SEGES INNOVATION

RAPPORT

Published 1 June 2023

Ecosystem functionality and water management in Danish coastal waters

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Introduction

The water environment in Danish coastal waters have since the 1980s been high on the political agenda. The first national actions plan was the “NPO action plan”, a plan against water pollution with focus on nitrogen (N), phosphorus (P) and organic matter (O), adopted by the Danish Parliament in 1986. The action plan was based on a report by the Danish Environmental Protection Agency in 1984, the NPO action plan included both wastewater from housing, industry, and aquaculture as well as pollution from agriculture.
Due to oxygen depletions in the coastal waters, it was decided in 1987 to implement the first “Water Environment Plan” (VMP I). The P-load from wastewater was to be reduced by 80 per-cent, and N-loads from agricultural fields, by 50 percent. It required extensive investment. Cities and companies had to expand the treatment plants so that they could meet the new demands and agriculture had to invest and adopt to new regulation concerning use of manure and mineral fertilizer. In order to reach the 50% reduction target for agricultural nitrogen, the requirements were tightened with Water Environment Plan II (VMP II) in 1998. This includes further re-strictions on the use of nitrogen in the agriculture. At the end of 2000, a mid-term evaluation of the water environment plans showed a noticeable decrease in the leaching of nitrogen but not enough to reach the 50% target. In 2004 a third Water Environment Plan III (VMP III) was implemented but this decision was made even though the 50% targets was achieved according to a final evaluation in 2003 concerning the 50% goal. The evaluation showed that annual nitrate leaching from the root zone under agricultural land had been reduced by 48%, but achieving this goal was not the same as achieving a good status in the coastal waters.

With the implementation of the Water Frame Directive (WFD) a new paradigm for water management was introduced. Instead of focusing on nitrate leaving the rootzone the focus now was on biological quality elements in the water bodies. This introduces potentially more complexity in the water management including ecosystem functionality in the coastal waters, multi press factors, nutrient loss and transport from the catchment as well as a more diverse use of different measures to reduce N and P to coastal waters.

Nutrient reduction to coastal waters

The different action plans had a significant effect on the N- og P-loads to coastal water during the late 1980s and up until around 2000 concerning P-loads and around 2010 concerning N-loads (fig1). Since 2000 the P-loads have been more or less constant but with a small decrease from point sources while diffuse P have been constant. N-loads have been more or less constant in the range of 50,000 to 60,000 tonnes from 2010 (ref1).

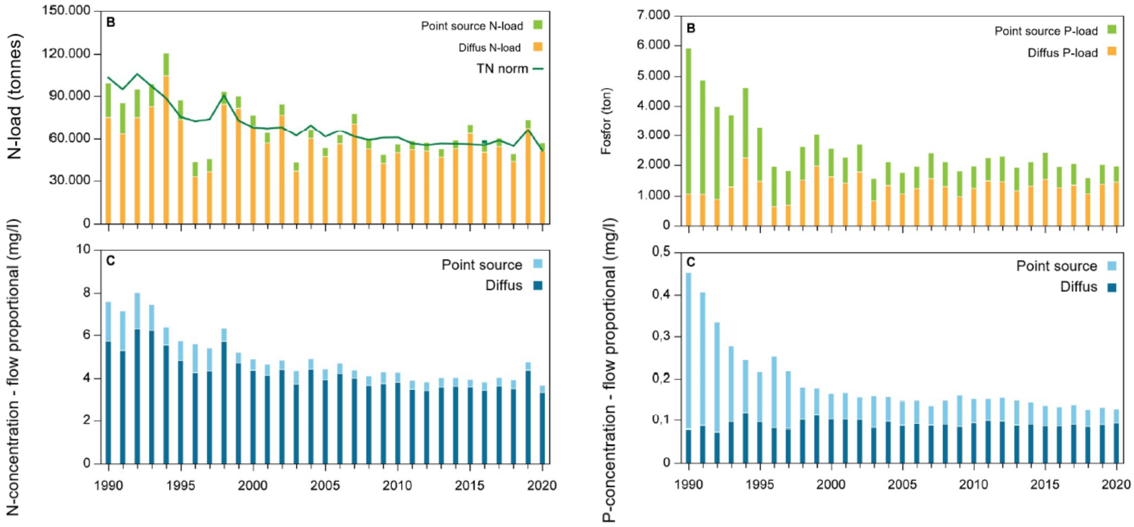

Fig1. Yearly N- and P-load to Danish coastal waters. Upper in tonnes and lower in flow proportional concentration. Modified to English after ref1.

