Resuspension effects in the shallow eutrophic lagoon: modeling & experimental study

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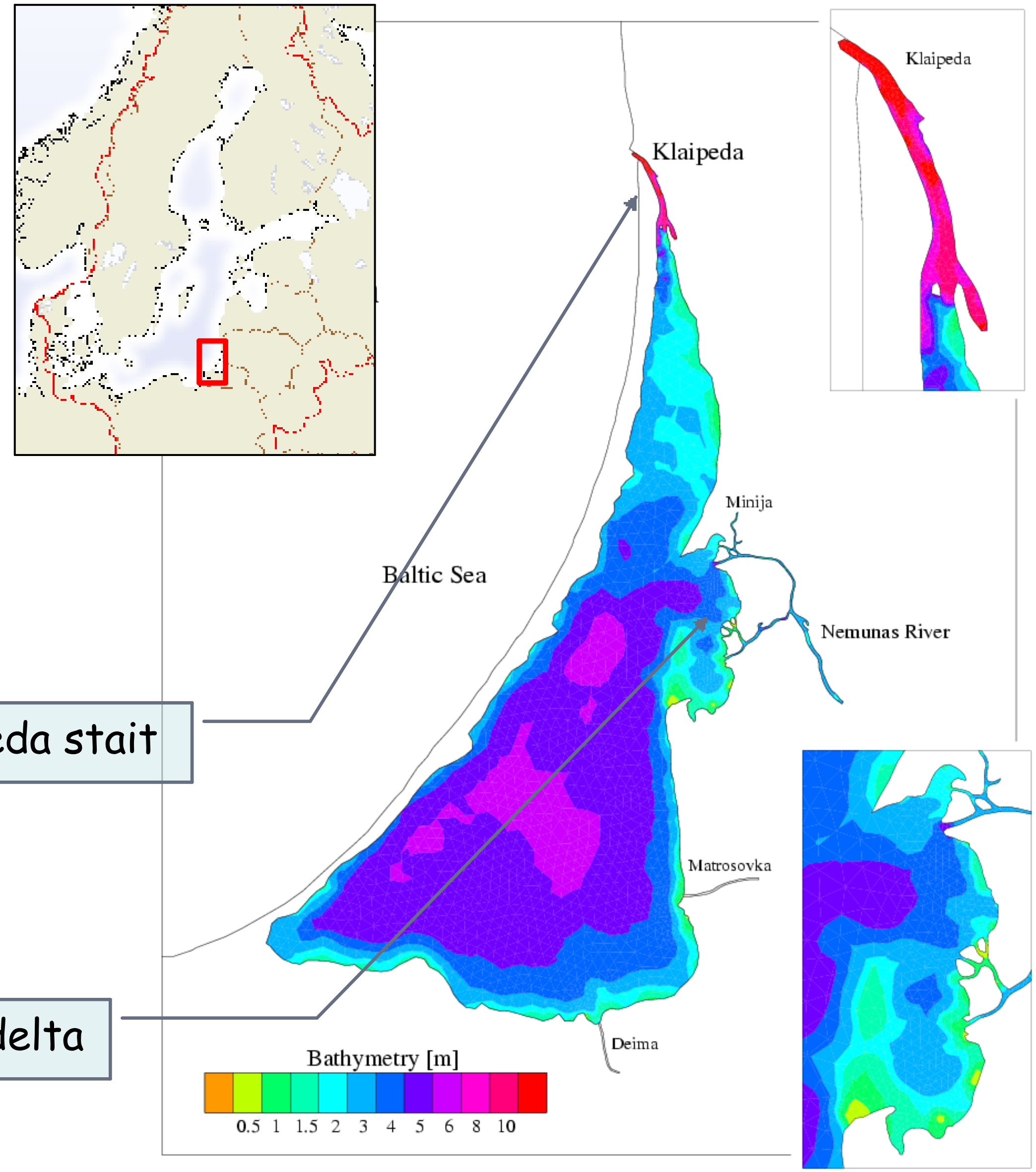
The Curonian Lagoon

It is an open predominantly freshwater system, influenced by the exchange of fresh Nemunas river water and saline water of the Baltic sea in the northern part.

