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Methods for establishing Chlorophyll-a references and target values applicable for the River Basin Management Plans 2021-2027

Background, method and data

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Eelgrass in Kertinge Nor

Photo: Peter Bondo Christensen

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Preface

This report is commissioned and funded by the Danish Environmental Protection Agency (EPA). The data, methods and results included in the report will be an integrated part of the material behind the Danish River Basin Management Plans (RBMP) 2021-2027.

The work reported was managed and performed by DHI and Danish Centre for Environment and Energy (DCE), Aarhus University. During the project, a steering committee followed the development and was involved through dialogue and follow-up on progress, etc. This steering committee consisted of members from the Danish Ministry of Environment and Food (MFVM), Danish EPA (MST), DHI and DCE.

In addition, a follow-up group consisting of members from The Danish Agriculture & Food Council, SEGES, the Danish Society for Nature Conservation, the Danish Sports Fishing Association, Danish Fishermen PO (DFPO), the Danish Ports and KL/municipalities were affiliated with the project. The follow-up group has been continuously informed about the progress of the project at meetings convened by the MFVM.

Choice of methods, data processing, description and presentation of results is solely DHI, DTU and DCE's decision and responsibility.

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1 Introduction

When preparing the Danish River Basin Management Plans 2015-2021 (RMBP 2015-2021), DHI and DCE developed a number of mechanistic (DHI) and statistical (DCE) models that were used for calculating Chlorophyll-a target values defining the threshold between ‘Good Ecological Status’ (GES) and ‘Moderate Ecological Status’.

The models were also used for calculating Maximum Allowable Inputs (MAIs) of total N from Danish catchments based on the modelled Chlorophyll-a threshold values and observations of eelgrass depth limit. Hence, the development aimed at both the estimation of Chlorophyll-a threshold values and the development of a method for calculating the MAIs.

As part of the political, regulatory package ‘The Food and Agriculture Package from 2015’ an international evaluation of the procedures used in the second generation RBMP 2015-2021 was conducted. The evaluation was finalized in the autumn of 2017 with a report (Herman *et al.* 2017) including a number of recommendations for improving the scientific background behind the RBMP 2021-2027.

To follow up on the international evaluation, the Danish EPA facilitated a range of projects with the overall aim to develop methods to calculate robust, transparent and differentiated Chlorophyll-a reference values (and corresponding target values) and MAI’s in as many water bodies as possible for incorporation into the third RBMP 2021-2027.

The present report describes the methods for establishing Chlorophyll-a references and target values applicable for the River Basin Management Plans 2021-2027, as well as the data behind the modelling of the reference Chlorophyll-a values.

2 Method

2.1 Background

The Water Framework Directive (WFD) requires that EU member states establish reference conditions for the biological quality elements and indicators in order to provide a baseline against which to assess and classify the environmental status of European surface waters.

According to the Water Framework Directive, the reference condition for a water body type is defined as:

The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion (Annex V, Directive 2000/60/EC).

In Guidance Document No. 10 the term “reference conditions” is expanded a bit more:

Reference conditions do not equate necessarily to totally undisturbed, pristine conditions. They include very minor disturbance which means that human pressure is allowed as long as there are no or only minor ecological effects.

Hence, the reference condition describes a situation with no or only minor disturbance from human activity. Based on WFD guidelines, the reference condition should be determined for each type of water body either from i) observations from existing undisturbed sites ii) historical data, iii) modelling or iv) expert judgement in prioritized order (Guidance Document No. 5).

All of these approaches have been used to develop reference values for several biological elements in different marine waters throughout Europe (Basset et al. 2013; Borja et al. 2012; Muxika et al. 2007; Bennion et al. 2004; Krause-Jensen et al. 2005; Schernewski et al. 2015).

GES values, as well as the boundary values separating the 5 classes (high, good, moderate, poor and bad), are normatively defined in the WFD as a deviation from the reference condition and quantitatively defined as part of the intercalibration process ensuring consistency and comparability of environmental boundary values among EU member states.

In Denmark, the mean Chlorophyll-a concentration from May to September is used as an indicator for the biological quality element ‘Phytoplankton abundance’ in the Danish part of the Baltic Sea region (from Skagen to Bornholm) and establishment of reference values (and corresponding target values) for this Chlorophyll-a indicator is a prerequisite for the Danish River Basin Management Plans (RBMP) 2021-2027. In the North Sea, the 90% percentile from March to October is used as the indicator for ‘Phytoplankton abundance’, and here they are based on intercalibrated values.

2.2 Objective

The establishment of Chlorophyll-a references and corresponding target values is a prerequisite for the Danish River Basin Management Plans 2021-2027, and the objective of this report is to present methods and describe the data required to establish Chlorophyll-a references and corresponding target values that comply with the Water Framework Directive and can be used as part of the Danish RBMP 2021-2027.

The method for establishing Chlorophyll-a reference values will be developed to ensure as high spatial differentiation as possible in order to reflect the heterogeneity of the water bodies while minimizing the uncertainty of the estimates as much as possible.

2.3 Conceptual Method

According to WFD, Chlorophyll-a data from undisturbed sites are preferable for establishing reference values for the Chlorophyll-a indicator. There are, however, no undisturbed marine areas in Denmark and to our knowledge no existing European marine areas have been identified as undisturbed. Hence, it is not possible to base the method for establishing reference conditions on Chlorophyll-a data from undisturbed marine sites.

Use of historical Chlorophyll-a data is the second choice for establishing reference values. However, to our knowledge, the first quantitative Chlorophyll-a measurements from Danish coastal waters are from the 1970's (Henriksen 2009), when eutrophication was already high. Hence, suitable historical Chlorophyll-a data is not available for establishing reference values for Danish coastal waters.

