Baltic Marine Environment Protection Commission

16th Meeting of the Intersessional Network on Eutrophication

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Background

IN-Eutrophication is in the process of developing a common indicator on shallow water oxygen. This work has high priority. Germany has undertaken investigations on selected sampling stations with the aim to further understand the challenges associated with assessing shallow water oxygen based on the currently available data. Detailed results of these investigations will be presented during the meeting. In this document, the relevant findings are summarised and proposals are made for a way forward to arrive at a Baltic-wide assessment of shallow water oxygen concentrations for HOLAS III and beyond.

Action requested

The meeting is invited to:

- take note and discuss the results of the investigations
- agree on a way forward for further developing the shallow water oxygen indicator based on a common approach

HELCOM indicator on near-bottom oxygen concentrations in shallow waters - towards a Baltic Sea wide application

Definition of bottom-water oxygen

Bottom water oxygen is operatively defined as the oxygen concentration at the lowest possible sampling depth by using CTD/water sampling bottles which is 0.5-1 m above bottom. (CTD stops best 0.5 m above ground and water sampling bottle is 0.6 to 1 m long – so the middle of the sampling bottle would be 0.8-1 m above the seafloor). By using sensors, oxygen could be measured down to 0.30-0.50 m above seafloor. Especially stable and reproducible maximum depths are achieved by using a compensation for ship movement. Currently, different approaches for the evaluation of oxygen in bottom waters are used.

Approaches used by Contracting Parties to assess shallow water oxygen concentrations

In the **Danish approach** two thresholds of 4 mg/L and 2 mg/L oxygen were applied to define affected water bodies by inter- (kriging) and extrapolating profiles. These were combined with bathymetric maps to also deduce affected seafloor areas by hypoxia resulting in areas of weak hypoxia, between 4 mg/L and 2mg/L, and areas of strong hypoxia < 2mg/L.

The **Swedish approach** uses 3.5 mL/L (~5 mg/L) oxygen as a universal threshold. The basis is the mean of the lower quartile of the respective data set. To identify the severity of the oxygen deficit the year is separated into a critical period of water column stratification and organic matter sedimentation and remineralization (June-December) and an uncritical period (January-May) with good preconditions for mixing and oxygen supply. For the evaluation a data set of monthly measurements for 3 years is required. First the mean of the lower quartile is calculated for the whole years: If it is > 3.5 mL/L, the status is high. If it is below 3.5 mL/L, the lower quartile of the uncritical period has to be determined. If this is above 3.5 mL/L the status of the sea area showing seasonal hypoxia is evaluated on the basis of the mean of the whole years (the first value):

good: 3.5>value$\geq$ 2.1 moderate: 2.1>value$\geq$ 1 insufficient: 1>value $\geq H_2S$ bad: H_2S

If the lower quartile of the uncritical period is still below 3.5 mL/L, it is the situation of permanent/perennial anoxia. In this case the affected seafloor area with oxygen below 3.5 mL/L has to be evaluated based on the depth of the threshold of 3.5 mL/L and the bottom bathymetry. Finally, the affected area is judged according to the percentage of the affected area and the prevailing bathymetric and hydrographic conditions. This means that the complete scale from high to bad is still applicable for sea areas affected by permanent/perennial hypoxia. The Swedish approach is data-demanding and is therefore not applicable for many monitoring stations due to a lack of data.

Germany has taken the Swedish approach as the basis but had simplify it due to a lack of data. The **German approach** distinguishes between stratification types of the sea area. The thresholds are defined accordingly for non-stratified (= well mixed) waters, it is 6 mg/l (~4.2 mL/L) O_2 as the minimum between July and November for GES, and for seasonally stratified (= stable thermohaline stratification in summer/ autumn), at least 4 mg/l (~2.8 mL/L) O_2 are accepted as the lowest value between July and November for GES. Then after evaluation of each station the results of GES or sub-GES of individual stations are combined for evaluation of sea areas. If more stations of an area reflect GES, the area is evaluated as being in GES. If equal or lower numbers of GES-stations represent an area, the whole area is evaluated sub-GES. This approach currently has several shortcomings. Firstly, the duration of the oxygen deficiency and the spatial extend cannot be evaluated. Secondly, the classification of stratified/non-stratified waters has only been based on limited data, considering only the vertical stratification but neglecting horizontal changes in

salinity that also influence stratification. Since it is not possible to increase the amount of data that can be collected in the short term Germany is planning to use a 3D-modelling approach using the ecological Regional Ocean Model (ERGOM) to further classify the monitoring stations and to get an estimate of the spatial extend of oxygen deficiency.

Finnish and Estonian approaches are still under development.

Issues

Even by monthly data collection, oxygen minima of one or two weeks may be missed. The inappropriate data coverage is caused by the variability of shallow sea areas – at least in the Belt Sea and the Arkona Sea areas – by physical, biological and chemical forcing. The lack of temporal and spatial data resolution may be overcome by including autonomous platforms (moored platforms, gliders, Argo floats ...) for a somehow continuous, in practice about hourly, oxygen data recording. This would clearly improve the reliability of the evaluation.

