- Answers from the Panel on how they took into account each of the technical questions and comments from the stakeholders (see Annex 3 of the evaluation report).
- Selected background materials cited by the researchers, the stakeholders and the Panel

The evaluation process

It is considered crucial that the evaluation of the Danish marine models be performed by independent scientists. In order to guarantee independence, it was decided that the Ministry of Environment and Food, the scientists from AU and DHI and the stakeholders should keep arm's length to the Panel throughout the process of the evaluation. Implement Consulting Group (Implement) was engaged by the Ministry to facilitate the process.

The evaluation process started in June 2017. It resulted in an evaluation report on 19 September, which was finalised after a writing workshop in Helsingør which took place between 11-15 September. After the hearing process between 19. September and 2 October some minor corrections were made to the final report which was completed on 10 October.

The hearing process

A hearing of the evaluation report among stakeholders from Blåt Fremdriftsforum and the scientists from AU and DHI took place between 19 September and 2 October. Three stakeholder organisations plus AU and DHI submitted additional comments and questions which were answered by the Panel between 2 and 9 October. The additional comments, questions, and answers are listed in the document *Høringsbilag* which was completed 10 October.

When studying the reactions of researchers and stakeholders, the Panel realized that a few factual errors occurred in its report, and that furthermore the choice of wording was not always entirely precise and consistent, with respect to the difference between water body specific, type-specific, and regionalized references, targets and MAIs. In order to avoid further confusion with other readers of the report, the Panel decided to slightly edit the report and the final version was therefore submitted on 10. October. The changes in the final version, compared to the version commented upon by the stakeholders and researchers, have been summarized in the first Table in the document *Høringsbilag*.

The Panel hopes that the attention given to the views of the stakeholders and the responses of the researchers during the scientific scrutiny of the Scientific Documentation Report will help to build trust between the parties and contribute to a successful outcome.

2. Overall assessment and conclusions

The Water Framework Directive aims at restoring Good Ecological Status in surface waters in Europe. The Scientific Documentation Report proposes measures of nutrient load reduction to reach this Good Ecological Status in Danish transitional and coastal waters. The Panel fully endorses the importance attached to nutrient reductions as a necessary requirement to reach this Good Ecological Status and stresses the importance of nutrient conditions as a modulating factor interacting with any additional measures taken to improve the state of the system.

In comparison with many other European countries, Denmark has excellent databases, models and scientific expertise as a basis for the implementation of the Water Framework Directive. The Panel was delighted to see that these resources have been mobilised to achieve a leading position at the European scale. The Panel was impressed by the openness and transparency of the interaction between government, researchers and stakeholders as well as by the high intellectual level of the discussions. This open exchange of ideas and opinions is a perfect basis for a further improvement of the scientific basis for the WFD implementation.

The Panel has reviewed the choice of indicators and procedures, in the context of the WFD requirements and specifications, and found that the indicators, the methods to determine reference conditions and the methods to determine required actions were WFD compliant. The Danish implementation is based on either direct historical observation or model determination of reference conditions. Little or no uncontrollable “expert judgement” is involved. In that respect, the Danish models are attaining the highest possible standard of WFD implementation.

The Panel has analysed the consequences of using a relatively coarse typology of coastal waters for calculating reference conditions, targets and Maximum Allowable Inputs of nitrogen. The Panel concludes that the use of a coarse typology has led to reduction requirements that are not optimal for each of the individual water bodies. The Panel is convinced that the full use of available data and models would allow Denmark to forego the typology and develop advanced, specific reduction targets for each water body. The Panel recommends focusing on the water body scale of resolution throughout the scientific process. The regional grouping of reduction measures should be decided upon only at the stage of translating scientific advice into management action plans.

The Panel has analysed the indicators used and concluded that Chlorophyll a is a useful intercalibrated indicator of phytoplankton, while Kd is less optimal as an indicator of benthic angiosperms and macrophytes. The other indicators, used in the statistical modelling only, currently present methodological problems and are not yet mature enough for inclusion in the management plans. The Panel has identified promising developments in the modelling with respect to angiosperm and macrophyte indicators and made recommendations on how to extend and develop the indicator set in the future.

In view of the large efforts in the past to remove P load from point sources, the Panel endorses the emphasis placed in the Scientific Documentation Report on reducing N loads from diffuse sources. However, at least in principle, there could be an additional role for P load reduction and for seasonal regulation of the N load. The Panel is of the

opinion that these options merit further scientific exploration, especially in watersheds where high efforts for N load reduction are required.

Although the maintenance of two parallel modelling lines (statistical and mechanistic) may seem redundant at first sight, the Panel strongly endorses maintaining these lines. Given the wealth of data available, it provides unique possibilities for evidence-based checking of mechanistic model results. The Panel assesses the mechanistic model as a state-of-the-art, very comprehensive tool, but emphasises that independent checking on data as well as uncertainty analysis remain necessary and can be performed by the statistical approach. This coherence can be optimised by improving the approach and methods of the statistical modelling.

