AMBER Assessment and Modelling of Baltic Ecosystem Response

Deliverable B1-2

WP B.1 Estimate of N-removal in contrasting estuarine systems (24 mo)

Aim: Loss rates of nitrogen through denitrification and anammox in relation to the total nitrate loads of the river will be determined in systems contrasting in nutrient loads and residence times: the Oder River and Lagoon, the Nemunas River with the Curonian lagoon at the southern Baltic Kalix River in northern Sweden.

Purpose: To improve the parameterization of the coastal biogeochemical model and thereby improve the predictive capacity of the models.

Method: Field investigation in 2009 and 2010 in the Curonian and Oder lagoon and in 2010 in the Kalix; isotope pairing technique to quantify denitrification and anammox; stable isotopes in nitrate (d15N and d18O); nutrient concentrations (NO3-, NO2-, NH4+, PO43-).

Deliverables: Overall assessment of nitrogen removal capacity in Baltic estuaries depends on loads and residence times.

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Partners: UH, IOW

Internal linkages: Input for WP C.4., D6, 10

Implementation: Due to the budget cuts the observation program was reduced. Samples were collected from the Arkona basin in southern Baltic Sea on several cruises 2009-2010 to follow the seasonality of nitrogen removal processes. The Oder lagoon was visited once during the active removal season (June 2010). These field campaigns were performed by researchers of University of Helsinki and Institute for Baltic Sea Research (IOW). The Curonian Lagoon nitrogen removal capacity of the River Nemunas nitrate loading was evaluated by researchers of the Klaipeda University.

Results:

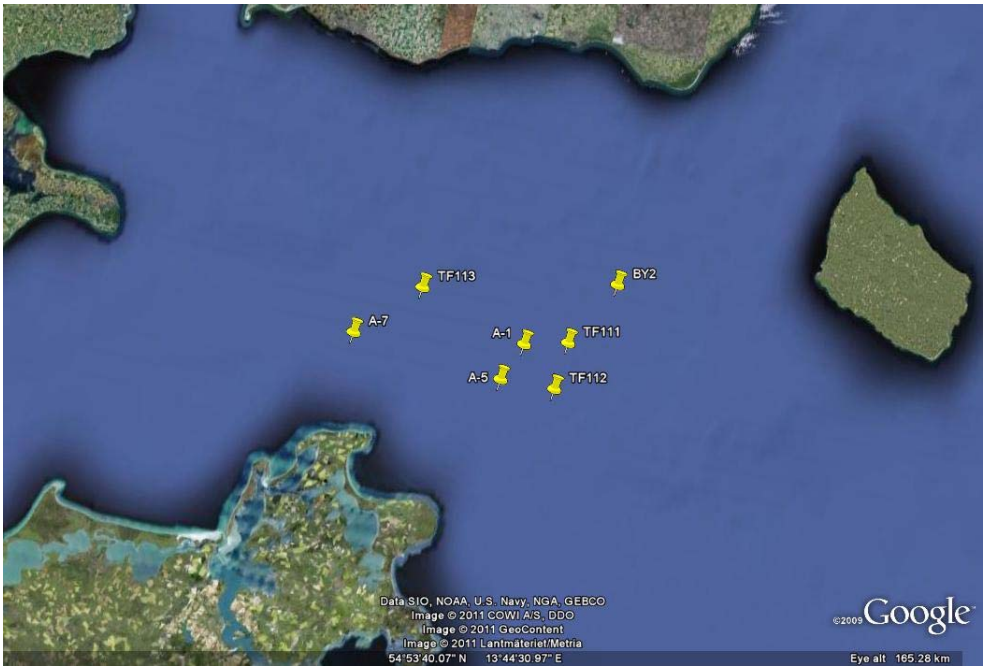
Arkona basin

The nitrogen removal capacity varied largely in the Arkona basin, and was probably mainly limited by substrate availability (the amount of nitrate to be reduced), as nitrate concentrations in the bottom water never exceeded 6 µM. It is remarkable that the rate was rather high both early in the spring when the temperature was below 3 °C and in the summer when the temperatures varied from 6 to 12 °C (Table 1). We also have data from an earlier cruise made in winter, and the rate measured then was similar to those measured here (210 µmol N m^{-2} d^{-1}, station GWB2, December 2007, unpublished data from Dr. Barbara Deutsch, IOW). Obviously, while temperature plays a large role in regulating these microbial processes, they are co- limited (with nitrate) by something else than temperature in the warmer season. The most likely regulators are the amount of organic carbon and oxygen. Lack of carbon both limits the growth of these heterotrophic bacteria and limits the amount of ammonium available for the aerobic nitrification process, feeding the removal processes. As the