Danish regulation

P-reductions have been almost entirely due to reductions in point sources. The P regulation for agriculture did only include P-surplus on the fields but lowering the surplus have had no or minor effect on the diffuse P loss to the coastal waters. The main P diffuse sources - riverbank erosion, field draining, organic rich low land soils and surface run off from fields (Ref2) - have never been targeted in the regulation except for 2 m mandatory buffer zones. The constructed wetland program aiming to reduce N from drained fields are not only reducing N but also reducing P losses, but the P effect is not implemented in the RBMP due to the “only N focus” line in RBMPIII.
N-reductions have been achieved by several regulation initiatives like mandatory green winter fields, mandatory catch crops, mandatory spread of manure in the spring, mandatory accounting and regulation of mineral fertilizer and manure. The last properly the most important resulting in an almost 50% reduction in the use of mineral fertilizer (ref3). Also, wetland restoration to reduce N to coastal waters have been a national program since late 1990s and more than 20.000 ha have been restored.
The mainly mandatory N-regulation approach have been a success during the 1990s and up until 2010. Hereafter it has been difficult to further reduce the N-load with the same measures. The N-load reduction was achieved through legislation to the farmer and not by farmer initiatives. A consequence of this is that the farmer and the agriculture advisory system, assisting farmers in Denmark with crop and field planning, have never been engaged in reducing nutrient losses more than just fulfilling the legislation.
From the first “NPO action plan” in the mid-1980s the focus from the political level, from authorities and from scientists gradually went from both N, P and O to mainly focus on only N concerning the

coastal waters. This is seen in the Water Environment Plan II and III from 1998 and 2004 and from the three RBMP I-III.

Scientific paradigm behind the Danish regulation

Together with “Water Environment Plan” an 85 Mio DKK research program for marine and coastal waters was established (HAV-90) with the goal to further strengthen and integrate the knowledge from marine biology, physical processes, and oceanography and to evaluate the “Water Environment Plan”. The program was running from 1988-1992. The program produced 60 reports in Danish, more than 150 peer review papers and more than 40 PHDs (ref4). One of the outcomes from the work was that it was confirmed that N plays a centrale role for the eutrophication of the Danish coastal waters but also P plays a role, and the Danish waters are a complex eco system.
Despite the increased knowledge of the complex biologically and oceanographically system of the Danish coastal waters it was decided to use a simple tool in the first RBMPI to calculate the N-reduction targets to the costal water bodies. The tool – called “The eelgrass tool” – was basically two relations: 1) a relation between N-loads from a catchment and a N-concentration in the downstream estuary and 2) a relation between N-concentration in the estuary and the eelgrass depth limit. The second relation was based on a peer reviewed paper (ref5) but the problem with the relation was that it was based upon “geographically distributed relations”, and it was later demonstrated that it was not possible to get the same relations for specific estuaries distributed in time instead of geographically: “The relationship between nitrogen concentrations and eelgrass, on the other hand, is far more complicated, site-specific, and probably non-linear. The reestablishment of the eelgrass under lower TN concentrations probably follows a completely different trend and link to the nutrient level than the trend during the period of strong eutrophication, and there may be a delayed effect of the slow recolonization. In certain areas, there may be feedback from the lack of eelgrass with a high resuspension of sediments, which will continue to prevent the eelgrass from re-establishing itself.” (ref6).
With “the eelgrass tool” the N-reduction was calculated to be 28,000 tonnes (ref7) corresponding to a MAI (Maximum allowable Input) of approx. 32,000 tonnes (60,000-28,000). That was later reduces with a national political deal in the “Green Growth” (Grønvækst, ref8) from 28,000 tonnes to 19,000 tonnes corresponding to a MAI of approx. 41,000 tonnes and also including a 210 tonnes P reduction corresponding to an approx. 10% P reduction.
A national work was done in 2011 to review eelgrass as an indicator and the “the eelgrass tool” (ref7) and in 2012 another national work was done to make recommendation for a better tool (Ref9). This led to include DHI and the MIKE modelsystem in the planning of the RBMPII and later RBMPIII.

