LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

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## A "model message" to decision-makers: Continued nutrient reduction measures will reduce "dead zones" in the end

*A team of climate modellers used an extensive multi-model ensemble to investigate the effects of climate change on the "dead zones" of the Baltic Sea. They showed that a reduction in the size of these areas can be achieved by 2100 if nutrient discharges are consistently reduced – despite climate change. Until then, however, the simulated changes are still within the range of natural variability, which – the authors also showed – represents the greatest uncertainty of future scenarios for the time being. For individual Baltic Sea regions, they determined an earlier visibility of changes than in others. They recommend intensifying observations there.*

The Baltic Sea has the largest area of oxygen-depleted water in the world, followed by the northern Gulf of Mexico, the north-western Black Sea and the East China Sea. These "dead zones" are generally seen as the result of excess nutrients in the system. For decades, therefore, attempts have been made to create improvements in some of these oxygen-deprived areas by reducing discharges, as has happened in the Baltic Sea, the Gulf of Mexico, and the Chesapeake Bay. In the case of the Baltic Sea, these are measures under the Baltic Sea Action Plan.

What all of these programs had in common was that they did not consider the effects of climate change on eutrophication. However, when attempts were made to use regional climate models to simulate the consequences of climate change on eutrophication and the spread of dead zones in order to adjust reduction measures in this way, it was found that the model results varied widely and did not directly lead to useful recommendations. This wide divergence of results is mainly based on four uncertainties: 1) natural variability, 2) differences in the models, 3) the correctness of the assumptions of future greenhouse gas concentration pathways – the so-called RCPs (**r**epresentative **c**oncentration **p**athways) – and 4) the correctness of the assumptions of future socioeconomic developments, expressed by the so-called SSPs – the **s**hared **s**ocioeconomic **p**athways. For the Baltic Sea the SSPs include, among others, assumptions on different nutrient discharges. In addition, the general weakness existed that too few models were compared. Previous ensemble simulations usually consisted of fewer than 10 members due to limited computing capacity.

In an article published this week in the renowned journal Communications Earth & Environment, German and Swedish climate modellers led by physicist Markus Meier of the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) used statistical methods applied to a large number of different model scenarios (48) to analyse, which uncertainties were mainly responsible for this divergence. Their aim was to support decision-makers, such as – in the case of the Baltic Sea – the Helsinki Commission (HELCOM), in their task of defining climate change-adapted measures to reduce nutrient discharges. The focus was on the question of when it will be possible to see whether environmental policy measures are actually having an effect and whether climate change will delay this visibility.

"The good news is: The planned measures will take effect," Markus Meier sums up. "But conditioned also by climate change, it will probably take several decades before a statistically sound trend for the Baltic Sea's 'dead zones' versus the 'flic-flac' of natural variability can be seen." In climate research, this point in time is called Time of Emergence (ToE). Markus Meier and his colleagues were able to show that the ToE varies with different environmental variables and different regions of the Baltic Sea. In the north-western Gotland Basin, for example, it will probably already be possible to see in the next few years whether the measures of the Baltic Sea Action Plan lead to higher oxygen levels at the bottom. Markus Meier: "Our results indicate areas where the 'time of emergence' of changes will occur earlier than elsewhere. We recommend keeping a particularly close eye on these locations in the future."

**Original Publication:**

Markus Meier, H.E., Dieterich, C. & Gröger, M. *Natural variability is a large source of uncertainty in future projections of hypoxia in the Baltic Sea.* Commun Earth Environ 2, 50 (2021).
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