Arkona area is very productive, shortage of organic matter is unlikely to occur. The basin seasonally turns hypoxic, with even anoxia found in late summer, but the lowest oxygen conditions measured during these field campaigns were about 5 ml O_2 l^{-1}, which is well above the hypoxia threshold of 2 ml O_2 l^{-1}. It is therefore possible that the rates we measured represent the "healthy" nutrient cycling situation, with lower N removal capacity during anoxia when no nitrate is formed to feed the removal processes. The removal rates we measured during these campaigns were very similar to rates measured elsewhere in the Baltic Sea muddy sediments.

Table 1. N removal in Arkona Basin during the field campaigns of AMBER project.

Date	Station	Depth m	N removal µmol N m^{-2} d^{-1}	Temp °C	Sal	O_2 ml/l	NO_x- µM	NH_4+ µM
March-2009	A1	45	130	2.5	12.5	8	6.1	
March-2009	A5	40	280	2.6	11.8	8.2	3.7	
March-2009	A7	41.5	60	2.7	11.2	7.74	4.6	
June-2009	BY2	48	90	9.4	15	5.3	1.0	1.1
July-2009	TF113	47	200	12		5.21	1.9	n/a
June-2010	TF112	37	250	5.98	7.98	5.46	0.6	1.2
June-2010	TF111	40	210	6.4	8.6	5.03	1.4	2.7



Estuary of River Nemunas and the Curonian Lagoon

N removal in estuarine system of the Curonian Lagoon was estimated by the Lithuanian group (Prof. Arturas Razinkovas and PhD student Mindaugas Žilius). Preliminary results suggest a balanced budget of inputs by the river Nemunas and the removal via denitrification in the Lagoon. Nevertheless the outflowing waters have still high concentrations of dissolved inorganic nitrogen (DIN, see cruise report and Poster by Korth et al. 1st annual BONUS conference in Vilnius January 19-21 2010). The nitrate isotopic value (d15N and d18O) has been measured from the Nemunas area

and the data is presented in "Scientific Report of AMBER subproject WP B.3 Isotopic signature in nitrate for source identification". Evaluation is in progress.

The Oder Estuary Lagoon

N removal in the estuarine system of the Oder Lagoon was measured in June 2010 using the IPT method. Extremely high removal rates were found, which was to be expected with the high temperatures of this shallow lagoon, and very high nitrate concentrations (around 60 µM). Nitrogen removal was nitrate limited despite the very high nitrate concentration at the stations 1 and 3, indicating that nitrate diffusion to the sediment was slower than the processing of nitrate by the bacteria. Nitrogen removal was highly dependent on the nitrate in the water column at these stations, with nitrification in the sediment showing minor contribution to feeding the process. At station 2 nitrate concentration did not limit nitrogen removal that was probably limited by availability of carbon (more sandy sediment). Nitrogen removal was also tighter coupled to nitrification in the sediment at this station.

Table 2. N removal in Oder Lagoon in June 2010 during the field campaign of AMBER project.

Station	Depth m	N removal µmol N m^{-2} d^{-1}	Temp °C	Sal	O_2 ml/l	NO_x- µM	NH_4+ µM	PO_4^{3}- µM
1	6.4	5100	18.7	0	4.3	65.7	1.2	1.7
2	6	6000	19.2	0	4.6	63.2	0.9	3.0
3	6.4	7900	18.5	0	3.8	60.9	1.5	1.6

These measured nitrogen removal rates are the highest ever measured in the Baltic Sea using the modern IPT technique. Still, plenty of nitrogen probably also left the estuary, as has been noticed also before, due to the short residence time of the lagoon water (high DIN concentrations were found off the outflow in spring 2009, see cruise report and Poster by Korth et al. 1st annual BONUS conference in Vilnius January 19-21 2010). In such shallow system the temperature variation probably plays a major role in regulating the nitrogen removal rate. The rates measured in June with

high temperature at the bottom water probably represent annual high rates, with considerably lower rates in the cold season, which should be taken into account when calculating the annual self-purification capacity of the Lagoon. Unfortunately no additional sampling could be done at this extremely active area to cover the seasonal variation. The nitrate isotopic value (d15N and d18O) has been measured from the Oder Lagoon and the data is presented in “Scientific Report of AMBER subproject WP B.3 Isotopic signature in nitrate for source identification”. Evaluation is in progress.