SEGES comments to the Danish tradition for mainly N-focus

Since the “NPO action plan” in the 1980s there have been a drive towards only focus on N concerning the coastal waters. This have been both in the scientific community as well as by authorities, journalists and therefore also by decision markers. This have been to an extent where good coastal water environment has been the same as “N-reduction” in the public discussions. The problem with such a simple approach is that it leaves out other important bricks in the puzzle concerning restoring the complex coastal ecosystem (ref26). It is well known and well documented that P plays an important role in the spring for limiting algae growth – both in estuaries and in open waters (ref14). Also, necessary restorations tasks for eelgrass recovery where light conditions have been favorable (ref36) have not been included in the RBMPIII. Other press factors like fishery have been approached only minor even though its it well documented that fishery can have direct negative impact on eelgrass (ref37) and have a top-down cascade effect on the marine ecosystem. The Danish estuaries are experiencing an almost invasive number of crabs (Carcinus maenas) (ref17) properly due to lack of predators like cods and it is

well documented that Carcinus maenas have a negative effect on eelgrass (ref18, ref19) and it is described in the Swedish coastal waters that the of lack of cods increases the biomass of algae within the eelgrass (ref20) and thereby have e negative effect on eelgrass.
The focus on yearly nutrient loads in the RBMP is further also problematic concerning the seasonality because of mostly low residence time in estuaries and due to the fact, that in the summer period point sources can in some catchments make up the main part of the nutrient load (Ref23) and in the same catchments the main target in the RBMP is the diffuse sources due to focus on yearly loads in RBMP.

SEGES comments to the use of MECH and STAT models in RBMPIII

The STAT model is simple statistical relations between nutrient loads and quality elements in the downstream estuary. There is a series of problems related to this method:

STAT models
- The STAT models use nutrient annual load from January – September related to annual summer chlorophyll-concentration (May-Sep) (ref10, page10). The problem with this approach is that the residence time in Danish estuaries are often days and weeks and for few estuaries it can be months (ref11). The larger nitrate winter loads from fields will be washed out of the estuaries before summer (see appendix). This was demonstrated by DHI in 2017 with Karrebæk Fjord (ref.12) and is mainly relevant for catchments with clay/drained – eastern part of Jutland and the islands of Fyn (Funen) Sjælland (Zealand) and islands around due to fast response from field to estuary on clay/drain
- There is a correlation between yearly loads of N from DK and neighboring countries and also to the Baltic Sea basin (ref.13). When the STAT models are based on N-loads from DK but N-loads correlates to N-loads from other countries the STAT models are not suited for regulating DK N-loads.
- The STAT models are using a specific “nutrient load” term in the relation to Chlorophyll. Later based on an evaluation on specific estuaries it is decided whether to use N or P as the load. Since N is the limiting nutrient from May/June, P is deselected for almost every estuary although that P is the limiting factor in the spring for all estuaries in DK (Ref.14).

It is SEGES opinion that the STAT models are not suited for the purpose to calculate MAI or setting reference condition mainly due to low residence time in the Danish estuaries and the fact that the models are using yearly loads from January to September. And further the models are not capable of distinguish between N- and P-loads and distinguish loads from DK and loads from neighboring countries due to correlations.

MECH models
The MECH models are complex modelsystem and by the international evaluation 2017 regarded as State of the art. SEGES have evaluated the calibration and use of only 3 estuaries, Ringkøbing Fjord, Skive Fjord and Mariager Fjord:
- The calibration concerning Mariager Fjord is problematic because summer DIN is not correct calibrated. Mariager Fjord is one of the only estuaries in DK with no or very minor DIN limitation during summer (ref14) but the model is calibrated to have DIN limitation during summer month while this is not what the monitoring data shows (ref22).
- The main problem for Ringkøbing Fjord is the use of the model but that could maybe relate to the calibration. Chlorophyll is limited by filtering Mya Arenaria (ref15, 16) and the eutrophication is instead related to the amount of Ulva except for special years (2019) where filtration is low due to lack of Mya Arenaria. But in the RBMPIII the relation is made between N-loads and Chlorophyll. This is scientifically flawed.

