Models and Management of the Baltic Sea

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Marine pollution has, until the last decades, been considered only as a local or regional problem, primarily due to the dilution effect of the vast oceans. The Baltic Sea was the first case where antrophogenic effects on an entire marine ecosystem were documented. The virtual elimination of top predators like eagles and seals, the development of anoxia in deep basins and toxic blooms are example of large-scale effects, caused by toxic substances and eutrophication in the Baltic.

It is however not surprising that the Baltic is particularly sensitive to pollution, considering that it is surrounded by 85 million people with intensive agriculture and industry in a drainage basin four times larger than the sea. The special physical properties of this enclosed shallow brackish water sea further enhance the effects of the large inputs of polluting substances. Originally an oligotrophic system, an increase of nitrogen and phosphorus inputs by four and eight times during this century, has increased productivity and dramatically changed the species composition and food webs. New species have been established as important components of the communities.

The effects of pollution the Baltic ecosystem are now well described in many scientific studies and has been followed by extensive monitoring programs. International agreements on the ban of various toxic substances have resulted in improved conditions. Endangered species of birds and marine mammals are now recovering. For nutrient loads and eutrophication no major improvements have occurred. In contrast to toxic substances, nutrients are natural and essential components of any ecosystem and should only be reduced to levels where the negative effect are eliminated. Recent estimates on the cost to reduce these loads indicate that major reductions are not possible to obtain by using only 'clean end-of-pipe technology'; major reduction from agriculture, traffic and energy sectors are needed. This will involve not only massive international funding but also difficult political decisions directly affecting living standards. This is particularly difficult in a region with large differences in economies and living standards between countries, i.e. between the western societies and the former east-bloc countries.

In addition, most of the causal relationships behind eutrophication are only understood qualitatively. The complex interplay between physical and biogeochemical processes, nutrient inputs and climatic variations, can only be understood by using models. Such models are also necessary in order to develop a management strategy on how, there and how much the nutrient inputs should be reduced.

Two different modeling approaches have been used i.e. 'empirical' and 'mechanistic' models. Empirical models are developed by using the large data sets from this region to develop nutrient budgets. These are then used to develop descriptions how changes in nutrient inputs will affect concentrations of both nitrogen, phosphorus and silica. These models demonstrate principal differences in the behavior of these nutrients and between the different sub-basins of the Baltic Sea. The results suggest that the Baltic has changed from an oligotrophic, phosphorus limited system to an mesotrophic system where primary production is nitrogen limited. These changes is to a large extent depending on the varying efficiency of the internal sinks (and sources) of phosphorus compared to nitrogen, at different levels of eutrophication.

Mechanistic models describe various physical and biogeochemical processes controlling nutrient levels and productivity of the sea. These models have been useful tools to test various hypotheses about the relative importance of different processes. Earlier versions are now expanded from dealing with only nitrogen to also include phosphorus. Although it is generally recognized that nitrogen is currently limiting productivity in the Baltic proper, phosphorus is limiting in the northern Bothnian Bay and in many coastal regions. However, this does not necessarily mean that a nitrogen reduction to the Baltic proper would lower organic production with the high concentrations of phosphorus that are now prevailing. Model simulations suggest that a reduction of nitrogen input could be compensated by enhanced fixation of atmospheric nitrogen by cyanobacteria. On the other hand, empirical evidence suggest that in those coastal archipelago regions where a drastic reduction of phosphorus input has been implemented, further reduction of production could only be initiated by a nitrogen reduction. Model simulations suggest that the optimal nutrient reduction strategy may be different if seen from a local, regional or large-scale perspective.