What ventilates the river?

Coastal Futures II: Physical Drivers of Oxygen Deficiency in the Warnow River Estuary

L. Reese, H. Burchard*, Leibniz-Institut für Ostseeforschung Warnemünde*

In Short

- Climate change and anthropogenic maintenance could lead to an increased occurrence of oxygen deficiency in German coastal water bodies, endangering aquatic animals
- We here aim to identify current and future risks leading to oxygen deficiency in the north-east German Warnow river estuary
- To this end, different scenarios are tested in high-resolved numerical hydrodynamic simulations
- Such simulations require high computational power with the option for job parallelization

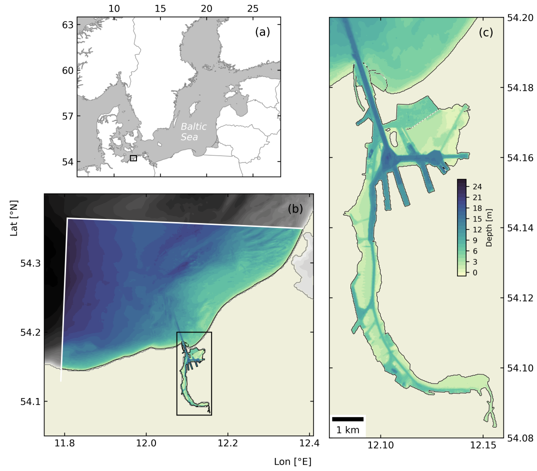

Figure 1: *Overview of the model domain. (a) Location of the domain at the Baltic Sea; (b) full extent of the model domain showing the water depth within the domain (colors) and in the surrounding Baltic Sea (grey-scale); (d) detail of the Warnow river estuary as it is included in the model domain. Color shading indicates the water depth and uses the same scale as in (b).*

In the deep basins of the Baltic Sea, “death zones” with no oxygen are a well-known result of excessive nutrient inputs from agriculture. In contrast, its shallow coastal water bodies were often overlooked as they were assumed to be well-mixed at all times due to their small depth, meaning that fresh oxygen from the surface would constantly be transported to the bottom. Yet, recent research has indicated a frequent occurrence of intermittent oxygen deficiency, often in close proximity to the bottom, e.g., in the Odra Lagoon [1]. Such deficiencies may easily be overlooked by governmental monitoring programs with only weekly to monthly, point-wise measurement schedules. Additionally, due to limitations of the devices, such measurements are typically stopped before reaching the ground, missing occurrences of near-bottom oxygen deficiency. Therefore, both the true extent and frequency of oxygen deficiency in Baltic Sea coastal waters are, as of now, unknown.

The current project aims to map and quantify potential regions of oxygen deficiency in a selected coastal water body of the non-tidal German Baltic Sea coast: the Warnow river estuary, where fresh water from the Warnow river interacts with salt water from the Baltic Sea. The Warnow river estuary shows an exchange of water with the Baltic Sea that is highly dependent on the adjacent Baltic conditions as well wind conditions [2]. Through this circulation, bottom waters in the estuary can be replaced with “newer” water that brings in fresh oxygen, thus helping the ventilation of the deeper parts of the estuary such as the navigational channel. Here, we therefore focus on physical drivers of potential oxygen deficiency which may affect this ventilation of bottom waters: namely, summer heat waves and the impact of channel deepening for ship traffic. While higher water temperatures as they occur during heatwaves lead to a reduced oxygen solubility and can further lead to a strengthened vertical density stratification that hampers the bottom water ventilation, therefore potentially aggravating existing oxygen deficiencies, the impact of channel deepening is less clear. On the one hand, a deeper channel may lead to a reduced exchange of oxygen with the surface, thus being more perceptive for bottom oxygen deficiency. On the other hand, it might also lead to a stronger circulation that could potentially mitigate already-occurring oxygen deficiency by more effectively ventilating the deeper water layers.

The above questions will be approached using highly resolved numerical simulations of the Warnow river estuary in combination with a simple, physics-based oxygen model. Model runs for conditions representative of the status-quo will be compared to model runs of the respective scenarios we aim to study, i.e., a deepened channel and a summer heatwave.

To realistically reproduce the conditions in the estuary, it is integral to resolve local structures of the topography, salt and temperature distribution, and circulation. The corresponding high spatial resolution brings the need for a high computational power since a parallelization throughout the model is nec-

Figure 2: *The Warnow river estuary at Mühlendamm, where the upstream end of the model domain is located.*

essary to perform the computations within a reasonable amount of time. While in-situ measurements can help us get an overview of the status quo in the estuary, we urgently need to combine them with computer simulations to properly cover the estuary at a high resolution in space and time and to be able to study specific scenarios.

From the study results, we will further identify locations of particularly high risk for oxygen deficiency as well as as locations that are representative for the overall oxygen conditions within the estuary. With this knowledge, specific recommendations for an improved monitoring strategy and an ecosystem-friendly management of the Warnow river estuary will be developed.

The present study is part of the BMFTR funded DAM mission sustainMare, project Coastal Futures II, which aims to assess the future development of coastal waters in the German Baltic Sea and North Sea regions. This project assesses both the impact of climate change and of diverse anthropogenic measures in the region, such as ship traffic or offshore wind farms.

WWW

https://www.coastalfutures.de/

More Information

[1] G. Schernewski, T. Neumann, S. Piehl, M. von Weber, *Front. Environ. Sci.* **13:1620191** (2025). doi:10.3389/fenvs.2025.1620191

[2] X. Lange, K. Klingbeil, H. Burchard, *J. Geophys. Res.: Oceans* **125(9)**, e2019JC015789 (2020). doi:10.1029/2019JC015789

Project Partners

HEREON, Institute of Coastal Systems – Analysis and Modeling; Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung; University of Kiel, Research and Technology Centre, West Coast; Leibniz-Institute for Baltic Sea Research Warnemünde; Leibniz University Hannover, Ludwig-Franzius-Institute; University of Veterinary Medicine Hannover, Foundation, Institute for Terrestrial and Aquatic Wildlife Research; Thünen Institute (SF/OF); Technische Universität Braunschweig, Leichtweiß-Institute for Hydraulic Engineering and Water Resources; Hamburg University of Technology, Institute of River and Coastal Engineering; University of Hamburg, Institute of Oceanography

Funding

BMFTR funded project Coastal Futures II (#03F0980B)

DFG Subject Area

3.41-02