Since options 1 and 2 are not applicable due to lack of suitable Chlorophyll-a data, quantitative modelling (option 3) is the most feasible way to establish the reference and 'good-moderate' (GM) targets. Different modelling approaches have been applied to both Danish waters (Carstensen & Henriksen 2009, Erichsen & Timmermann 2017) and other regions of the Baltic Sea area (Schernewski et al. 2015; Gustafsson et al. 2012; Schernewski & Neumann 2005). In this study, we base the establishment of reference Chlorophyll-a concentrations on model scenarios using the mechanistic and statistical models developed for estimating maximum allowable nutrient input (MAI) ensuring fulfilment of the WFD requirement of obtaining 'good ecological status' in all Danish marine water bodies.

The model scenario is supposed to reflect an undisturbed, or only very minorly disturbed, situation (henceforth designated reference scenario), in order to ensure that the resulting Chlorophyll-a values are in compliance with the WFD definition of reference values. Hence, the models are forced with input data (boundary and initial conditions) corresponding to a situation as close to an undisturbed situation as possible.

The resulting Chlorophyll-a values will, in principle, reflect the Chlorophyll-a concentrations for each water body under undisturbed – or close to undisturbed – conditions. However, model predictions of reference conditions are inherently uncertain, and the scenario results will be critically evaluated and the data post-processed in order to reduce uncertainty.

According to WFD, water bodies should be divided into different types. This work is reported in Erichsen & Timmermann (2019), and the WFD also requires establishment of type-specific reference values which will have the same or lower uncertainty than water body specific reference values. Type-specific reference values may, however, not fully reflect the characteristics of the individual water bodies within each type. In order to optimize the balance between low uncertainty and high spatial differentiation, the typology described in Erichsen & Timmermann (2019) will be applied in combination with the regression-based approach described in Timmermann et al., (2020). A regression-based approach will allow for differentiated Chlorophyll-a reference values based on hydro-morphological characteristics while reducing the uncertainty by including all estimated reference values and hydro-morphological data characterizing each water body. Hence, we will minimize the use of typology and type-specific reference values as much as possible and to the extent possible apply a regression-based approach.

3 Data

The establishment of reference Chlorophyll-a concentrations is based on model scenarios reflecting an undisturbed, or only very minorly disturbed, situation. In order to perform such a reference scenario, model-specific forcing data representing an undisturbed/minor disturbed situation is required. For the statistical models the required forcing data is restricted to Danish land-based reference loadings, whereas the mechanistic models also require reference nutrient inputs originating from the atmosphere, Baltic Sea, North Sea as well as adjustments in the sediments etc.

3.1 Danish land-based reference loadings

Reference TN loadings used in the marine Chlorophyll-a reference scenario is estimated as background concentrations of TN in streams from each catchment multiplied with the corresponding catchment specific water flow. Estimation of background stream TN concentrations is described in Bøgestrand et al. (2014b) and Kronvang et al. (2015).

Briefly, background TN concentrations are based on measured concentrations of TN, NO_3, NO_2 and NH_4 in streams draining catchments with a low (< 10%) proportion of agricultural land and no or very few point sources from scattered households. This is in line with the WFD guidelines stating that areas applicable as reference sites require identification of 'areas of no or very minor pressures from land-based activity (i.e. areas with no or low intensity agricultural practices and no or few point sources of pollution' (CIS No. 5). Here we define 'minor pressures from land-based activity' as up to 10% proportion of agricultural land and few or no point sources. On top of this, the catchments are also affected by atmospheric deposition, and the effects from this source are not quantified.

20 streams with distinctive geological and geographical differences (and hence different soil types, etc.) distributed around Denmark fulfil the criteria of low anthropogenic impact, and measurements from these sites were used to establish reference stream TN concentrations.

Quarterly or monthly nutrient measurements were obtained from the 20 streams in 2004-2005 and again in 2011. Based on a model linking stream TN concentrations from undisturbed sites with information of geomorphological characteristics (Kronvang et al., 2015), it is possible to estimate the background TN concentrations in streams in Denmark with a spatial resolution resembling ID15[1]. The background concentrations applied in the different catchments are illustrated in Figure 3-1.The catchment specific water flow used to establish reference TN loadings is similar to the water flow used for model development and calibration and is based on nationwide time series data (1990-2018) from the national monitoring network of water flow to the coastal zone.

[1] Danish catchments are divided into sub-catchments of approximately 1500 ha, and they are named ID15.

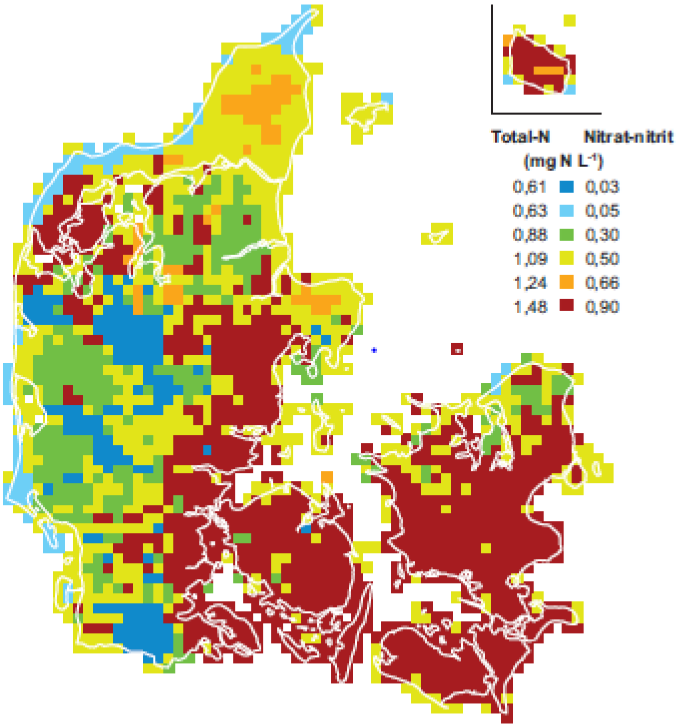

Figure 3-1 Map shoving the distributed background concentrations of TN and NOx (copy from Bøgestrand et al., 2014b).

