AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

DTU

DHI

Application of the Danish EPA's Marine Model Complex and Development of a Method Applicable for the River Basin Management Plans 2021-2027

Management Scenario 2a – Land-based nutrient scenarios (basis period 1997-2001)

Miljø- og Fødevareministeriet
Miljøstyrelsen

Technical Note
October 2021

The expert in **WATER ENVIRONMENTS**

Application of the Danish EPA's Marine Model Complex and Development of a Method Applicable for the River Basin Management Plans 2021-2027

Management Scenario 2a – Land-based nutrient scenarios (basis period 1997-2001)

Prepared for	Danish EPA (Miljøstyrelsen, Fyn)
Represented by	Mr Harley Bundgaard Madsen, Head of Section

Eelgrass in Kertinge Nor
Photo: Peter Bondo Christensen

Authors	Anders Chr. Erichsen (DHI), Karen Timmermann (DTU), Trine Cecilie Larsen (DHI), Jesper Christensen (AU), Sophia Elisabeth Bardram Nielsen (DHI) & Stiig Markager (AU)
Quality supervisor	Mads Birkeland (DHI), Nikolaj Reducha Andersen (AU) & Signe Jung-Madsen (DCE)

Project number	11822953
Approval date	29-10-2021
Classification	Open

DHI • Agern Allé 5 • • DK-2970 Hørsholm • Denmark
Telephone: +45 4516 9200 • Telefax: +45 4516 9292 • dhi@dhigroup.com • www.dhigroup.com

Preface

This report is commissioned and funded by the Danish Environmental Protection Agency (EPA). The data, methods and results included in the report are intended to 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 AU/DCE. During the project, a steering committee followed the development, and was involved through dialogue and follow-up on progress, etc. The steering committee consisted of members from the Danish Ministry of Environment and Food (MFVM), the Danish EPA (MST), DHI and AU.

In addition, a follow-up group consisting of members from The Danish Agriculture & Food Council, SEGES, Sustainable Agriculture (BL), the Danish Society for Nature Conservation, the Danish Sports Fishing Association, Danish Fishermen PO (DFPO), the Danish Ports, and KL/municipalities was 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 have been solely AU's and DHI's decision and responsibility. A draft version of this report has been reviewed by MST and the follow-up group.

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

DHI

CONTENTS

FIGURES

TABLES

APPENDICES

1 Introduction

When preparing the Danish River Basin Management Plans 2015-2021 (RMBP 2015-2021), DHI and Aarhus University (AU) developed a number of mechanistic (DHI) and statistical (AU) models that were used for calculating chlorophyll-a target values defining the threshold (GM) between ‘Good Ecological Status’ (GES) and ‘Moderate Ecological Status’. The models were also used for calculating Maximum Allowable Inputs (MAIs) of total nitrogen (N) from Danish catchments based on the GM threshold value and a proxy for eelgrass depth limit. Hence, the development aimed at both the model development and the development of a method for calculating the MAIs.

As part of the political, regulatory package ‘The Food and Agriculture Agreement from 2015’ an international evaluation of the procedures used in the RBMP 2015-2021 was conducted. The evaluation was finalised autumn 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 research and development projects (R&D) projects with the overall aim of developing methods to calculate robust, transparent and differentiated chlorophyll-a reference values (and corresponding GM values) and MAIs in as many water bodies as possible for implementation into the RBMP 2021-2027.

Two central R&D projects relate to the continued model development in the assessment of reference chlorophyll-a values (and corresponding target values) and final MAI calculations. Other projects support different aspects of the final MAI calculations, but here we focus on the following two central R&D projects:

- ‘Recommendations for the continued development of models and methods for use in the River Basin Management Plan 2021-2027. Follow-up on the international evaluation of marine models behind the River Basin Management Plan 2015-2021’ (Erichsen & Timmermann 2018)
- ‘Application of the Danish EPA’s Marine Model Complex and Development of a Method Applicable for the River Basin Management Plans 2021-2027’.

The outcome of the above research projects is a set of MAIs based on a range of scenarios reflecting different assumptions regarding future developments in nutrient loading from neighbouring countries and the atmosphere as described in Erichsen *et al.* 2020. In the present technical note, the assumptions and input data behind management scenario 2a and corresponding results are described. In management scenario 2a, it is assumed that neighbouring countries have had the same percentage of land-based nitrogen reduction as Denmark when Danish water bodies have reached GES. The reduction percentage is relative to the basis period 1997-2001**.**

2 Preconditions for MAI Calculations

The Danish MAIs will, among other things, also depend on future loadings from neighbouring countries and atmospheric N-depositions as described in more detail in Erichsen *et al.* 2020. In addition, some water bodies may also respond to Danish land-based P loadings, which is why one set of Danish land-based N-MAIs corresponds to a set of Danish land-based P-MAIs.

In order to calculate a set of Danish land-based N-MAIs with the developed models, we need to make assumptions on future loadings and management strategies from neighbouring countries (management scenarios), and Danish land-based P loadings.