- Skive fjord seems to be well calibrated. Summer DIN limitation and spring DIP limitation are well described by the model and also the stratification and the oxygen depletion that every year leads to release of nutrients from the sediment during summer.
- The review of the model performance performed by DHI do not include DIN summer and DIP summer – only winter and annual. This is highly problematic because it is crucial to have the model calibrated correct concerning DIN and DIP limitations periods. As a result of this miscalibration, the model will not respond correct on reduction scenarios.
- Most of the MECH models do not have good model performance on Kd and Chlorophyll – this is problematic when both are key quality elements.

For an unknown reason the MECH models have not been used to include seasonality in RBMPIII as recommended by the international evaluation in 2017. Beside misuse of the models due to poor calibration for at least some estuaries, the lack of using seasonality is a major problem for the eastern part of Denmark with clay and drain-systems due to the fact that the main part of the N-load is delivered during winter. Danish estuaries have a residence time of days and weeks and in few occasions months (Ref11 & appendix) - this combined with the fact that measures in RBMP is reducing N in the autumn and winter (ref21) introduces a mismatch between a reduction in N-load (winter) and a goal for chlorophyll reduction. Eastern part of Jutland and the Islands Fyn, Sjælland (and more) are mainly clay soils and drained hence a short and fast N-load travel from field to estuary. While western and northern part of Jutland is mainly sandy soils introducing a delayed N-load response and therefore seasonality is properly not relevant in these parts of DK.
The MECH models are calibrated in a period with eutrophication but is used to setting the reference conditions for chlorophyll with a much lower N-load (natural background) but the N-load for the year 1900 (Ref34) is not used as validation for the model. This is a main problem due to the big discussion concerning setting reference conditions (Ref29).

DIN and DIP limitation
Both DIN and DIP plays a role for limiting primary production in Danish coastal waters. In the estuaries DIP limitation typically starts in February and Marts and typically in April, May or June, DIN is becoming the limiting factor for primary production for the rest of the summer in most estuaries. For a few estuaries DIN do only play a minor or no limiting role for example Felsted Kog (inner part of Nissum Fjord and Mariager Fjord) The pattern for open coastal waters like Kattegat and the straights is different. DIN and DIP limitation happens here at the same time in early spring February and Marts and both DIN and DIP becomes limiting over spring and summer and DIP more than DIN in spring and vice versa in the summer. DIN limitation seems to be ongoing for a longer period into the late summer and autumn (Ref14).
Due to the WFD definition of “summer chlorophyll” (May – September) DIN is then - in most water bodies – more relevant than DIP for limiting primary production/chlorophyll in the period defined by WFD. An issue here is that the spring bloom of chlorophyll is not considered because it happens before May. Primary production is not only chlorophyll but also Ulva, epiphytes etc. Both Ulva and epiphytes have been part of the eutrophication problem in Denmark and can have a direct negative effect on eelgrass. Limiting primary production in the spring by DIP decrease have had positive effect not only on chlorophyll concentrations but also directly on eelgrass. This perspective is not considered in the Danish RBMP since the focus concerning eelgrass is not “cover” but only “depth limit” and therefore indirectly on chlorophyll. From an ecosystem perspective it seems obvious to use a “Dual Nutrient (N and P)” reduction perspective (Ref32) because in most estuaries DIP and DIN limitation are more or less separated to spring and summer respectively. The idea behind the work done in the RBMPIII to investigate whether P-load reductions can compensate for lessor N-load reductions seems therefore not relevant for most Danish estuaries.