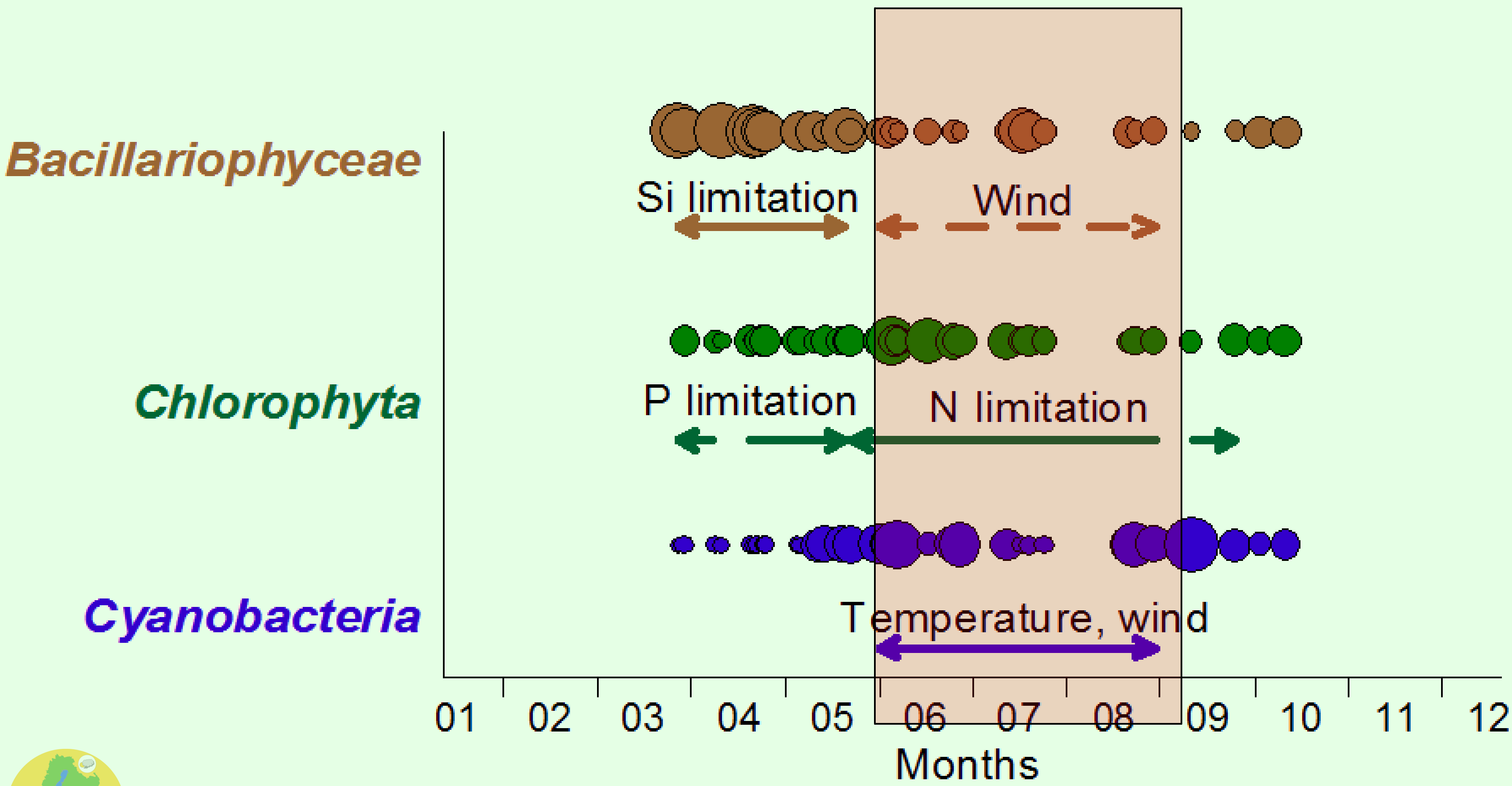
Area characteristics:
- surface = 1600 km2
- average depth = 3,6 m
- salinity = 0 - 7 psu