With respect to reductions in neighbouring countries, the Danish EPA has defined a set of preconditions to be used for constructing management scenarios defining potential developments in future non-Danish land-based loadings and atmospheric deposition. For each scenario, Danish land-based N-MAIs are calculated based on 0%, 10%, 20%, 30% and 50% Danish land-based P reductions, respectively.

In this technical note, we have not assessed the feasibility of the scenarios defined by the Danish EPA, but solely provided N-MAIs that will ensure that the targets are reached given that the preconditions related to nutrient loading from other countries, atmospheric N deposition and P loading from Danish catchments are fulfilled.

2.1 Management Scenario Definitions

As mentioned above, the Danish EPA has defined a set of assumptions regarding nutrient inputs from other countries and the atmosphere to be used as preconditions for the Danish land-based N-MAI calculations. The preconditions are grouped into three management scenarios and one scenario related to the interpretation of the Water Framework Directive (WFD-scenario). The different assumptions are described in general terms in Erichsen *et al.* 2020, whereas the present technical note describes management scenario 2a in more detail (also see 'bold' description below).

2.1.1 Management Scenario 2

The second group of scenarios encompasses alternative preconditions for the land-based loadings from neighbouring countries that are not based on adopted treaties. The assumptions include:

a) **Neighbouring countries are assumed to have had the same percentage of nutrient reduction as Denmark when Danish land-based N-MAIs are reached. The reduction percentage is relative to the basis period 1997-2001.**

b) Neighbouring countries are assumed to have the same area-specific anthropogenic loadings (kg/ha) as Denmark when Danish N-MAIs are reached.

c) Loadings from neighbouring countries are unchanged compared to the present-day loadings (2014-2018).

d) Danish land-based N-MAIs assuming updated BSAP targets. A new set of targets is being developed in HELCOM and will be adopted by the end of 2021.

e) Additional Wadden Sea P-reductions[1]

[1] This scenario is in addition to what has been reported in previous technical notes (e.g. Erichsen *et al.* 2020) and is a supplement to the series of management scenarios.

For the above five sub-scenarios, the atmospheric deposition will be kept as described in management scenario 1, i.e. full implementation of the NEC-directive with respect to atmospheric N-deposition (see Erichsen *et al.* (2020) for details).

2.1.2 Method

The background for this scenario is an assumed precondition where every country reduces their individual N loadings by 1% every time Denmark reduces by 1%. The starting point for the calculations is the basis period 1997-2001, and the scenario will correspond to an overall equal reduction needed in Denmark and all neighbouring countries to ensure GES in all Danish water bodies.

The calculation of Danish MAIs is carried out for each individual water body, but the overall reductions (in tons N) are summed and compared to the national average annual loads 1997-2001 and recalculated into a percentual reduction which is then compared to the reductions obtained in neighbouring countries. In practice this is done by reducing land-based N-loadings from neighbouring countries between 5-45% (with steps of 1%) relative to the current loading, calculate the corresponding N-MAI from Danish catchments and then identify when the nutrient reduction in percentages (relative to 1997-2001) in Denmark and other countries are identical. Hence, when the Danish MAI (in % reduction on national scale) equals to the nutrient reductions (in %) from neighbouring countries, this reduction corresponds to the resulting MAI from scenario 2a.

The data behind the present scenario is described in section 2.1.3, whereas an update of the model results is described in section 0.

2.1.3 Scenario Loadings

The full overview of the scenario reductions applied for management scenario 2a in other countries than Denmark, and atmospheric depositions are summarised in Table 2-1, and explained briefly in the following sections.

Present-Day Loadings

Concerning management scenario 2a the present-day loadings to the Baltic Sea and the North Sea from all other countries than Denmark are applied.

These loadings correspond to the loadings included in the calibration and validation of the mechanistic models and are described in more detail in Erichsen & Birkeland (2020).

When comparing present-day (2014-2018) N loadings to 1997-2001 loadings, we find that Denmark has reduced N-loadings by 19%, Baltic Sea countries (Baltic Proper and Danish Straits) have reduced by 28%, while Germany has reduced N-loadings to the German Bight by 40% in the same period. The data behind those estimates are based on actual yearly loadings for the period 2014-2017/2018 and can be extracted from HELCOM (Long-term-trends-of-nitrogen-and-phosphorus-inputs-since-1995.pdf (helcom.fi)) and Beusekom *et al.* (2019).

NEC-Directive

According to Blicher-Mathiesen & Sørensen (2020), the reductions in atmospheric N deposition after full implementation of the NEC-directive altogether amount to 16% or a 10% reduction in 2027, if the different countries' predictions are implemented. The full reduction of 16% is used for management scenarios 1 and 2, whereas the prediction of 10% reduction is used for management scenario 3a (see Erichsen *et al.* 2020 for details).

Data are delivered by AU, and the reductions are resolved on an overall water body scale and implemented in the Danish land-based N-MAIs calculations (see Figure 2-1 for data).