Delayed response in the ecosystem due to pools of N and P is important. For the Baltic Sea “Approximate residence times calculated as reservoir sizes divided by permanent sinks are for TC, TN, and TP 38, 9.0, and 49 years respectively (including both pelagic and benthic reservoirs).” (Ref33). In Danish estuaries with a short residence time an almost instant decrease in chlorophyll concentration is documented (Ref14) as a response to decreased P-loads in the 1980s and early 1990s. More studies are probably necessary to conclude whether older P-pools in the sediment still effecting the primary production or the P-pools mainly have a season variability.
Concerning to larger P-pools in the Baltic Sea the large delay is not included in the scenarios made in RBMPIII. All scenarios include the current P status effecting the ecosystem in the Baltic Sea and there is made no scenarios that include a P balance situation maybe 30-50 years ahead and therefore the Danish MAI in RBMPIII are compensating for the current high P level in the Baltic Sea.

Response curves
Both the STAT and MECH models are used to make liner response curves for each water body. So far, the authorities and institutes (DHI) have not allowed these response curves to be public. It its known from the model work by DHI in RBMPII that the response curves in open sea and Danish straights are almost flat. This is also seen from a large-scale accident when 2.755 tons N over 2 days was running into Lillebælt (Little Belt) in February 2016. Besides a properly instant toxic effect there was seen no elevation in chlorophyll during spring and summer in Lillebælt (ref27) and after 2 month the N spill was mainly in Skagerrak, modelled by DHI (ref28).
The flat response curves introduce the problem that even a small decrease in chlorophyll concentration correspond to a high N-load reduction demand. There have been no open discussions related to response curves concerning this dilemma. This should also be seen in the light that GES concerning chlorophyll are lowered from RBMPII to III and in many water bodies (open sea) GES (chlorophyll) are below the intercalibrated values (ref24)
Further, the response curves are liner, and this introduces not realistic responses (ref25).

SEGES comments to the Danish use of eelgrass as a quality element

WFD states: “*The level of macroalgal cover and <u>angiosperm abundance</u> show slight signs of disturbance*”. In the Danish context depth limit is used as a proxy for “abundance” but the depth limit is only one element of “abundance” the other element is “cover”. What is often seen in Danish coastal waters is none or very scattered cover of eelgrass at sites with enough light conditions for eelgrass growth. An area could therefore have good depth limit but bad cover and that would today be regarded as good even though it would not be a biologically healthy system. The problem with only focusing on depth limit is only focusing on light conditions while other stressors can be problematic for eelgrass cover. These stressors can be biological (ref18/19/38) and physical (ref39/40) but also nutrient in the form of algae’s (epiphytes) covering the eelgrass and they are not addressed when only focusing on depth limit (light). The model for eelgrass references is based on observations from inner Danish coastal waters and no data from the lagoons on the west coast of Jutland (Ringkøbing Fjord and Nissum fjord). These two lagoons are characterized by much more resuspension than other water bodies included in the model. The resuspension effects the light conditions, and the model are not suited for waters with high resuspension. Further, the depth limit for GES ends up being higher than the actual water depth in Nissum Fjord and higher than needed for eelgrass to grow at the deepest area in Nissum Fjord (ref35)

SEGES comments to reference conditions and the 1900 problematic

The problem is further described in the paper: Comments to setting reference conditions – eelgrass and chlorophyll (ref29) but the main concern is the use of eelgrass the year 1900 and at the same time calculating the reference for chlorophyll by using N-load from "natural catchment" corresponding to a time before Viking age.

SEGES comments to the N-loads reductions demands in RBMPIII.

