Understand the meaning of nitrogen in ten minutes - special pixi edition for e.g. politicians:

The botched water planning

Aarhus University (AU) has once again recalculated the target load for nitrogen emissions. Now the current water plan's target load of 44,700 tonnes of N is no longer considered enough. For the upcoming third water plan period, AU has now reached all the way down to 36,600 tonnes of N. AU is hereby proposing a totally unrealistic tightening of an already strict reduction target.

It is not the first time that AU has tightened the target - it has happened many times. And every tightening of the N requirement lays the groundwork for the next tightening. Every time it succeeds in reducing emissions of N, it naturally leads to stronger nitrogen limitation, and this nitrogen limitation is abused through unrealistic calculation models to make new demands for further reduction of N. This development will continue as long as Denmark allows the use of flawed models with "Screw-without-end-effect".

Therefore, the demand for the 36,600 t N is not only totally unrealistic, but also professionally incorrect and unnecessary.
The basic theory behind the nitrogen models is an incorrect definition of the term "nitrogen limitation". Abuse of Justus von Liebig's "minimum law".

Fallacy in the 1980s Things

went awry in 1986, when the oxygen depletion in some Danish coastal waters culminated in the "famous" oxygen depletion north of Gilleleje, where some dead lobsters were brought into the harbor and shown on TV with great drama in prime time. DN's director at the time demanded quick action - "no time for more investigations". And there was no time for serious consideration.

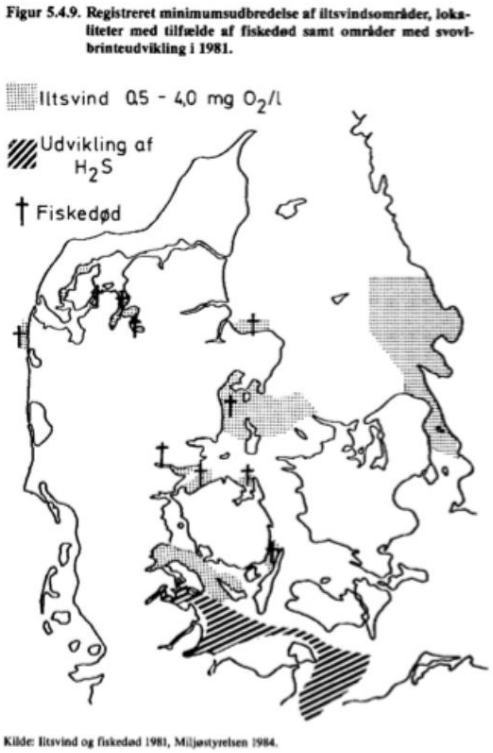
For the same reason, actual science was not involved in the diagnosis: A marine biologist at Denmark's Environmental Investigations (DMU), who was also the brother of the fisherman who landed the dead lobsters, "shot from the hip" with an explanation that no one in the Danish Environmental Protection Agency or the ministry evaluated. A press release was hastily issued stating that the oxygen depletion was due to agricultural emissions of nitrogen. The marine biologist later described how he arrived at his diagnosis: *"From the Belt Project we knew that primary production was mainly nitrogen-limited (controlled by the supply of nitrogen). The only place in society where there had been a significant increase in the use of nitrogen was in agriculture."*

Here is a blatantly wrong conclusion: The nitrogen limitation cannot possibly be due to "a significant increase in the use of nitrogen"! This would precisely never lead to nitrogen limitation, but instead to phosphorus limitation.

Wrong diagnosis – wrong solution model

The observed nitrogen limitation in the oxygen wind area was a result of massive pollution (including phosphorus) from Copenhagen and Swedish Øresund cities. For many years before the catching of the dead lobsters, Copenhagen had emitted approx. 1 million tonnes of sludge in the Øresund, where the dominant northerly current carried it north. After the "bottleneck"
Elsinore-Hälsingborg, the current is spread out so that the speed decreases and the sludge particles

settles in the area north of Gilleleje on the Danish side and in Skälderviken and Laholmsbukten on the Swedish side. These were exactly the areas that were affected by oxygen depletion in the 1980s, see the figure from the NPo report from 1984, which shows the situation in 1981.



