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The Baltic Sea coast in the Anthropocene: a model for the consequences of climate change

Under the lead of the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), a review article outlined the state of the Baltic Sea coast and its expected development as a result of climate change. The article shows that the Baltic Sea can serve as a model for the consequences of climate change and that interdisciplinary research is needed to investigate changes in its shallow coastal zones. A focus is on researching the interactions between the coastal area and the open ocean and the aim is to develop a basis for marine conservation measures. The feature article was recently published in the journal Estuarine, Coastal and Shelf Science.

Coasts as key regions under pressure

The Baltic Sea is an inland sea that is connected to the North Sea only via the Kattegat and is almost entirely surrounded by land. As a result, there is little water exchange between the Baltic Sea and the ocean, causing nutrients and pollutants to accumulate in the Baltic Sea and remain there for decades. Additionally, the Baltic Sea warms up more intensely than the open ocean and is characterized by high nutrient inputs from the surrounding catchments. Today, 85 million people live in the Baltic Sea catchment area. Since the Baltic Sea is shallow, there is a strong interaction between the seabed and the water column. The article shows that human influence along the Baltic Sea coast has increased significantly in recent decades. Nutrient inputs have contributed to further eutrophication and, thus, to the occurrence of partly toxic algal blooms as well as to coastal oxygen decline. It was probably the combination of eutrophication and weather-related upwelling that led to oxygen depletion and mass fish deaths near Rostock in September 2025.

Climate change as an amplifier of existing pressures

The Baltic Sea is a sensitive ecosystem whose threats will be intensified by climate change in the future. For example, climate change is expected to cause more severe marine heat waves, further oxygen depletion, and more frequent and intense storms, which will affect marine material turnover and may harm marine life. The lead author of the study, Maren Voss, emphasizes: “The consequences of climate change and human activity will become particularly visible in the Baltic Sea.” There is an exceptional need for research into the intervowen and diverse effects of climate change on shallow coastal sediments, which are home to, for example, the resting stages of phytoplankton and the eggs of zooplankton. Phytoplankton includes single-celled algae and cyanobacteria, which can release toxic substances into the water during blooming. Zooplankton such as small copepods feed on phytoplankton and serve as food for marine animals such as fish. How coastal phytoplankton and zooplankton react to rising sea temperatures in the context of climate change has not yet been researched.

The following scenarios, among others, are possible in the context of climate change:

• **High nutrient inputs combined with rising water temperatures** will contribute to increased toxic algal blooms.

• **Oxygen deficits** in deep water may be further exacerbated by the microbial decomposition of dead algal blooms, leading to the spread of so-called dead zones into shallow water. In addition, greenhouse gases such as methane will be released.

• **Declining biodiversity in coastal areas** as land use increases, algae communities and seagrass beds decline, and important habitats for bottom-dwelling animals and fish fry disappear.

Interdisciplinary research as a basis for future measures

The study highlights that interdisciplinary research is essential for investigating coastal zones in the Baltic Sea and for evaluating their long-term development through observation programs. It remains methodologically difficult to carry out regular sampling campaigns of shallow coastal waters. State-of-the-art equipment and methods are currently developed at IOW for this purpose. According to the research team, suitable methods include, for example, measuring systems anchored to the seabed that send their data directly to the coast, drones that assist with sampling along the coastline, and optical remote sensing methods. Non-invasive methods for studying biodiversity, such as environmental DNA (eDNA), will continue to gain importance. There is also a particular need to develop models that simultaneously map various stressors in high spatial resolution—such as how nutrient inputs, warming, and sea level rise interact. This is essential to create realistic scenarios for the future that can serve as a basis for political decision-makers to take measures for marine and coastal protection. The IOW has launched the Shore2Basin (S2B) program to further develop methods for observing the Baltic Sea coastal zones, which will make an important contribution to the spatial and temporal resolution of observations. Furthermore, there are collaborations regarding international joint projects such as CoastClim between Swedish and Finnish universities. In August 2025, after years of planning, the first major research cruise with the vessel Elisabeth Mann Borgese took place as part of the S2B program. Further research cruises to study shallow Baltic Sea coastal waters will follow in the coming years. The collected data will allow new insights into the shallow water system and will be incorporated into the development of new measurement methods and long-term observation programs for marine protection.

Original publication:

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Scientific contact:
Prof. Dr. Maren Voss | Phone: +49 381 5197 209 | Email: maren.voss@io-warnemuende.de

Dr. Peter Holtermann | Phone: +49 381 5197 173 | Email: peter.holtermann@io-warnemuende.de

IOW media contact:
Dr. Sonja Ehlers | Phone: +49 381 5197 109 | presse@io-warnemuende.de

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