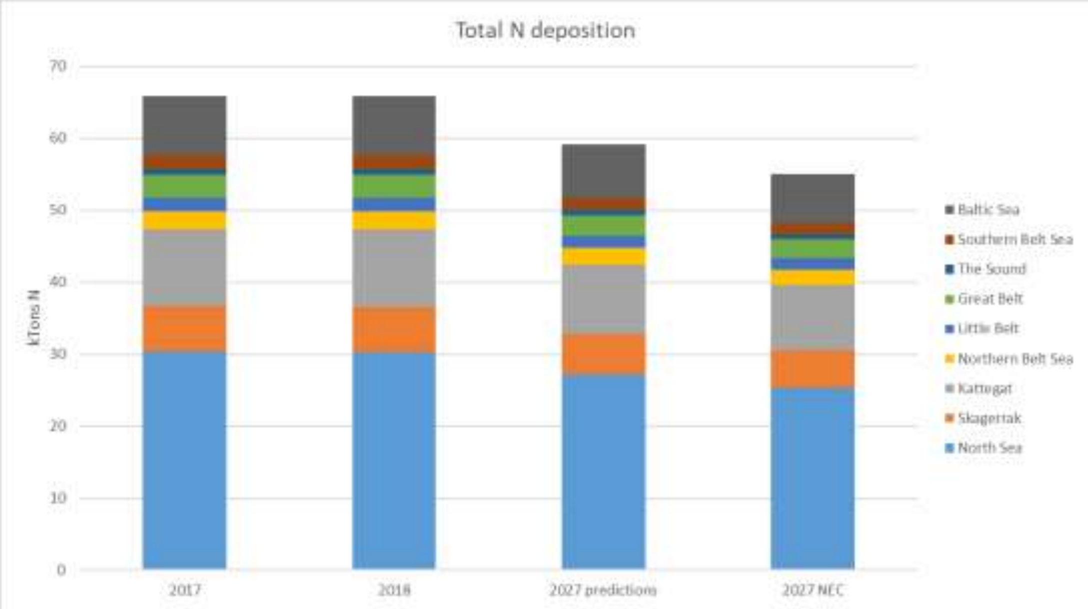

Figure 2-1 Atmospheric N deposition to the total surface of Danish Exclusive Economic Zone (EEZ) and summarised at overall water body level. '2017' and '2018' represent present-day atmospheric N-depositions whereas '2027 NEC' represents agreement behind the directive, and '2027 predictions' represent the different country prognosis.

Table 2-1 Overview of input data used to construct management scenario 2a.

Danish water areas affected	N load reduction in management scenario 2a. Reductions are in % of current (2014-2018) load	P load reduction applied in management scenario 2a. Reductions are in % of current (2014-2018) load	Adopted treaties
Western Baltic Sea (Light blue area, Figure 2-1)	5-45% (steps of 1%)	27%	Effect of BSAP to DS and BAP
Great belt and Kattegat (dark blue area, Figure 2-1)	5-45% (steps of 1%)	27%	Effect of BSAP and German RBMP, using Helcom allocation scheme
Southern Little Belt (yellow area, Figure 2-1)	5-45% (steps of 1%)	27%	Effect of German RBMP
North Sea water bodies and Limfjorden (brown area, Figure 2-1)	5-45% (steps of 1%)	0%	Effect of German RBMP
Atmospheric deposition, all Danish water bodies	16%	0%	NEC directive

2.2 Method for Calculating Danish N-MAI

Based on the assumed future load reductions from neighbouring countries and atmospheric deposition as described above, N-MAIs from Danish catchments to each of the 109 water bodies is calculated. This is based on the status value of the indicators in each water body, as well as a defined target value (*Erichsen & Birkeland 2020b*). The status values for the two indicators are based on measurements. Target values are defined as a "slight deviation from reference conditions", where reference conditions refer to a state with minimal human influence. Based on the method described in richsen *et al*. (2020), each target value will have a MAI which will support the system to achieve GES.

Since all Danish water bodies are connected to a higher or lesser degree, the reduction needed for a single water body cannot be assessed in isolation. In addition, it is necessary to consider the load reduction requirement estimated for nearby water bodies. To account for connected water bodies, the following scheme was applied:

1) Catchments are assigned to each water body. Local catchments are assigned to the inner part (sub-catchments) of estuaries (upstream water bodies), whereas two or more local catchments (main-catchments) are assigned for downstream water bodies (e.g. the outer part of estuaries) and more open water bodies.

2) Load reductions (in %) for each individual water body are calculated as described in Erichsen *et al.* (2020) and transformed into a N-reduction requirement in tons using the load of the assigned catchment.

3) For up-stream water bodies (with local catchments) the calculated reduction is a minimum requirement that should be obtained independently of downstream waterbody requirements.

4) Reduction requirements for downstream water bodies are corrected, considering any minimum reduction handled by up-stream water bodies.

5) Reduction requirements are transformed into MAIs by subtracting the required load reduction from the average annual load and aggregated to the corresponding local and/or regional catchment.