Partially toxic Cyanobacteria blooms
Chlorophyll A up to 300 mg/l

Succession patterns

(*after Pilkaityte and Razinkovas, Hydrobiologia, 2006*)



Methods

SHYFEM - Hydrodynamic model

Water currents and water level are computed in function of the forcings: tide, wind and pressure.

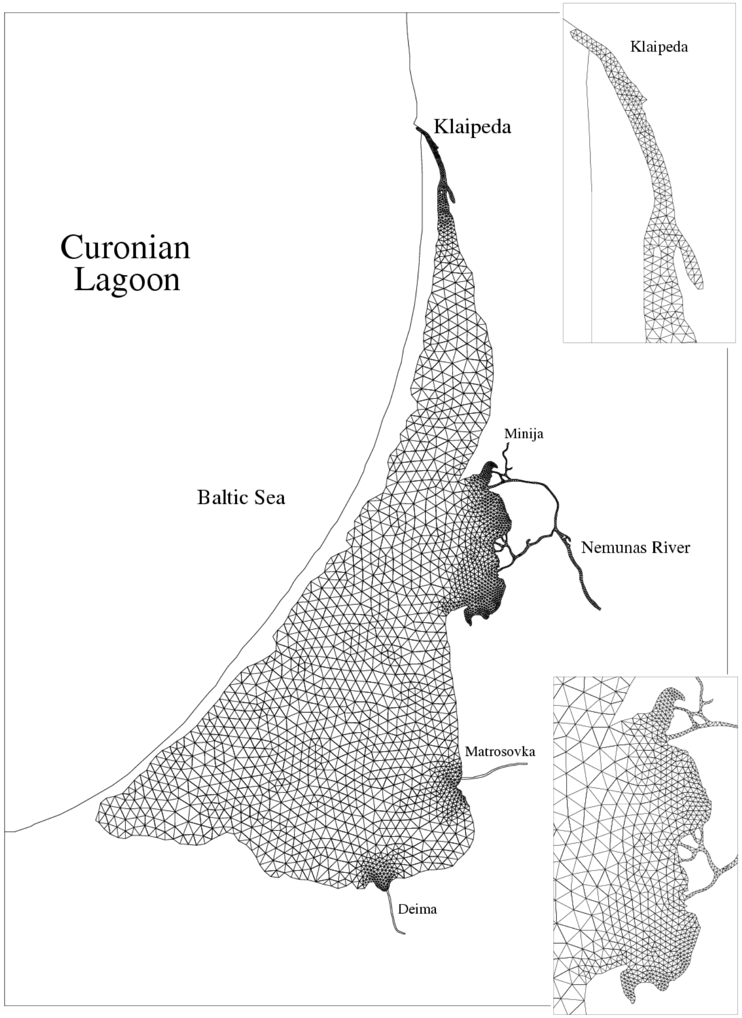
2-3D Finite element hydrodinamic model which resolves the SHALLOW WATER equations:

$$\frac{\partial U}{\partial t} - fV + gH\frac{\partial \zeta}{\partial x} + RU + X = 0$$

$$\frac{\partial V}{\partial t} + fU + gH\frac{\partial \zeta}{\partial y} + RV + Y = 0$$

$$\frac{\partial \zeta}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$$

ζ = water level
H = water depth
g = gravity
f = Coriolis parameter
R = friction coefficient
U, V = velocities
X, Y = all other terms



The finite element method permits to follow faithfully the morphology and the bathymetry (channels, barene, ecc…) using different resolution.