Figur 5.4.9. Registreret minimumsudbredelse af iltsvindsområder, lokaliteter med tilfælde af fiskedød samt områder med svovlbrinteudvikling i 1981.

Kilde: Iltsvind og fiskedød 1981, Miljøstyrelsen 1984.

The treatment plant Lynette, which was established in 1980, still had frequent operational disruptions. As recently as 1984 and 1985, approx. 200,000 tonnes of sludge per year. It was many thousands of percent above what was allowed, and the Environmental Appeals Board imposed a drastic requirement on Lynette to halve the sludge discharge every six months until it reached 1/16 or 440 tons.

Continued misdiagnosis

The false diagnosis about nitrogen is still the basis for the authorities' environmental efforts (nitrogen models). Senior researcher Karen Timmermann, DCE, Aarhus University, confirmed at the Plant Congress in January 2017 that Aarhus University, which is responsible for the administration, continues to base its strategy on Justus von Liebig's minimum law (1855). This is disastrous because Justus von Liebig's theory does not apply in connection with the marine ecosystem. It only applies in closed systems (e.g. laboratory conditions) cut off from the marine ecosystem. Therefore, Professor Stiig Markager, Aarhus University, has no evidence for his often stated claim that Danish agricultural emissions of nitrogen are *"the* decisive factor" for the environmental problems in the coastal waters. Nitrogen is one of many factors – and nitrogen from agriculture is only one part of it. The primary factor is phosphorus.
Without a relatively high phosphorus concentration (N:P < approx. 7), nitrogen limitation does not occur at all!

In addition, the nitrogen interventions have other flaws, because the measures are implemented without regard to the different conditions of different water areas and without regard to the time of year of discharge. Thus, it is not taken into account that nitrogen discharge in winter - outside the algae growth season - disappears with the ocean currents and is therefore irrelevant.

In the ocean's ecosystem, it's all about balance

Justus von Liebig's theory is therefore useless in the marine ecosystem, whereas the oceanographer Alfred C. Redfield's balance theory (1934) is relevant here. Like other biological processes, it is here, too, that equilibria determine the processes.

The tension between the two theoretical platforms is fierce, because they state completely different (in fact oppositely directed) effort requirements in the same situation.

Here, since the 1980s, Denmark has unilaterally built environmental efforts on the wrong theory and thus ignored the right one. Sooner or later, of course, this error must be recognized and corrected (the ecosystem does not surrender).

The nitrogen standards have damaged the CO2 accounts

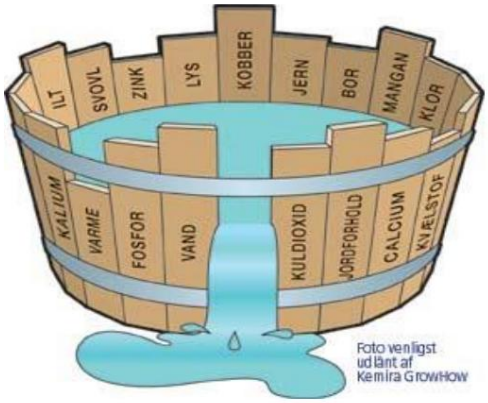
The nitrogen standards have limited agriculture's use of the essential production factor nitrogen, which has resulted in lower yields and lower protein content in the crops. The undersupply of nitrogen has also damaged Denmark's climate account due to mineralization of the soil with CO2 emission/lack of CO2 sequestration as a result.

Conversely, the nitrogen standards have not had the intended effect on the marine environment. The improvement that has taken place in the marine environment since the severe oxygen depletion in the 1980s is due to other factors – mainly better treatment of waste water for organic matter and phosphorus. However, phosphorus purification is still far worse than in our neighboring countries, because the priority over decades has been wrong with nitrogen being the main focus.

Currently, problematic subsidies are given to wetlands that limit nitrogen discharge, but at the same time have the serious side effect that they increase the more harmful phosphorus discharge ("phosphorus mobilization") and thus make coastal waters worse.

