

Nitrogen cycling in shallow estuarine systems

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Eutrophication is the biggest environmental problem affecting the Baltic Sea. It is primarily driven by nutrient inputs from land and atmosphere that stimulate excess algal blooms, which shade out benthic vegetation in shallower waters and deoxygenate deeper waters. Healthy coastal ecosystems, characterized by structured habitats such as eelgrass meadows, large perennial macroalgae species and shellfish beds, possess the ability to retain and remove a substantial part of the nutrient inputs - until the systems become overloaded and these important ecosystem functions deteriorate. However, the factors regulating nutrient and organic matter processes remain poorly constrained in the complex coastal ecosystems. Previous studies have shown that the transitional zone from freshwater to marine is a potential hotspot for nitrogen removal and therefore, this project focuses on understanding the nitrogen cycle in such highly dynamic environments.

Studying the transitional zone is challenging due to rapidly changing hydrodynamics, creating a highly variable physical and chemical environment. Consequently, nitrogen cycling is understudied in such systems. To improve our scientific understanding of nitrogen cycling in these shallow estuarine systems, a group of nine international experts met in Roskilde, Denmark, in July 2025 to define the most important research questions and formulate a field sampling program to answer these questions. The expert group involved scientists from Sweden, Denmark, Germany, Netherlands, Lithuania and USA.



Photos from workshop with experts in nitrogen cycling in Roskilde, July 2025.

The main outcome of the workshop was designing a seasonal sampling campaign for the outlet of Hove Å in Roskilde Fjord, a small stream draining a catchment of ~70 km² dominated by agricultural land use. This sampling site is conveniently located to a campus of Aarhus University, simplifying the logistics, and more

important, the transition from freshwater to marine occurs over a relatively short distance with diverse habitats. In other words, this sampling site allows us to identify N-cycling processes in the shaded muddy part of the stream mouth, in mud/sand flats with benthic microalgae along the main channel of the small estuary, in the eelgrass meadows bordering the deeper areas of Roskilde Fjord, and in the deeper dark sediments beyond the eelgrass meadow. Hence, the sampling site allows us to compare N-cycling processes across this range of different habitats.



The stations at Hove Å mouth and estuary with different types of sampling carried out.

Bringing this group together also meant that many different aspects of N-cycling could be addressed with the broad expertise covered by the experts. These include examining for the different habitats the transformation of nitrogen compounds and phytoplankton community in the water column across the rapidly changing salinity gradient, sediment-water fluxes in light/dark conditions, N-processes (denitrification, Anammox, DNRA) in the sediment, sediment transport towards the deeper areas, high-resolution oxygen dynamics, greenhouse gas production (N_2O and methane), DNA/RNA of the microbial communities, and the presence of cable bacteria. These different aspects were solicited to the different research groups, ensuring that measurements were carried out by the most experienced scientists. This extensive collection of information related to the nitrogen cycle in the transitional zone from land to sea will give us all the puzzles to understand the role of these shallow estuarine systems for transforming and removing nitrogen, before it reaches deeper areas that are better studied.

The Björn Carlson Prize has been used to maintain a baseline monitoring program, infrastructure for the entire sampling program and support the many different research groups venturing to Hove Å for sampling. After a trial campaign in October 2025, eight campaigns were planned for 2026. Initially, the first campaign should have been carried out in January 2026, but this was not possible due to ice conditions. So far, four campaigns

have been conducted (March, April, May, June) and three more are in the planning (September, October, December). If resources and weather allow, a last campaign will be carried out in January 2027 to cover the coldest part of the year.



A small collection of photos from the sampling campaign in May 2026.

All samples from the campaigns are expected to be analyzed in spring 2027, and a one-week workshop for all the scientists in the campaigns is planned for summer 2027 for synthesizing all the results into scientific papers. Several high-impact papers are expected from this exercise, which could not have been possible without the support of the Björn Carlson Foundation.