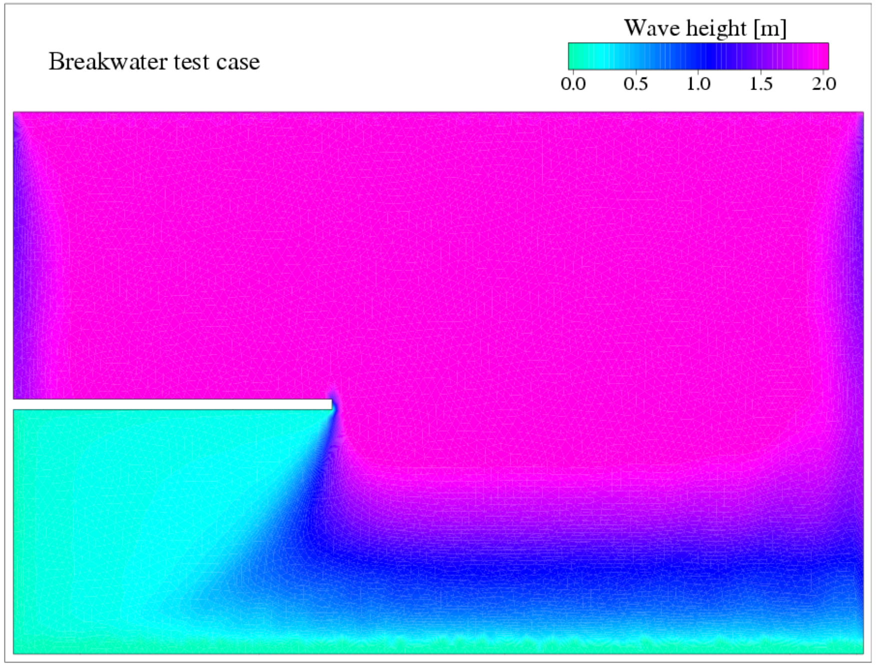
Wind Wave model

Waves play an important rule on the resuspension of sediment in shallow water enviroment, like lagoons and coastal areas.

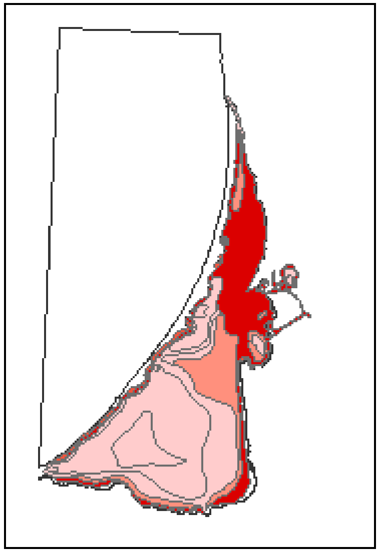
Finite element spectral wave model based on the spectral action balance equation (Hsu et al, 2005):

$$\frac{\partial N}{\partial t} + \frac{\partial (C_x N)}{\partial x} + \frac{\partial (C_y N)}{\partial y} + \frac{\partial (C_\sigma N)}{\partial \sigma} + \frac{\partial (C_\theta N)}{\partial \theta} = S_{total}$$

N = wave action density
S = source term



Resuspension



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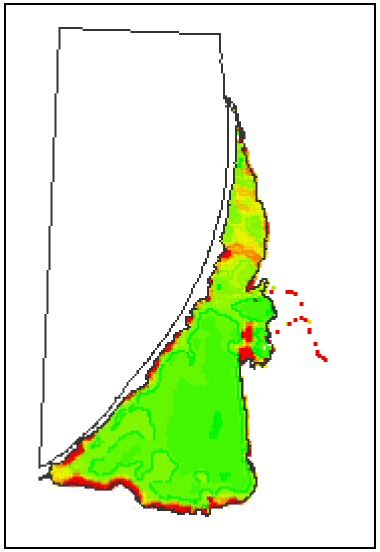