2.3 Results

Based on the above-described assumption (implementation of the Baltic Sea Action Plan, German nutrient reductions according to RBMP 2015-2021, additional Wadden Sea P-reduction and reductions in atmospheric N deposition according to the NEC directive) the different reduction requirements and corresponding MAIs are calculated.

In Figure 2-2 the results of the different nutrient reductions from neighbouring countries (5-45% of current loading which is equivalent to 31%- 57% of the 1997-2001 loading) and the corresponding Danish MAIs (in % reduction relative to 1997-2001 Danish loading) are pictured (blue curve). From the figure it can for example be seen that a 40% reduction in loading from neighbouring countries requires a 52% reduction in Danish loadings for reaching GES.

It can also be seen from Figure 2-2 that the blue curve and the line where Danish reductions equals neighbouring reductions (red line) has an intercept at approximately 50% reduction,

Hence, the result from the present scenario shows that an overall nutrient load reduction of 50% (relative to 1997-2001) from both Denmark and neighboring countries will provide GES in Danish water bodies.

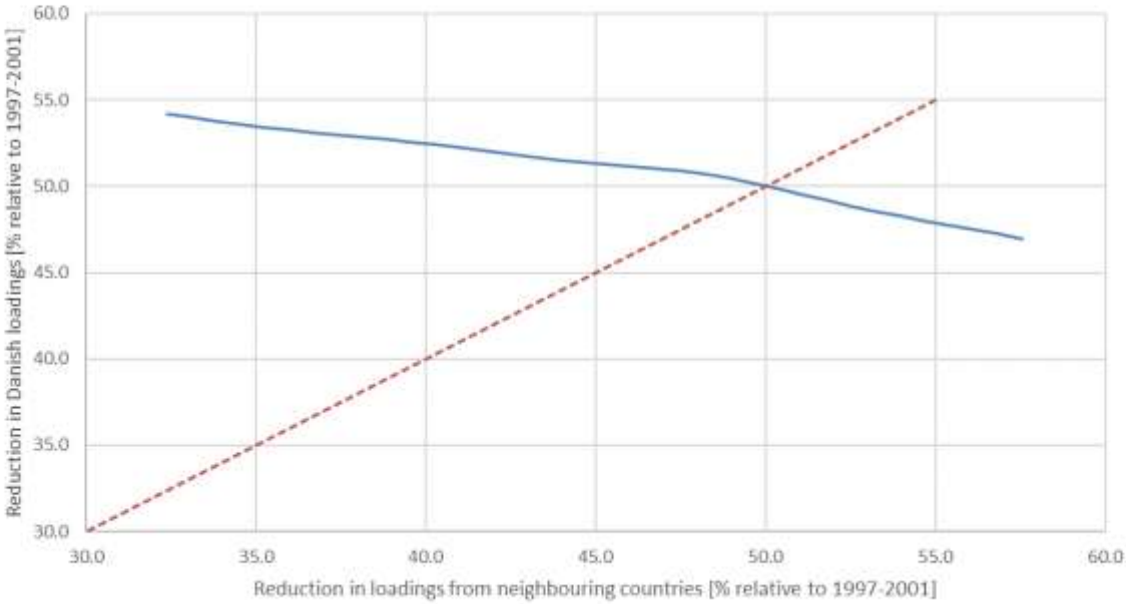

Figure 2-2 Overall Danish nutrient load reductions necessary to reach GES in Danish water bodies as a function of reductions in neighbouring countries (blue curve). All reductions are relative (%) to the basis period 1997-2001. Red curve is the x=y line (Danish load reductions equals neighbouring load reductions) and the intersection of the curves shows when the Danish reductions necessary to reach GES equals the reduction in loadings from neighbouring countries.

An overall Danish nutrient load reduction of 50% relative to the basis period 1997-2001 correspond to a load reduction of approximately 38% relative to present days loadings. For neighbouring countries, a load reduction of 50% relative to 1997-2001 corresponds to a load reduction of 30% relative to present days.

The different reduction requirements (%-wise and in actual tons) based on the different indicators and different models are included in Appendix A, whereas the aggregated MAIs are reported in Table 2-2.

Table 2-2 Maximum Allowable Nitrogen Inputs (N-MAIs) for Danish water bodies given present-day loadings from neighbouring countries and reductions in atmospheric N deposition according to the NEC directive.
The table shows N-MAIs in tons N per year, where 'main' denotes main-catchment, and 'sub' denotes sub-catchments being part of a main-catchment. The table shows average annual loads and N-MAIs calculated for 1 specific phosphorus reduction scenario designated P0, where phosphorus loadings from Danish catchments are reduced by 0%. The column 'aggregated' denotes sub-catchments included in specific MAIs.