According to RBMPIII, the total N load to coastal water bodies must be reduced by 13.018 tons N. In average for all coastal water bodies, N load from agricultural activity must be lowered by 37 per cent to obtain the reduction requirements (Ref30). Required reductions in N load from agricultural activity varies considerably between water bodies. 7 out of 109 coastal water bodies require more than 80 per cent reduction in N load from agricultural activity. 35 out of 109 coastal water bodies require more than 50 per cent reduction in N load from agricultural activity (Ref30). SEGES Innovation has estimated the need for cessation of agricultural production to meet the required N load reductions. The estimate is based on N load reduction potentials for nitrate leaching reduction measures and nitrogen removal measures. It is estimated that up to 590.000 hectares of crop land must be converted to either fallow, permanent low yielding grassland or forest (Ref30), corresponding to approximately 25 per cent of the agricultural area in Denmark. In some catchments 100% of crop land must be converted to either fallow, permanent low yielding grassland or forest (ref30). In 40 per cent of the catchments, MAI is lower than the N-load in the year 1900 (Ref31/34), while in the rest of the catchments MAI is higher than the N-load in 1900. In 15 percent of the catchments, MAI is less than 60 per cent of the N-load in 1900 (Ref31/34). Some of the catchments with the highest N reductions demands have a downstream estuary with a low residence time clearly pointing at the problem that RBMPIII do not include seasonality as recommended by international experts in 2017 (ref41)
The N-load reduction demands has changed from RBMPI to RBMPII to RBMPIII introducing new high demands at new locations for example parts of Zealand (Sjælland), Bornholm and Djursland in RBMPIII while other areas like North of Jutland have reduced demands significant in RBMPIII. Further, there are also changes in chlorophyll status classes between RBMPII and III without any changes in chlorophyll concentrations in the water bodies but probably due to changes in setting refence: 2 water bodies have moved maximum 4 classes from "high" status to "bad" and other 4 water bodies have moved 3 status classes in the direction of worse and 7 water bodies have moved 2 classes to the worse and 23 water bodies have moved 1 class to the worse (ref24). The model complexity seems to be at a level where no one can explain the changes besides that the authorities are referring that the newest model system is better than the previous. The significant change in reduction demands from one plan to another together with the complexity of the model system have led to a significant lack of trust to the authorities concerning RBMP. This mistrust is not only seen from farmers and the agri-consulting complex but also from local authorities working with implementing measures like wetlands because the need for wetlands in different catchments are also changing according to the changed MAI from plan to plan.

SEGES comments to Danish water governance

The water governance for coastal waters was established in the 1980s and 1990s with the aim of achieving the general goals of a 50% N-load reduction and an 80% P-load reduction. The goals have been achieved and this shows that the governance structure that was built at that time was successful in solving that specific task. A governance structure must be built specifically for the task to be successful (ref42). When entering the RBMPIII, and still almost no coastal waters have achieved GES, and nitrogen emissions have not decreased since 2010, an important question much be asked, how a governance structure should be built so that it is suitable for solving the task today? The task has

become considerably more complex than just reducing nitrogen. The marine environment includes complex biological processes and feedback mechanisms. At the same time, land must be taken out in the catchment area on a large scale for wetlands and lowlands, etc., and space must also be made for nature and climate measures. Much suggests that the logical path towards being able to solve the challenges requires a new governance structure. This is why the government in 2021 as part of the "Agreement on the green transformation of Danish agriculture" ("Aftale om grøn omstilling af dansk landbrug", Ref44) decided to test a new local based water plan structure with the aim to find alternative ways to GES. This test is arranged under the" second opinion" program.
Implementation of the test have been initiated by the Danish Environmental Protection Agency sent out application material in 2022 to establish local coastal water boards. The coastal water boards must contribute local knowledge and have the task, together with recognized experts, of clarifying the main challenges of coastal waters in order to achieve GES, as well as preparing qualified proposals for a local based action program that ensure GES.
A total of 8 applications were submitted, of which the following 4 were granted a coastal water council: Wadden Sea (Varde Municipality), Ringkøbing Fjord (Ringkøbing-Skjern Municipality), Odense Fjord (Odense Municipality), Skive Fjord, Lovns Bredning, Hjarbæk Fjord (Viborg Municipality). The 4 collaborations/coastal water boards have until the end of 2023 to carry out analyzes of the fjord and the catchment and draw up an action plan. The starting point is that it must be based on professional analyses, and it may contain marine measures and measures against nutrients in the catchment area, where measures must be placed at ID15 level (approx. 1500 ha sub-catchment areas). Most of the funds applied for (13 mio. DKK), go to professional assistance from Danish and foreign experts. The difference to the current RBMP is not the experts, who in both cases have a central importance for calculations etc., but the difference is the use of the expertise, which in the case of local planning gets more time to participate in discussions and adjust calculations more to the local conditions than has been possible when relatively few central experts have had to develop over 100 reduction targets in parallel, as has happened in the RBMP. In simple terms, it can be said that it is expected that the individual fjord and the individual catchment will receive greater attention, and it is SEGES opinion that more important details will be included in the local based RBMP and there will be more ownership to the plans.