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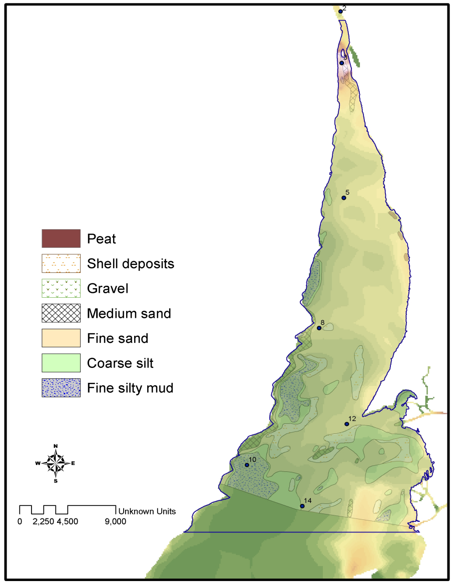


Empirical critical stress values for different sediment types

Calculated daily bottom shear stress maps

Resuspension events, days/year

Experimental approach

A)

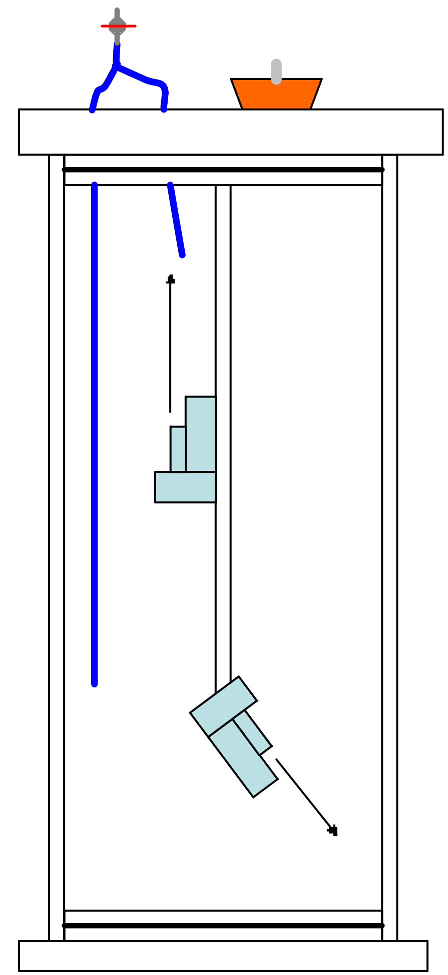
- 15 d cm intact sediment cores (muddy&sandy)
- Resuspended manually (~5 cm layer)

B) Seasonal experiment

- 9.5 d cm intact sediment cores (muddy&sandy)
- Upper 5 cm resuspended
- 3 replicates for each type of sediment (sandy & muddy)
- Incubation of resuspended sediments in benthic chambers for 32 h

C)