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
1	Roskilde Fjord, ydre	1,2		764		559
2	Roskilde Fjord, indre	2		388		380
6	Nordlige Øresund	6	1,098		1,098	
16	Korsør Nor	16		40		30
17	Basnæs Nor	17		69		50
18	Holsteinborg Nor [c)]	18		22		22
24	Isefjord, ydre	24,165		899		588
25	Skælskør Fjord og Nor	25		44		36
28	Sejerø Bugt	28	164		159	
29	Kalundborg Fjord	29	69		40	
34	Smålandsfarvandet, syd [c)]	34	523		523	
35	Karrebæk Fjord	35		1,272		1,005
36	Dybsø Fjord	36		61		61
37	Avnø Fjord	37		238		184
38	Guldborgsund [c)]	38	419		419	
44	Hjelm Bugt	44	91		91	

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
45	Grønsund	45	278		186	
46	Fakse Bugt	46,47	509		444	
47	Præstø Fjord	47		208		142
48	Stege Bugt [c)]	48,49	259		250	
49	Stege Nor	49		24		15
56	Østersøen, Bornholm	56	860		522	
57	Østersøen, Christiansø	57	3		2	
59	Nærå Strand	59		98		23
62	Lillestrand	62		11		6
68	Lindelse Nor	68		50		50
72	Kløven	72		43		43
74	Bredningen	74		128		44
80	Gamborg Fjord	80		80		65
82	Aborg Minde Nor	82		152		34
83	Holckenhavn Fjord	83		290		100
84	Kerteminde Fjord	84,85		50		40
85	Kertinge Nor	85		24		20
86	Nyborg Fjord	83,86		308		119
87	Helnæs Bugt	87		216		141

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
89	Lunkebugten	89		16		10
90	Langelandssund	83,86,89,90	768		573	
92	Odense Fjord, ydre	92,93		1,358		835
93	Odense Fjord, Seden Strand	93		1,288		764
95	Storebælt SV	95	188		115	
96	Storebælt NV	96, 84, 85	227		132	
101	Genner Bugt	101		35		13
102	Åbenrå Fjord	102		130		59
103	Als Fjord	103,104,105		269		115
104	Als Sund	104		68		68
105	Augustenborg Fjord	105		62		43
106	Haderslev Fjord	106		239		132
107	Juvre Dyb	107		349		119
108	Avnø Vig	108		60		26
109	Hejlsminde Nor	109		138		93
110	Nybøl Nor	110		66		43
111	Lister Dyb	111		2,155		877
113	Flensborg Fjord, indre	113		51		22
114	Flensborg Fjord, ydre	110,113,114		219		97

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
119	Vesterhavet, syd	119, 107, 111, 121, 120	8,538		2,883	
120	Knudedyb	120		2,910		841
121	Grådyb	121		2,920		842
122	Vejle Fjord, ydre	122,123		968		716
123	Vejle Fjord, indre	123		561		486
124	Kolding Fjord, indre	124		493		224
125	Kolding Fjord, ydre	124,125		528		259
127	Horsens Fjord, ydre	127,128		833		446
128	Horsens Fjord, indre	128		782		421
129	Nissum Fjord, ydre	129,131,130		2,412		1,079
130	Nissum Fjord, mellem	130,131		2,083		750
131	Nissum Fjord, Felsted Kog	131		1,938		1,300
132	Ringkøbing Fjord	132		4,748		2,465
133	Vesterhavet, nord	133,129,130 ,131, 132	7,237		3,622	
136	Randers Fjord, indre	136		2,925		2,201
137	Randers Fjord, ydre	136,137		3,078		2,137
138	Hevring Bugt	138, 137, 136	3,235		2,294	

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
139	Anholt [c)]	139	9		9	
140	Djursland Øst	140	856		590	
141	Ebeltoft Vig [c)]	141	14		14	
142	Stavns Fjord	142		5		4
144	Knebel Vig	144		18		14
145	Kalø Vig	144,145		190		185
146	Norsminde Fjord	146		140		93
147	Århus Bugt og Begtrup Vig	144,145,147	656		601	
154	Kattegat Læsø [c)]	154	78		78	
157	Bjørnholms Bugt, Riisgårde Bredning, Skive Fjord og Lovns Bredning	157,158		3,632		1,280
158	Hjarbæk Fjord	158		1,795		537
159	Mariager Fjord, indre	159		516		142
160	Mariager Fjord, ydre	159,160		963		589
165	Isefjord, indre	165		812		501
200	Kattegat Nordsjælland	1,2,24,165,200	1,857		1,342	
201	Køge Bugt	201	1,109		995	
204	Jammerland Bugt og Musholm Bugt	204	1,327		818	

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
206	Smålandsfarvandet, åbne del	16,17,18,25,35,36,37,206	2,014		1,656	
207	Nakskov Fjord	207		454		384
208	Femerbælt	207,208,209	1,530		1,196	
209	Rødsand og Bredningen	209		521		315
212	Fåborg Fjord	212		30		20
214	Det sydfynske Øhav	68,72,212,214	633		228	
216	Lillebælt, syd	87,101,102,103,104,105,110,113,114,216	1,309		867	
217	Lillebælt Bredningen	74,82,106,108,109,217	956		375	
219	Århus Bugt, syd, Samsø og Nordlige Bælthav	59,62,92,93,127,128,142,146,219	2,810		1,718	
221	Skagerrak	221	1,423		1,423	
222	Kattegat Ålborg Bugt [c)]	222,159,160	2,026		1,652	
224	Nordlige Lillebælt	122,123,224	1,588		988	
225	Nordlige Kattegat Ålbæk Bugt	225	706		684	