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“*These findings strongly indicate that benthic standing stock system-wide is food limited and indicate the importance of interaction between loading and estuary residence time (flushing) for the outcome of eutrophication. The findings are in agreement with reports that high estuary flushing rate may modify effects of eutrophication*”

Kilde: Naturen i Danmark, Havet, 2006. 1. oplag. (Book)
Redaktør Prof. Tom Fenchel, KU, Hovedredaktør Prof. Kaj Sand-Jensen, KU
Kap 15. De frie vandmasser stofomsætning side 357 ved Matthias Middelboe, lektor KU og Michael Olesen lektor KU

”*Om vinteren og efteråret når udvaskning og afstrømning fra land er størst føres der store mængder kvælstof og fosfor til fjordene.*
Det udledte kvælstof vil derimod forblive i vandet som opløste kvælstof-ioner i vinterhalvåret og vil derfor i højere grad end fosfor blive ”skyllet” ud af systemet til de tilstødende farvande.”

Translated from Danish to English
"*In winter and autumn, when nutrient losses and runoff from land is greatest, large amounts of nitrogen and phosphorus are carried to the fjords.*
The discharged nitrogen, on the other hand, will remain in the water as dissolved nitrogen ions in the winter and will therefore be "flushed" out of the system to the adjacent waters to a greater extent than phosphorus."

Møhlenberg, F., J.H. Andersen (red.), C. Murray, P.B. Christensen, T. Dalsgaard, H.
Fossing & D. Krause-Jensen (2008): Stenrev i Limfjorden: Fra naturgenopretning til supplerende virkemiddel. DHI rapport, 45 sider + bilag. https://www.stenrev.dk/media/44061/faglig-rapport-stenrev-i-limfjorden.pdf
”*Derfor vil reduktioner i N-fluxe om sommeren have betydeligt større positiv effekt, end hvis en tilsvarende stor N-reduktion fordeltes gennem året, fordi en betydelig del af det kvælstof, som tilføres i vinterhalvåret fra land, ”skylles” ud af fjorden og ”tabes” til atmosfæren ved denitrifikation, inden det kan indbygges i primærproducenterne*.”

Translated from Danish to English
"*Therefore, reductions in N fluxes in the summer will have a significantly greater positive effect than if a similarly large N reduction were distributed throughout the year, because a significant part of the nitrogen supplied in the winter from land is "washed" out of the fjord and is "lost" to the atmosphere by denitrification before it can be incorporated into the primary producers*."

Jesper Goodley Dannisøe, Optimisation of the Nitrogen Loadings to Karrebæk Fjord - Seasonal Effects from Nitrogen Reductions, DHI 2017 (SEGES report): https://www.landbrugsinfo.dk/-/media/landbrugsinfo/public/B/9/6/cowi_report_optimisations_of_the_nitrogen_loadings_to_karrebak_fjord

"*The results from the modelling study have shown that the timing for reduction is important for the changes in the summer bloom. Three scenarios were analysed in this project, and they suggest that some optimisation could be applied and poten-tially help fulfil the requirements from the Water Framework Directive*"

Anders Chr. Erichsen (DHI), Sophia Elisabeth Bardram Nielsen (DHI), Karen Timmermann (DTU), Anker Højberg (GEUS), Jørgen Eriksen (DCA), Birger Faurholt Pedersen (DCA), 2021. Muligheder for optimeret regulering af N- og P-tilførslen til kystvandene med fokus på tilførslen i sommerhalvåret. Analyse og kvantificering.
https://pure.au.dk/portal/files/228142340/Muligheder_for_optimeret_regulering_af_N_og_P_tilf_rslen_til_kystvandene_med_fokus_p_tilf_rslen_i_sommerhalv_ret.pdf

"*Nærværende tekniske notat bekræfter, at der er enkeltstående vandområder (18 ud af 109 vandområder), hvor en optimeret regulering af næringsstoffer fokuseret på tilførslerne i sommermånederne (maj-september) potentielt kan have stor betydning*."

Translated from Danish to English
"*This technical note confirms that there are individual water bodies (18 out of 109 water bodies) where an optimized regulation of nutrients focused on the inputs in the summer months (May-September) could potentially be of great importance*."