The reference TP loading is based on background TP concentrations from 26 streams draining catchments with less than 20% agricultural land and no or only a few point sources. In order to obtain enough sites for estimating TP background concentrations it was necessary to allow for a higher proportion of agricultural land compared to the maximum of 10% used as the criteria for establishing background TN stream concentrations. Background TP stream concentrations were estimated for 9 geo-regions and multiplied with catchment specific water flows to obtain reference TP loadings.

An overview of the reference loadings as well as present day (average 2012-2018) loadings to the water bodies in the inner Danish waters is shown in Figure 3-2 (based on RBMP 2015-2021 water bodies). As can be seen from this figure, reference N and P loads are generally significantly lower than present day loadings expressed both as total N and total P loadings per year and per area. The accumulated N loadings in a reference condition calculates at 16 kton N year^{-1} (average between 2012-2018) from all Danish catchments and 11 kton N year^{-1} when only considering loadings to inner Danish waters. This should be compared to the present-day loadings of 68 kton N year^{-1} and 58 kton N year^{-1}, respectively.

Similar figures for TP are 0.7 kton P year^{-1} (average between 2012-2018) from all Danish catchments and 0.5 kton P year^{-1} when only considering loadings to inner Danish waters. This should be compared to the present-day loadings of 2.0 kton P year^{-1} and 1.5 kton P year^{-1}, respectively.

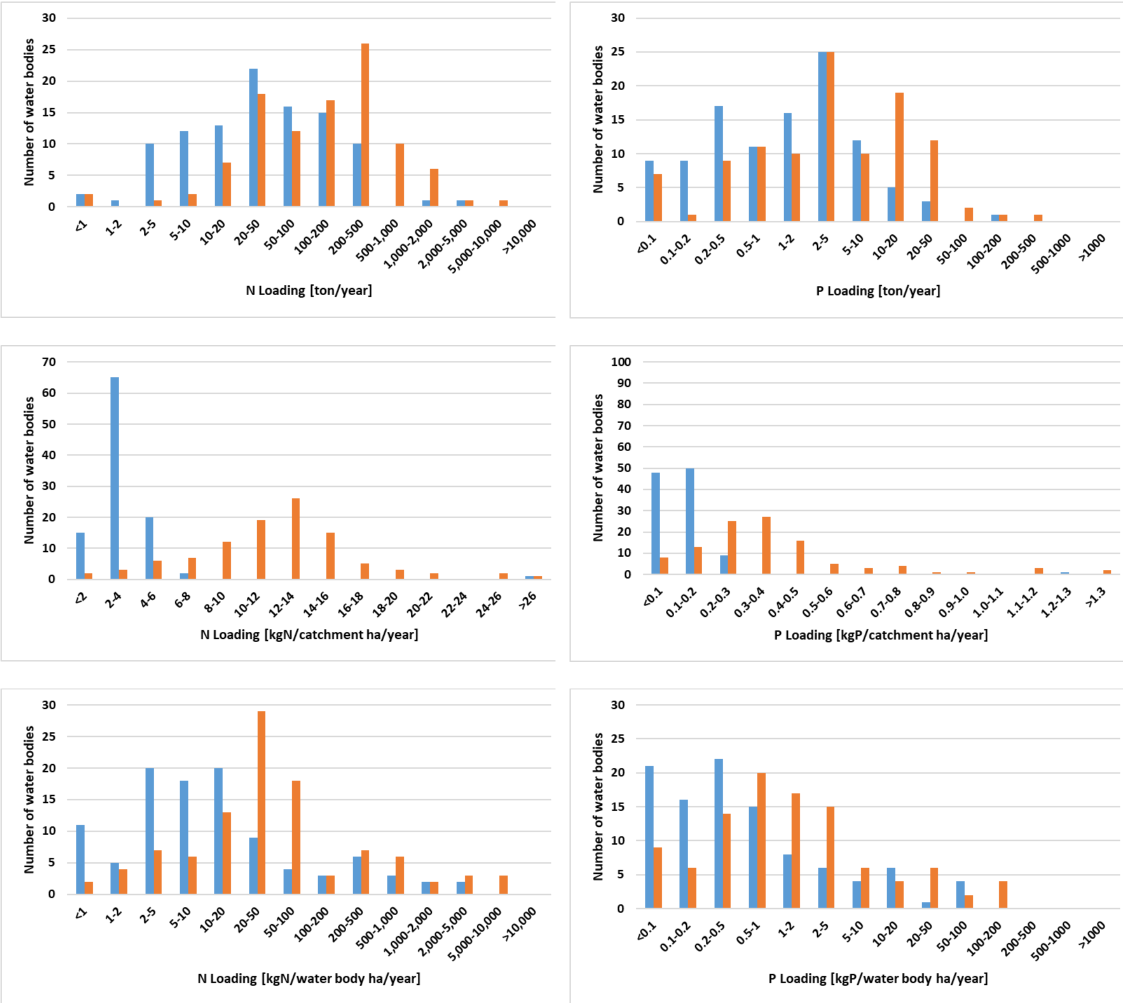

Figure 3-2 Statistics based on average yearly nutrient loadings to each of the 119 Danish WFD water bodies (defined under RBMP 2015-2021) based on background concentrations (blue columns) and present-day concentrations (2012-2018; orange columns). The water bodies are divided according to the grouping indicated by the x-axes. Left vertical panel shows N loadings and right panels P loadings. Top panel presents the distribution according to loadings per water body, middle panel according to loadings per Danish catchment area, and bottom panel according to loadings per water body area.

Compared to the present-day situation, loadings per catchment area show limited variation in the reference situation (most loads are within 2-6 kg N ha^{-1} $year^{-1}$) whereas the majority of loadings in the present-day situation varies between 6-18 kg N ha^{-1} $year^{-1}$. Reference loadings per water body area do on the other hand have the same range as present-day loadings but with most of the water bodies having loads less than 50 kg N ha^{-1} $year^{-1}$ while most water bodies show higher loads under present conditions.

For the mechanistic model development, the nutrient loadings need to be split into different nutrient species, see Erichsen & Birkeland (2020a) for details. The data were provided as uniform concentrations (no seasonal variations) for the different water body catchments. From present-day analysis, seasonal differences in concentrations exist over the entire study area, but no information exists on the seasonality in a reference situation why we keep the concentrations constant over the year.