No.	Name	Aggregation	Average annual (main)	Average annual (sub)	P0 (main)	P0 (sub)
231	Lillebælt Snævringen	231,124,125 ,80	789		259	
232	Nissum Bredning	232	880		470	
233	Kaas Bredning og Venø Bugt	232,233		1,955		1,124
234	Løgstør Bredning	157,158,234 , 233, 236		4,336		2,802
235	Nibe Bredning og Langerak	157, 158, 233, 234, 235, 236, 238	11,064		6,858	
236	Thisted Bredning	236		1,091		378
238	Halkær Bredning	238		620		114
	Danish N-load ***(National MAI)***		58,100		36,173	

[c] Chlorophyll-a and light 'good-moderate' target obtained based on measurement (and not dependent on reductions from neighbouring countries or atmospheric depositions

2.4 Closing Remarks

The estimated Maximum Allowable Nitrogen Input (N-MAI) to Danish water bodies presented in this report is based on the preconditions that the BSAP, the RBMP 2015-2021, additional Wadden Sea P-reductions (20% and 30%), and the NEC directive will be fully implemented. These treaties have been adopted but not yet fully implemented. These assumptions, which have not been assessed as part of this study, are accepted as preconditions.

If the preconditions are fulfilled, and the MAI for Danish water bodies is reached by the end of 2027, all Danish water bodies will most likely not have reached Good Ecological Status (GES) as defined in the WFD. This is because:

- The MAI estimation is based on the depth of light as a proxy for the indicator eelgrass depth limit. Hence, even if light has reached the target value, recovery of eelgrass after light improvements may take years to decades. In addition, other factors, such as sediment suitability, lack of seedlings, etc., may delay or prevent eelgrass recovery.

- With the given preconditions in management scenario 1, one or both of the indicators (chlorophyll-a and light) may not reach the target value despite reductions from Danish catchments. In these situations, the reduction requirement for that indicator is cut off/truncated at the reference loading. A cut-off at reference loading indicates that due to the scenario and associated preconditions, a specific MAI for that water body that ensures GES cannot be obtained, and administrative choices have to be made, like applying an average reduction from neighbouring water bodies, reductions to down-stream water bodies or a general MAI (kg/ha) for those water bodies. However, the implication is that GES for both indicators cannot be expected in these water bodies, even if MAI is obtained.

- The method is not based on the one-out-all-out principle as required in the WFD, but on an average of two indicators. Hence, it is expected that both indicators will be as close to the target value as possible, but one will theoretically be above and one below the target value.

- In this management scenario, we are using the boundary between good and moderate status as the target value for each of the indicators. Due to uncertainties, there is a 50% chance that the indicator value will end in good status and a 50% chance that the indicator value will end in moderate status, if MAI for that indicator is reached, assuming the measured indicator follows a symmetrical distribution.

- As some ecosystems respond with significant time-lags to changes in loadings, it will take years before the full environmental effects of nutrient reductions can be observed. Hence, reaching MAI will provide the conditions for obtaining GES but the achievement of GES will likely be delayed.

3 References

/1/ Blicher-Mathiesen G & Sørensen P (red) (2020). Baseline 2027 for udvalgte elementer. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 120 s. - Teknisk rapport nr. 184 http://dce2.au.dk/pub/TR184.pdf

/2/ COWI (2018). Nabotjek af EU-landes fremgangsmåder ved planlægning for marine vandområder i henhold til Vandrammedirektivet. Komparativ rapport. COWI rapport.

/3/ Erichsen AC (Ed.), Timmermann K (Ed.), Birkeland M, Christensen JPA, Markager S, Møhlenberg F. (2018) Recommendations for continued development of models and methods for use in the River Basin Management Plan 2021-2027. Follow-up on the international evaluation of marine models behind the River Basin Management Plan 2015-2021. Technical report. DHI.

/4/ Erichsen AC, Birkeland M, Timmermann K, Christensen J & Markager S (2020). Application of the Danish EPA's Marine Model Complex and Development of a Method Applicable for the River Basin Management Plans 2021-2027. Conceptual Method for Estimating Maximum Allowable Inputs. Technical report. DHI.

/5/ Erichsen AC, Birkeland M (2020a). Development of Mechanistic Models – Short Technical Description of Biogeochemical Model Input Data. Technical report. DHI.

/6/ Erichsen AC, Birkeland M (2020b). Methods for establishing Chlorophyll-a references and target values applicable for the River Basin Managements Plan 2021-2027. Technical report. DHI.