Laboratory experiments versus reality

In a closed system, reduced nitrogen supply will reduce production if there is "nitrogen limitation":



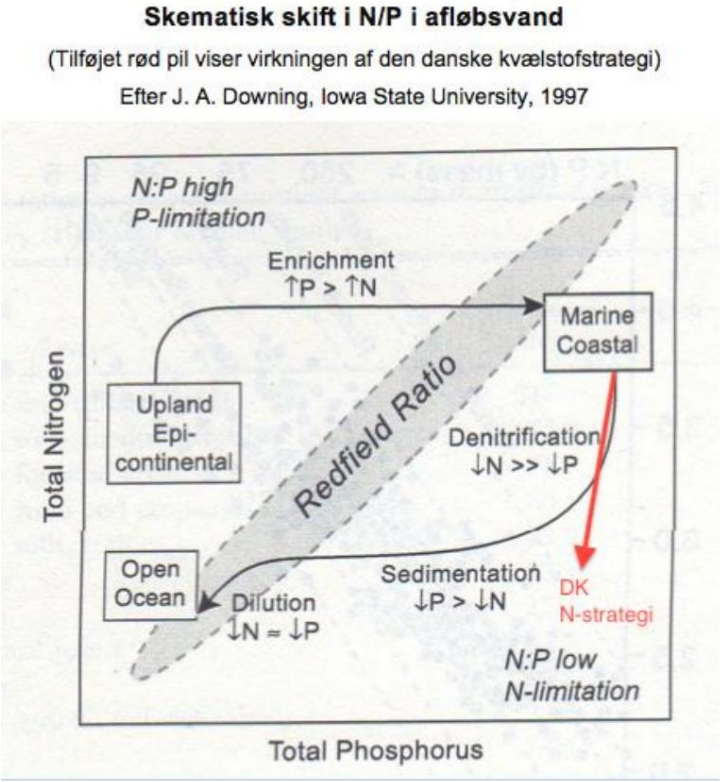
The tub illustrates Justus von Liebig's law of the minimum: Production is limited by the factor of production that is in deficit in relation to the need.

If nitrogen is in deficit, (algae) production can therefore be limited by limiting the nitrogen supply.

But Liebig's minimum law applies in principle only to a well-defined plant in a closed system in the laboratory – cut off from the marine ecosystem. If there is a connection to open sea areas, the nutrients are transported around (flux).

It can be stated that the state of "nitrogen limitation" is absolutely not due to nitrogen discharge, but rather to an excess of phosphorus - usually as a result of the discharge of

wastewater from drainage systems with low N:P. Therefore, physiological "nitrogen limitation" is only found in areas that are heavily loaded with phosphorus.



The oval field "Redfield Ratio" illustrates the ratio between nitrogen and phosphorus that is optimal for the ecosystem.
Professor John A. Downing summarizes his research as follows:

In the upper fresh waters of the water system, originating mainly from high N:P precipitation and from runoff from "pristine" high N:P areas, P concentrations are low, N:P is high, and primary production is severely P limited.

As the water moves down through the water system, P is added through runoff from drainage systems with low N:P. This means that P increases and N:P decreases, resulting in more frequent N limitation of primary production and blooms of N-fixing cyanobacteria. This nutrient enrichment takes place to varying degrees, depending on the size of the catchment area, land use and extent of housing.

The inserted red arrow shows that the Danish unilateral efforts against nitrogen in reality work against the ecosystem's natural regulation of the N:P ratio in the direction of the ideal balance.

Conclusion

It is absolutely crucial that, after a delay of more than 30 years, the misunderstanding that the state of "nitrogen limitation" means that nitrogen emissions must be limited is put to rest. According to modern ecological stoichiometry, "nitrogen limitation" shows that there is too much phosphorus in the ecosystem (cf. NPo statement page 19).

It is important to understand that Justus von Liebig's minimum law applies in controlled laboratory experiments, but does not belong in the open ocean environment. Here it is Redfield's balance theory that is relevant. That this is the case is supported by, among other things:

- The NPo statement from 1984 •
- Professor David Schindler, Canada, and Professor Robert Hecky, USA, from 37 years full-scale studies completed in 2006
- Professor John A. Downing, USA, studies from the 1990s onwards • Professor Patricia M. Glibert, USA from 2011 • Professors Robert W. Sterner and James J. Elser: Ecological Stoichiometry • The international evaluation panel from 2017

The evidence for Denmark's mistake in the water environment is glaring.

Professionally and scientifically, the importance of nitrogen is clear. The big challenge is of a pedagogical and political nature.

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