3.2 North Sea and Baltic Sea land-based reference loadings

3.2.1 North Sea loadings

The present-day loadings to the mechanistic North Sea model are based on model data from SMHI (https://hypeweb.smhi.se/explore-water/historical-data/europe-time-series/). These model data include both freshwater and nutrient concentrations (see Erichsen & Birkeland 2020b) for more details). To estimate a land-based reference loading to the North Sea that reflects the method applied for the Danish land-based loadings, the freshwater input is maintained unchanged (corresponding to the model calibration, see Erichsen & Birkeland (2020c) for details) whereas the nutrient concentrations have been modified.

In Gadegast & Venohr (2015) historical nutrient concentrations in 7 different German and Dutch rivers were estimated, compiled into an average concentration from the North Sea and compared to 2005 concentrations. According to Gadegast & Venohr (2015) the historical concentrations have changed from 1.63 g TN m^{-3} to 4.04 g TN m^{-3} (2005 data) and from 0.04 g TP m^{-3} to 0.14 g TP m^{-3} (2005 data). Hence, the reference loadings correspond to a reduction from present-day concentrations of 60% in TN concentrations and 71% in TP loadings.

These reductions are applied in all rivers in the mechanistic North Sea model. We do not have information to estimate specific reductions for France, UK or Norway. The governing nutrient sources (beside Danish nutrient inputs) along the Danish west coast do, however, origin from sources discharging into the German Bight, and no other locations in the North Sea.

3.2.2 Baltic Sea loadings

As for the North Sea model the mechanistic IDW model (Inner Danish Waters) requires boundary concentrations from the non-Danish Baltic Sea catchments. The development of the IDW model (Erichsen & Birkeland (2020b; 2020d) is based on daily model data from SMHI (https://hypeweb.smhi.se/explore-water/historical-data/europe-time-series/) and annual loadings according to HELCOM's Baltic Sea Pollution Load Compilation (HELCOM (in prep.)).

In the HELCOM project TARGREV (HELCOM 2013) Baltic Nest Institute (BNI) reconstructed nutrient loadings covering the period 1850-2006 (Gustafsson et al. 2012; Savchuk et al. 2012), and these data were used as reference loadings to estimate target loadings within the different HELCOM basins of the Baltic Sea.

Here we combine the reconstructed data with the HELCOM (in prep.) data to estimate the relative difference between historical loadings and present-day loadings (based on modelled data from SMHI and HELCOM (in prep.)). The relative difference within the different sub-basins defined in Gustafsson et al. (2012) and Savchuk et al. (2012) between the present day (average 2012-2016) and historical (average 1890-1910) data from the reconstruction, see example in Figure 3-3 and Figure 3-4, was inflicted on the IDW land-based non-Danish source data to provide a reference loading dataset applicable in the mechanistic model. This method was applied for both TN and TP loadings.

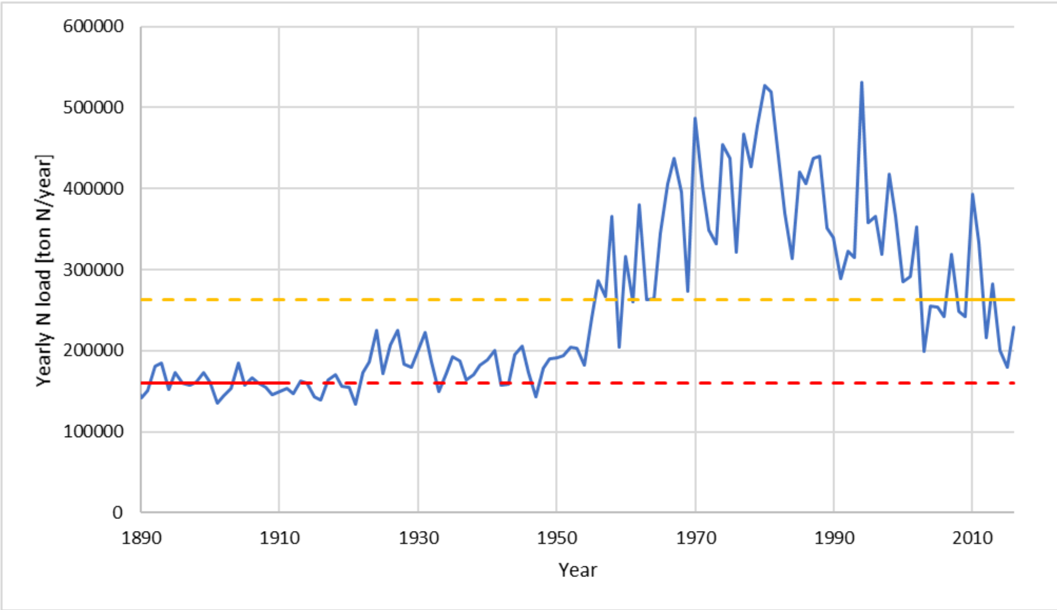

Figure 3-3 Yearly riverine and point source N loadings to the Baltic Proper, modified from Savchuk et al. (2012) (blue line). Red line indicates average 1890-1910 N loadings whereas orange line indicates average 2002-2016 N loadings.