/7/ Gadegast M & Venohr M (2015). Modellierung Historischer Nährstoffeinträge und -Frachten zur Ableitung von Nährstoffreferenz – und Orientierungswerten für Mitteleuropäische Flussgebiete. Technical Report

/8/ Herman P, Newton A, Schernewski G, Gustafsson B, Malve O (2017) International Evaluation of the Danish Marine Models, Danish EPA.

Appendix A – Maximum Allowable Nitrogen Inputs (N-MAIs) based on management scenario 2a and assuming 0% reduction in Danish land-based P-loads

Table A- 1 Water body-specific MAIs based on the two individual indicators chlorophyll-a (Chl-a) and light penetration depth (light) estimated from statistical models (STAT) and mechanistic models (MEK), respectively.
The table shows both the individual calculations and the averaged water-specific MAIs (without any aggregation) and the corresponding need for reduction in %. The data in this table are based on Management scenario 2a and Danish land-based P-reductions set at 0%.

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
1	Roskilde Fjord, ydre	1,2	764			668	451		559	559	27
2	Roskilde Fjord, indre	2	388	388		388	355	388	371	380	2
6	Nordlige Øresund	6	1,098			1,098	1,098		1,098	1,098	0
16	Korsør Nor	16	40			40	20		30	30	25
17	Basnæs Nor	17	69			69	31		50	50	28
18	Holsteinborg Nor[c)]	18	22			22	22		22	22	0
24	Isefjord, ydre	24,165	899	574	833	616	861	703	738	721	20
25	Skælskør Fjord and Nor	25	44			36	37		36	36	17
28	Sejerø Bugt	28	164			164	153		159	159	3
29	Kalundborg Fjord	29	69	13	40	35	69	27	52	39	43
34	Smålandsfarvandet, syd	34	523			523	523		523	523	0
35	Karrebæk Fjord	35	1,272			1,272	737		1,005	1,005	21
36	Dybsø Fjord	36	61			61	61		61	61	0
37	Avnø Fjord	37	238			238	129		184	184	23
38	Guldborgsund	38	419			419	419		419	419	0
44	Hjelm Bugt	44	91			91	91		91	91	0
45	Grønsund	45	278			278	94		186	186	33

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
46	Fakse Bugt	46,47	509			509	509		509	509	0
47	Præstø Fjord	47	208			147	137		142	142	32
48	Stege Bugt	48,49	259			259	259		259	259	0
49	Stege Nor	49	24			18	11		15	15	38
56	Østersøen, Bornholm	56	859			184	860		522	522	39
57	Østersøen, Christiansø	57	3			0	3		2	2	48
59	Nærå Strand	59	98			24	22		23	23	77
62	Lillestrand	62	11			8	5		6	6	44
68	Lindelse Nor	68	50			50	50		50	50	0
72	Kløven	72	43			43	43		43	43	0
74	Bredningen	74	128			46	42		44	44	66
80	Gamborg Fjord	80	80			51	80		65	65	18
82	Aborg Minde Nor	82	152			34	34		34	34	78
83	Holckenhavn Fjord	83	290			81	120		100	100	65
84	Kerteminde Fjord	84,85	50			29	50		40	40	21
85	Kertinge Nor	85	24	22		23	13	22	18	20	15
86	Nyborg Fjord	83,86	308			152	267		210	210	32
87	Helnæs Bugt	87	216			67	216		141	141	35
89	Lunkebugten	89	16			5	16		10	10	34

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
90	Langelandssund	83,86,89,90	768			459	768		613	613	20
92	Odense Fjord, ydre	92,93	1,358	823	1,202	982	1,111	1,012	1,047	1,030	24
93	Odense Fjord, Seden Strand	93	1,288		683	1,288	402	683	845	764	41
95	Storebælt SV	95	188			41	188		115	115	39
96	Storebælt NV	96, 84, 85	227			38	227		132	132	42
101	Genner Bugt	101	35			13	13		13	13	62
102	Åbenrå Fjord	102	130	59		59	60	59	60	59	55
103	Als Fjord	103,104,105	269			67	163		115	115	57
104	Als Sund	104	68			68	68		68	68	0
105	Augustenborg Fjord	105	62	29		50	62	29	56	43	31
106	Haderslev Fjord	106	239			106	159		132	132	45
107	Juvre Dyb	107	349			119			119	119	66
108	Avnø Vig	108	60			31	22		26	26	56
109	Hejlsminde Nor	109	138			126	59		93	93	33
110	Nybøl Nor	110	66			40	46		43	43	35
111	Lister Dyb	111	2,155			878			878	878	59
113	Flensborg Fjord, indre	113	51	19		19	31	19	25	22	57
114	Flensborg Fjord, ydre	110,113,114	219	129		66	66	129	66	97	56