The Panel endorses the general logic of the methodology to derive reference and target values from the models and to calculate the required N load reduction to reach the targets. The Panel has identified several points in the workflow where averaging is performed. This results in interdependence of model types, loss of indicator resolution and loss of spatial resolution. It also adds complexity to the procedure and makes it very difficult to understand. None of these losses are necessary since the model results and database do permit a fully transparent derivation of water body-specific required nutrient reduction.

Summing up these different aspects of the work, the Panel positively evaluates that nutrient load reductions are based on **solid** scientific evidence and generally high-level modelling approaches. The Panel is very positive about the near lack of expert judgment in the work and is of the opinion that in the few places where it does occur, it is not necessary and can be removed. The general (country-averaged) level of required nutrient load reduction compares favourably with independent efforts in similar areas and seems a **robust** measure of what is needed. At the same time, the Panel assesses the spatial resolution of the required efforts as **unnecessarily coarse**. The Panel is convinced that the rich database, combined with an **improved statistical approach** and the high-resolution mechanistic modelling tools, are able to derive improved, water body-specific MAI values. Current scientific insight endorses the view that the overall reductions proposed are **necessary**, but cannot guarantee that they will be **sufficient**. Especially for benthic angiosperms and macrophytes, additional measures may be needed.

3. Recommendations for going further

Monitoring: The Danish national monitoring programme used in the Scientific Documentation Report includes more than 90 stations along the coast and in the sea. It is very comprehensive and is generally well adjusted to the WFD requirements. It forms the basis for the further development of models, for most calculations and is required to evaluate the success of measures and whether the targets of the WFD are met. The Panel recommends maintaining this monitoring system at full strength and assessing if additional monitoring stations will be required for a water body-specific management.

Typology: The typology has weaknesses in reflecting the individual properties of fjordic water bodies. Instead of suggesting a refinement of the existing typology, we recommend calculating reference conditions and targets for each of the 119 water bodies in Denmark. Denmark is one of the few countries in Europe, where the necessary data, expertise and models are available for such a comprehensive approach. By taking specific conditions and individuality of every water body into account, the calculated targets and water body-specific Maximum Allowable Inputs will be optimised and lead to

minimal waste of resources. For purposes of intercalibration, a robust typology can be based on the results of the water body-specific analyses.

Choice of indicators: Chlorophyll a is a generally accepted and intercalibrated indicator of phytoplankton. Kd, as a measure for macrophytes and angiosperms, has certain limitations. The Panel recommends building on recent efforts towards comprehensive modelling of eelgrass in order to derive a better indicator of macrophytes, but to keep Kd as a proxy meanwhile. The other indicators used in the statistical modelling address important ecological questions, but are not mature in the sense that they lack a clear quantitative relation with nutrient loading. The Panel recommends leaving them out of the present modelling and developing targeted modelling directed at their incorporation into the indicator system.

Statistical modelling: The Panel sees great merit in the strategy to maintain two independent lines of modelling, one based on statistical data analysis and the other based on mechanistic modelling. The Panel recommends reorienting the statistical modelling towards optimal estimation of the long-term slopes of the indicators on nutrient loading in a cross-systems analysis way and keeping in principle both N and P loading as explanatory variables. The Panel recommends elaborating the uncertainty analysis in the statistical modelling and suggests that this will be facilitated when a single cross-system advanced modelling approach is chosen.

Mechanistic models: The mechanistic models are state-of-the-art, both in terms of numerical technique and included processes. They are powerful tools for providing a sound scientific basis for the implementation of the WFD in Denmark. A shortcoming is that they do not cover all water bodies. As a consequence, different approaches were used for the definition of reference conditions, targets and MAI in different water bodies. We recommend extending a mechanistic modelling approach to as many water bodies as possible to ensure that, in future, a uniform methodology can be used for the definition of water body-specific MAI.

Methods to derive targets and MAI from the models: The Panel recommends simplifying the calculation procedure by removing the averaging steps between models, between indicators, between water bodies within types and between water bodies on a regional basis. In this way, the differences and correspondences between modelling approaches, indicators and water bodies will become clear and can be further analysed. Cross-checking of results of the statistical and mechanistic model approaches in systems, where both are available, will form a basis for extrapolation to all systems. The Panel recommends deriving one MAI per water body in this way and only deciding in a later phase on regional averaging or lumping, when scientific results are translated into management actions.

River basin interactions: River basin models allow calculating the load reduction potential of nitrogen and phosphorus for each river basin, the development of water body-specific nitrogen and phosphorus load reduction scenarios and cost estimates. Further, they allow addressing seasonal load and limitation patterns. The Panel recommends a combination of river basin and coastal water models to enable the development of water body-specific optimised management concepts that consider both nitrogen and phosphorus.

International approach: The technical WFD implementation guidelines force similar approaches in all member states. As a consequence, requirements, modelling and challenges are similar in different countries. Further, the WFD asks for an intercalibration and harmonisation of targets with neighbouring countries. Therefore, the Panel recommends a co-ordinated joint scientific approach, especially between Denmark, Germany and Sweden.