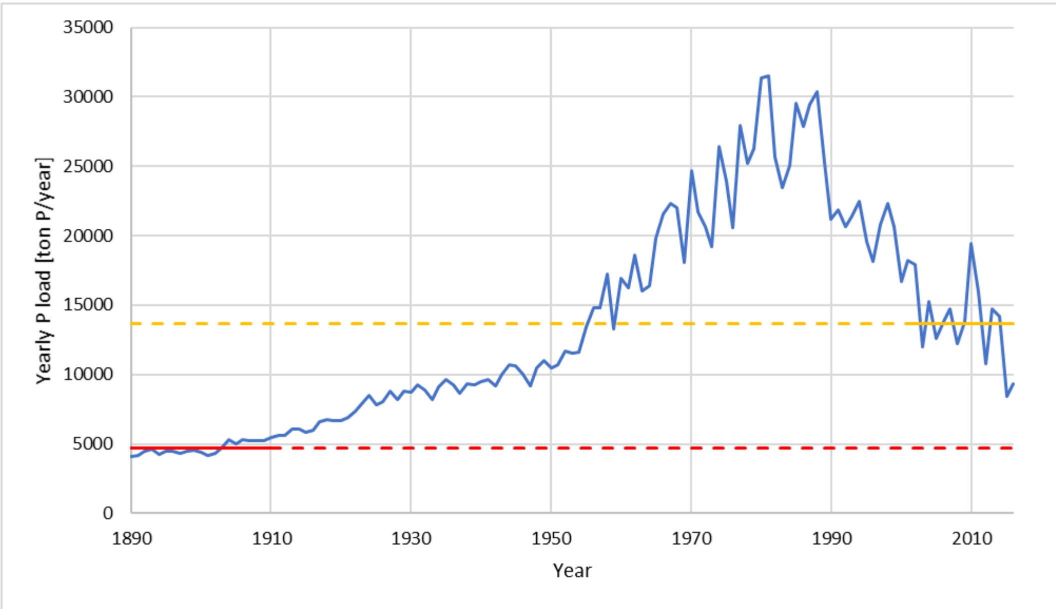

Figure 3-4 Yearly riverine and point source P loadings to the Baltic Proper, modified from Savchuk et al. (2012) (blue line). Red line indicates average 1890-1910 P loadings, whereas orange line indicates average 2002-2016 P loadings.

3.3 HELCOM background concentrations

According to (HELCOM PLC-7 IG 10 doc. 4-1 from Germany) the HELCOM contracting parties report natural background land-based riverine concentrations (similar to reference concentrations in the WFD perspective) every 6th year. However, the contracting parties are working on a harmonized method behind the reporting, and the result of the harmonized method is included in (HELCOM PLC-7 IG 10 doc. 4-1 from Germany). The data is included in Table 3-1.

No concentration data are reported for Germany, but in Schernewski et al. (2015) a reference TN concentration of 1,46 g m^{-3} was applied. Similarely, the concentrations in Gadegast & Venohr (2015) are similar to the concentrations in Table 3-1, although the TN concentration (1.63 g m^{-3}) is in the higher end compared to the data reported in Table 3-1.

The reconstructed loads (Gustafsson et al. 2012; Savchuk et al. 2012) applied in the present study are based on Savchuk et al. (2008). The river concentrations in Savchuk et al. (2008) were following the work by Schernewski & Neumann (2005). These concentration data (data not shown) also compare well to the background nutrient concentrations reported in Table 3-1.

Table 3-1 Annual natural flow-weighed concentrations of nutrients as reported by HELCOM Contracting Parties (HELCOM PLC-7 IG 10 doc. 4-1 from Germany).

Country	Total N (g m^{-3})	Total P (g m^{-3})	Comments
Denmark	0.61 – 1.48	0.021 – 0.089	Sub-catchment depending
Estonia	1.21	0.04	
Finland	0.169 – 0.752	0.0051 – 0.034	Sub-catchment depending
Germany			
Latvia	0.78 – 2.25	0.035 – 0.082	Sub-catchment depending
Lithuania	0.58	0.0339	
Poland	0.96 – 1.9	0.04 – 0.11	Depending on soil and slope conditions
Sweden	0.11 – 2.1	0.04 – 0.11	Depending on different land use areas

3.4 Atmospheric reference deposition

Model data on atmospheric nitrogen deposition under reference conditions are provided by AU, Department of Environmental Science. The model simulation is conducted with an atmospheric model describing transport, chemical reactions and deposition of various chemical species including NO_X and NH_4 (Geels et al, 2012).

The atmospheric model is forced with historical emissions provided by IIASA, 'Representative Concentration Pathways' (RCPs; from http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome), while the meteorological forcing corresponds to present days (2002-2016). Hence, the latter is coherent with the mechanistic modelling meteorological forcings (see Erichsen & Birkeland (2020b)).

The resulting N deposition data are provided as monthly means (from a 15-year simulation) with a spatial resolution of 5 × 5 km^2 and used without any post processing in the marine mechanistic model covering the North Sea while the N-deposition data covering the Baltic Sea are corrected according to the model data used in the model development (see Erichsen & Birkeland (2020b) for more details). More detailed descriptions can be found in Geels et al. (2012) and Ellermann et al. (2013).

3.5 Boundary concentrations

All the mechanistic models must be forced by boundary conditions describing the state variables at the boundary of the model domains. The mechanistic North Sea model has three open boundaries in the eastern part of the North Atlantic Ocean and one boundary in Kattegat.

Here we assume that no significant anthropogenic changes are detectable at the three open boundaries in the North Atlantic Ocean, even in a reference situation, why we do not adjust the concentrations at those three boundaries.

The western boundary and the southern boundary of the North Sea model domain account for the majority of the North Sea waters all together (see Figure 3-5), whereas the freshwater sources discharging into the German Bight play an important role in the coastal waters along the Danish west coast, see Figure 3-6, corresponding to the WFD water bodies. Hence, the reference concentrations modelled in these water bodies will be affected by the changes in nutrient loadings from land-based sources and atmospheric deposition.