To investigate the challenges of the evaluation of shallow Baltic Sea waters by using bottom water oxygen, a few findings based on IOW data and an example evaluation of ICES stations are shown:

- CTD-profiles from different season – with emphasis on the near bottom range in summer.
- “MARNET Platform Arkona Sea Basin” time-series at 40 m depth from 2012 to summer 2017
- Evaluation of the recording by summing up monthly according to 2 mL/L concentration intervals
- Comparison of the time-series of the oxygen concentration at 40 m depth, about 4 m above the sea floor, and at 0.25 m above the sea-floor at the “MARNET Platform Arkona Sea Basin”.
- Application of the Swedish evaluation approach on selected ICES-Stations.

Of the investigated stations only for 7 stations sufficient data were available to apply the Swedish approach.

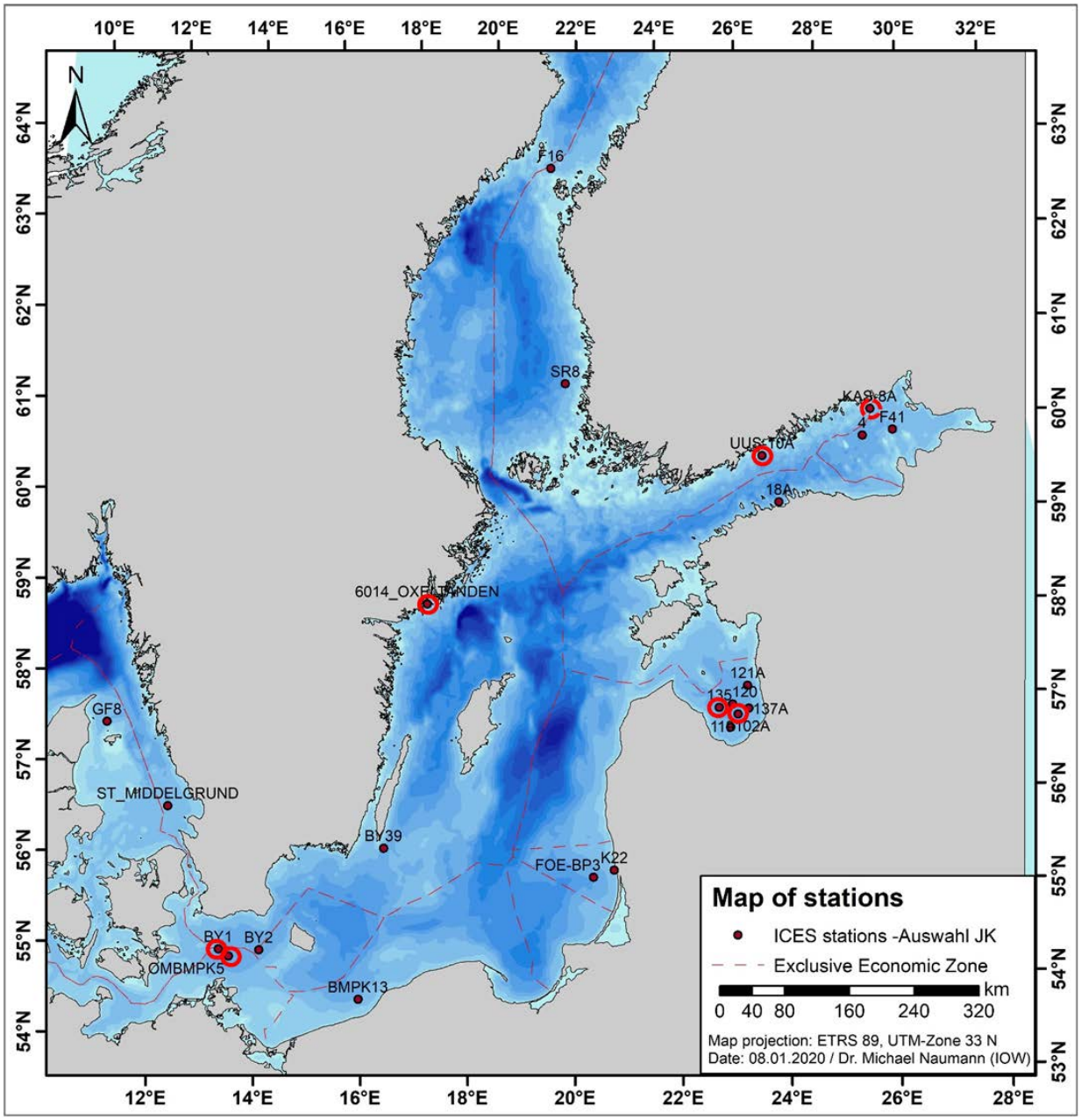

Fig. 1 Map of the Baltic Sea showing the sampling stations were bottom water oxygen concentrations were investigated. Only the statios with a red circle had sufficient data to apply the Swedish assessment approach.

Operative solution

The sampled water depth and the oxygen threshold should fit to enable oxic life at the bottom for GES by considering oxygen decline between the depth of measurement and the bottom. Observed gradients could be 0.5-1 mg/L via 1 m of depth.

The approach to just rely on the lowermost water sample suffers from by-chance observation or missing of hypoxia. So continuous recording vertically by CTD-oxygen sensors or continuous temporal recording by a mooring/platform increases the reliability.

Further suggestions

- use oxygen profiles in combination with threshold values and bathymetric maps to investigate affected areas of harmful hypoxia or week hypoxia and to identify bottom waters of high or good status.

- make time series of bottom water oxygen measurements and to sum up times of hypoxia of certain severity, e.g., below 6 mg/l, 4 mg/l and 2 mg/L as a basis for evaluation.