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
119	Vesterhavet, syd	119, 107, 111, 121, 120	8,538			3,934			3,934	3,934	54
120	Knudedyb	120	2,910	841		841		841	841	841	71
121	Grådyb	121	2,920			842			842	842	71
122	Vejle Fjord, ydre	122,123	968			465	968		716	716	26
123	Vejle Fjord, indre	123	561	525	432	522	466	478	494	486	13
124	Kolding Fjord, indre	124	493	188		244	276	188	260	224	55
125	Kolding Fjord, ydre	124,125	528			278	372		325	325	38
127	Horsens Fjord, ydre	127,128	833			496	395		446	446	47
128	Horsens Fjord, indre	128	782			404	439		421	421	46
129	Nissum Fjord, ydre	129,131,130	2,412			1,357	1,016		1,186	1,186	51
130	Nissum Fjord, mellem	130,131	2,083			898	601		750	750	64
131	Nissum Fjord, Felsted Kog	131	1,938	1,938		662	662	1,938	662	1,300	33
132	Ringkøbing Fjord	132	4,748		1,679	4,748	1,756	1,679	3,252	2,465	48
133	Vesterhavet, nord	133,129,130 ,131, 132	7,237			7,237			7,237	7,237	0
136	Randers Fjord, indre	136	2,925	2,925	1,477	2,925	1,477	2,201	2,201	2,201	25
137	Randers Fjord, ydre	136,137	3,078	3,078	1,196	3,078	1,196	2,137	2,137	2,137	31
138	Hevring Bugt	138, 137, 136	3,192		3,235	3,062	3,235		3,149	3,149	1

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
139	Anholt [c)]	139	9			9	9		9	9	0
140	Djursland Øst	140	856			323	856		590	590	31
141	Ebeltoft Vig	141	14			14	14		14	14	0
142	Stavns Fjord	142	5			5	2		4	4	31
144	Knebel Vig	144	18			10	18		14	14	23
145	Kalø Vig	144,145	190	190	190	190	190	190	190	190	0
146	Norsminde Fjord	146	140			140	47		93	93	33
147	Århus Bugt og Begtrup Vig	144,145,147	656	533	656	560	656	594	608	601	8
154	Kattegat Læsø	154	78			78	78		78	78	0
157	Bjørnholms Bugt, Riisgårde Bredning, Skive Fjord og Lovns Bredning	157,158	3,632			992	1,568		1,280	1,280	65
158	Hjarbæk Fjord	158	1,795			426	648		537	537	70
159	Mariager Fjord, indre	159	516			84	200		142	142	73
160	Mariager Fjord, ydre	159,160	963			783	515		649	649	33
165	Isefjord, indre	165	812	393		408	812	393	610	501	38
200	Kattegat Nordsjælland	1,2,24,165,200	1,857			1,857	1,674		1,765	1,765	5
201	Køge Bugt	201	1,109	881		1,109	1,109	881	1,109	995	10
204	Jammerland Bugt og Musholm Bugt	204	1,327			1,327	308		818	818	38

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
206	Smålandsfarvandet, åbne del	16,17,18,25,35,36,37,206	2,014			2,014	1,558		1,786	1,786	11
207	Nakskov Fjord	207	454			433	334		384	384	15
208	Femerbælt	207,208,209	1,530			861	1,530		1,196	1,196	22
209	Rødsand og Bredningen	209	521			281	348		315	315	40
212	Fåborg Fjord	212	30			10	30		20	20	33
214	Det sydfynske Øhav	68,72,212,214	633	176	323	176	238	250	207	228	64
216	Lillebælt, syd	87,101,102,103,104,105,110,113,114,216	1,309			462	1,309		885	885	32
217	Lillebælt Bredningen	74,82,106,108,109,217	956	276		276	675	276	475	376	61
219	Århus Bugt, syd, Samsø og Nordlige Bælthav	59,62,92,93,127,128,142,146,219	2,810			626	2,810		1,718	1,718	39
221	Skagerrak	221	1,423			1,423			1,423	1,423	0
222	Kattegat Ålborg Bugt	222,159,160	2,026			2,026	2,026		2,026	2,026	0
224	Nordlige Lillebælt	122,123,224	1,588			389	1,588		988	988	38
225	Nordlige Kattegat Ålbæk Bugt	225	706			662	706		684	684	3

No.	Name	Aggregation	Average annual N-load	Chl-a (STAT)	Light (STAT)	Chl-a (MEK)	Light (MEK)	N-MAI (STAT)	N-MAI (MEK)	Avg. MAI	Avg. reduction [%]
231	Lillebælt Snævringen	231,124,125 ,80	789		134	134	145	134	140	137	83
232	Nissum Bredning	232	880	297	603	297	682	450	490	470	47
233	Kaas Bredning og Venø Bugt	232,233	1,955			1,450	798		1,124	1,124	43
234	Løgstør Bredning	157,158,234 , 233, 236	6,501			1,980	3,623		2,801	2,801	57
235	Nibe Bredning og Langerak	157, 158, 233, 234, 235, 236, 238	11,064		9,754	2,978	9,734	9,754	6,356	8,055	27
236	Thisted Bredning	236	1,091			269	487		378	378	65
238	Halkær Bredning	238	620			114	114		114	114	82