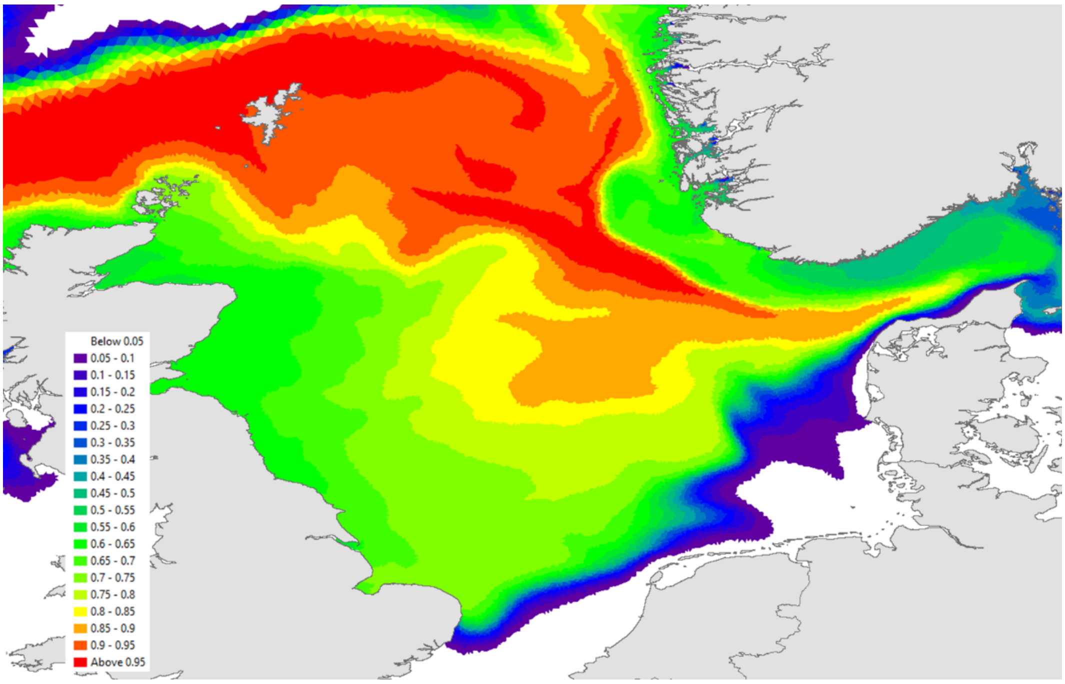

Figure 3-5 Conservative tracer originating from the western boundary in the North Sea model (1/1-2017). A value of 1 indicates 100% originating from that boundary. Data originating from Larsen et al. (2020).

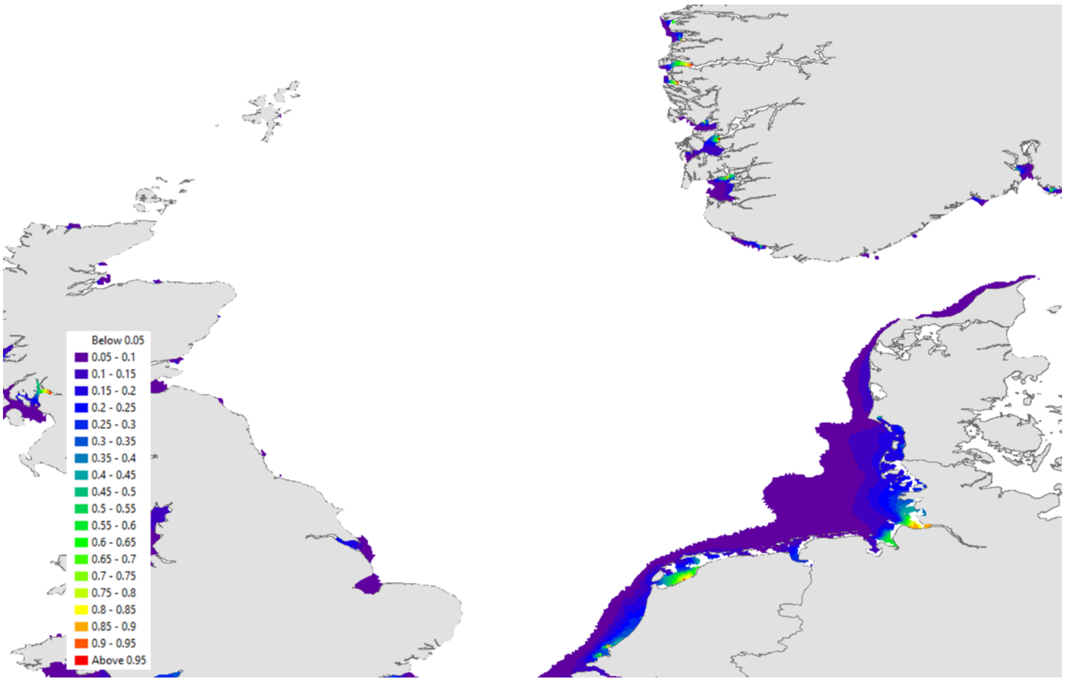

Figure 3-6 Conservative tracer originating from the Freshwater sources in the North Sea model (1/1-2017). A value of 1 indicates 100% originating from a freshwater source. Data originating from Larsen et al. (2020).

In Kattegat the situation is somehow different. Here we need to adjust the model boundary concentrations according to the expected changes between present-day concentrations and a situation matching undisturbed – or close to undisturbed – conditions. To account for the expected changes at the Kattegat boundary all parameters (C, N and P parameters) were adjusted based on modelled changes (Gustafsson et al. (2012, 2017)).

A relative difference between modelled historical concentrations and present-day modelled concentrations (Gustafsson et al. (2012, 2017)) in the southern part of Kattegat at various depths was inflicted on the boundaries used for the North Sea model development and then applied for the reference model scenario.

The reference model results from the North Sea model was subsequently used to create boundaries for the Ringkøbing Fjord model, the Nissum Fjord model, the IDW model and the western boundary in the Limfjord model. The reference model results from the IDW model were used to create boundary data for the three local models (Northern Belt Sea model, Southern Belt Sea model and the Smålandsfarvandsmodel), the three remaining estuary specific models (Mariager Fjord, Odense Fjord and Roskilde Fjord) and the eastern boundary in the Limfjord model.

3.6 Initial values – pelagic phase

The retention time in the Baltic Sea is significant (approximately 30 years according to Wulff et al. (1990)) why the initial values in the different sub-basins of the Baltic Sea were adjusted to match a reference situation. As for the Kattegat boundary in the North Sea model, we applied relative differences between modelled historical concentrations and modelled present-day concentrations (C, N and P parameters) in the different sub-basins and at different depths. An example of the relative differences from the Gotland Sea is included in Figure 3-7.

The pelagic initial fields in the three local models (Northern Belt Sea model, Southern Belt Sea model and the Smålandsfarvandsmodel) were adjusted similar to the IDW model adjustments.

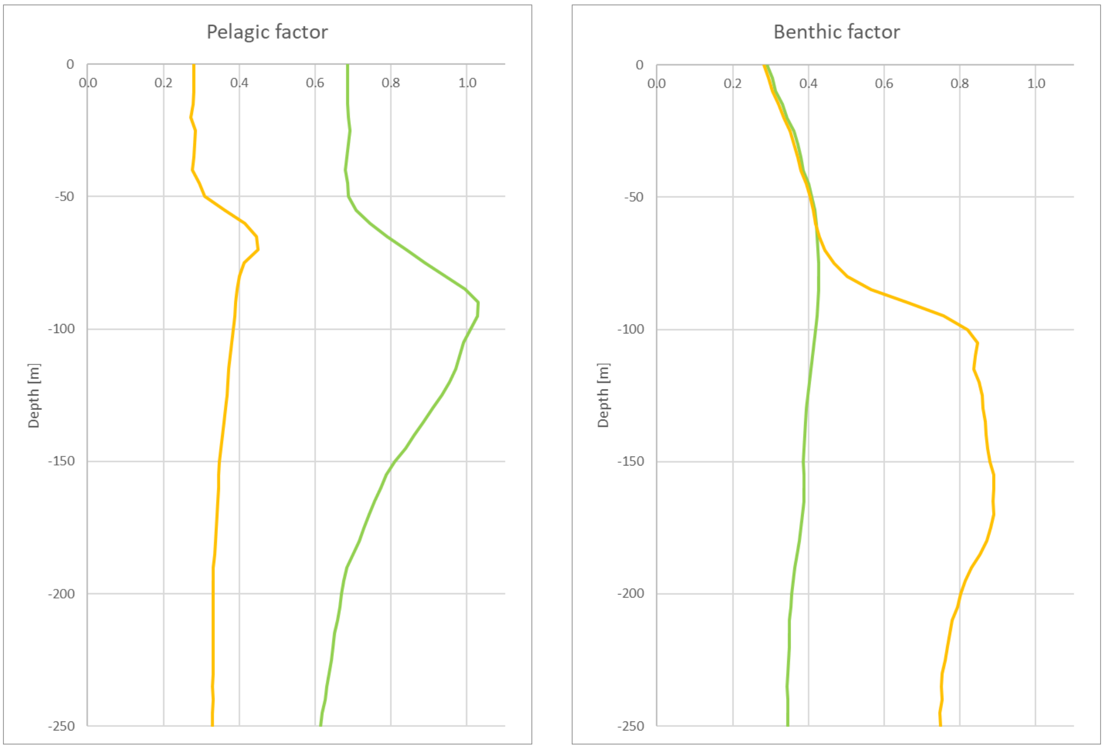

Figure 3-7 Estimated changes in the pelagic compartment (left figure) and the benthic compartment (right figure) between the reference and the present-day situation within the Gotland Sea. Orange curve indicates the factor between reference and present-day TP concentrations and green curve the similar factor for TN.

While all C, N and P parameters are adjusted in the IDW model and the three local models, no other pelagic initial values were adjusted before running the remaining models.

With respect to the North Sea model, most North Sea water originates from the eastern part of the North Atlantic Ocean (western and south-western boundaries of the North Sea model) where no changes were inflicted on the boundaries (see previous section). Hence, the reference scenario includes changes in land-based loadings and atmospheric conditions, and we allow the model to adjust the overall concentrations to a scenario situation by letting the model run for the 15 years and only use the results from the last five years.

Similarly, no adjustments were inflicted on the estuary specific models. The retention times in those models are relatively short (e.g. the residence time in Odense Fjord, the Limfjorden and Roskilde Fjord is < 1 year according to Kuusemäe et al. (2016)) why the impact from not adjusting the initial fields is quickly vanishing.

3.7 Sediment initial pools

Sediment pools react slower than the pelagic phase why potential adjustments in sediments pools to account for a reference situation also need to be considered. According to (Høgslund et al. 2019) and knowledge obtained from previous model work (Erichsen & Timmermann 2017) the sediment pools reach a new equilibrium in the nutrient fluxes between the pelagic and benthic compartments within 5-15 years depending on retention time, whereas the time horizon for structural changes in sediment compositions might extend to several decades (Valdemarsen et al. 2014).

In Erichsen & Timmermann (2017) only changes in the sediments covering the Baltic Sea were introduced, but in the present study we adjust sediment pools in both the Baltic Sea (IDW model) as well as all local and estuary specific models. Again, we apply relative differences between modelled historical sediment pools and modelled present-day pools carried out by Baltic Nest Institute (Gustafsson et al. (2012, 2017)). In Figure 3-7 an example from the sediments in Gotland Sea is included.

In the IDW model and the local models we apply the relative differences in the various sub-basins of the Baltic Sea, whereas we use a common adjustment in estuary specific models based on the relative difference estimated in the sub-basin, Danish straits. In the Danish straits the average factor between reference sediments and present-day sediment is 0.57 for both N, P and C.

3.8 Eelgrass coverage

The final adjustment applied in the mechanistic models relates to eelgrass coverage. Besides the North Sea model all other models include eelgrass (biomass and number of shoots) as specific state variables. To allow for eelgrass to develop in a reference scenario eelgrass needs to be initialised based on the historical observations. The eelgrass initial fields have been developed based on the findings in (Timmermann et al. 2020) and we have assumed a steady increase in eelgrass biomass between 0.5m and 2.0m peaking at 100 g C m^{-2} followed by a steady decrease in biomass between 2.0m and the historical depth limited reported in Timmermann et al. (2020).

Examples of the eelgrass biomass applied as initial fields in the reference scenario are included in Figure 3-8 and Figure 3-9. The figure shows eelgrass coverage, estimated by combining bathymetry information with data from Timmermann et al. (2020). The resulting initial fields match the historical eelgrass coverage reported in Christensen et al. (2011) and Boström et al. (2014).

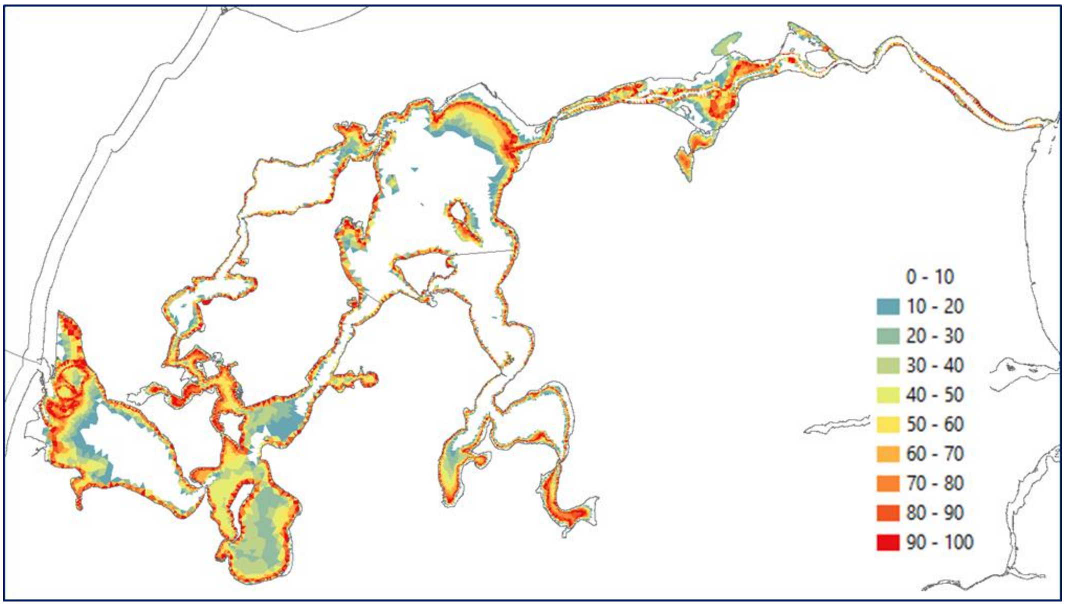

Figure 3-8 Eelgrass biomass maps (g C m^{-2}) in Limfjorden applied as initial fields in the reference scenario.

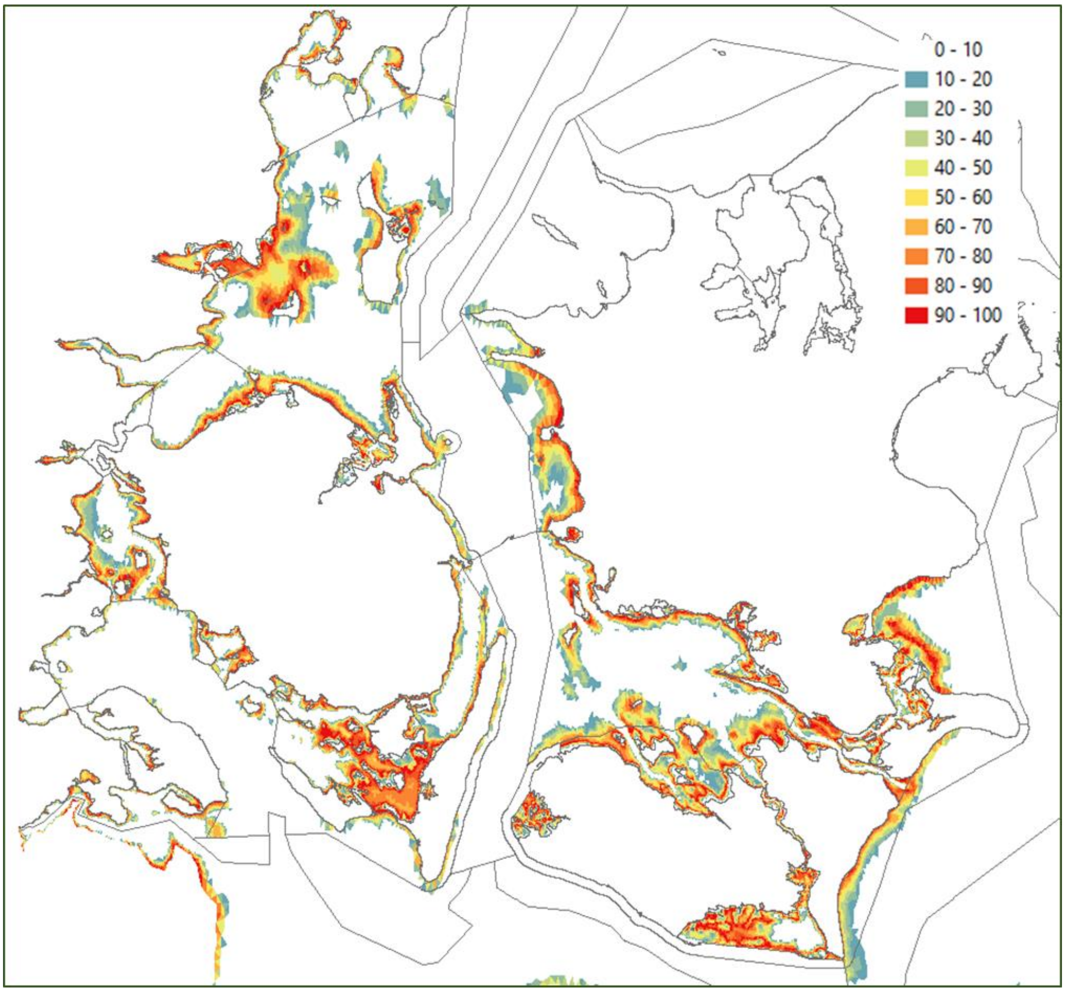

Figure 3-9 Eelgrass biomass maps (g C m^{-2}) in the three local models (Northern Belts Sea model, Southern Belt Sea model and Smålandsfarvandsmodel) as well as Odense Fjord applied as initial fields in the reference scenario.

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