- Natural wind induced resuspension events followed in the field study



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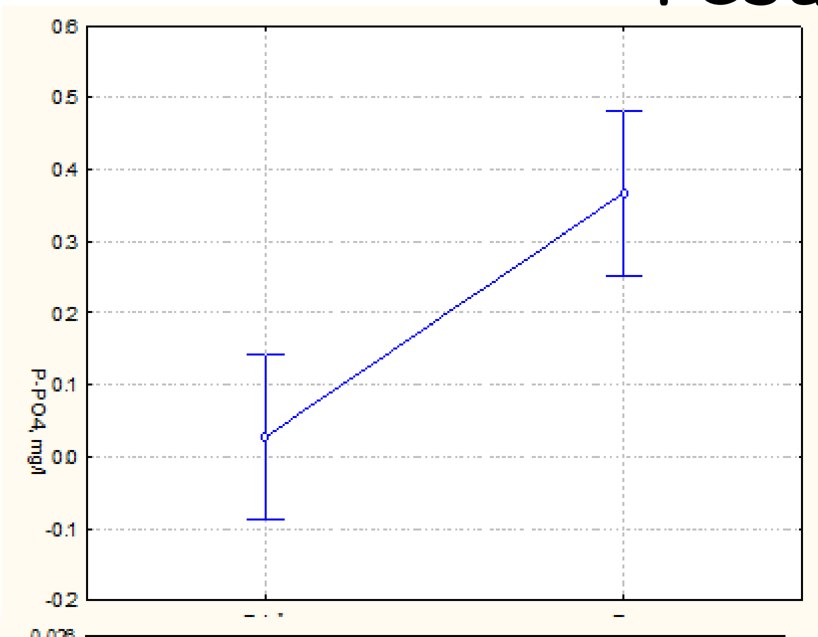
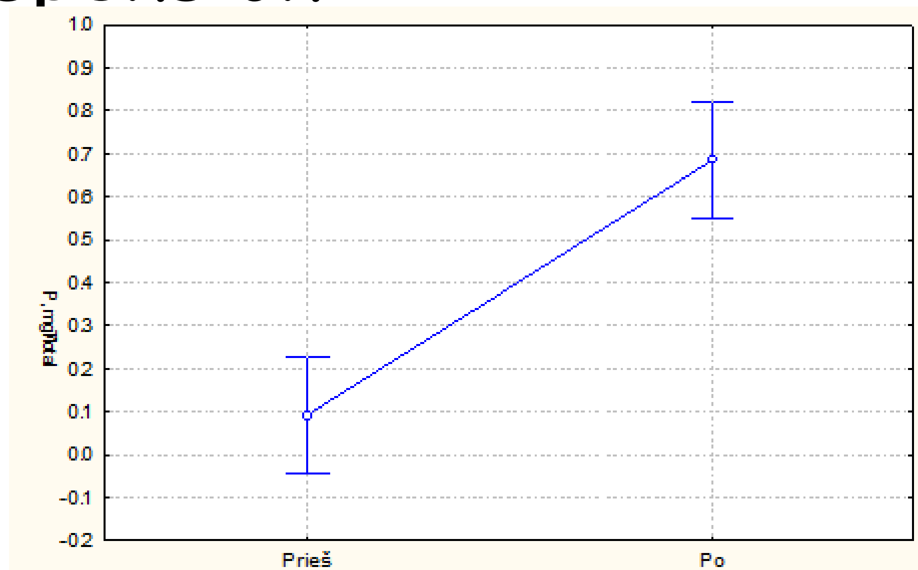
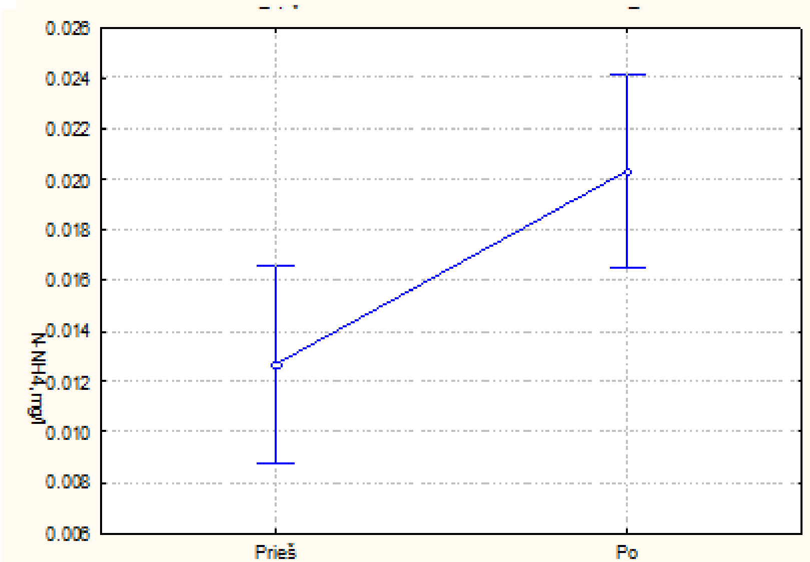
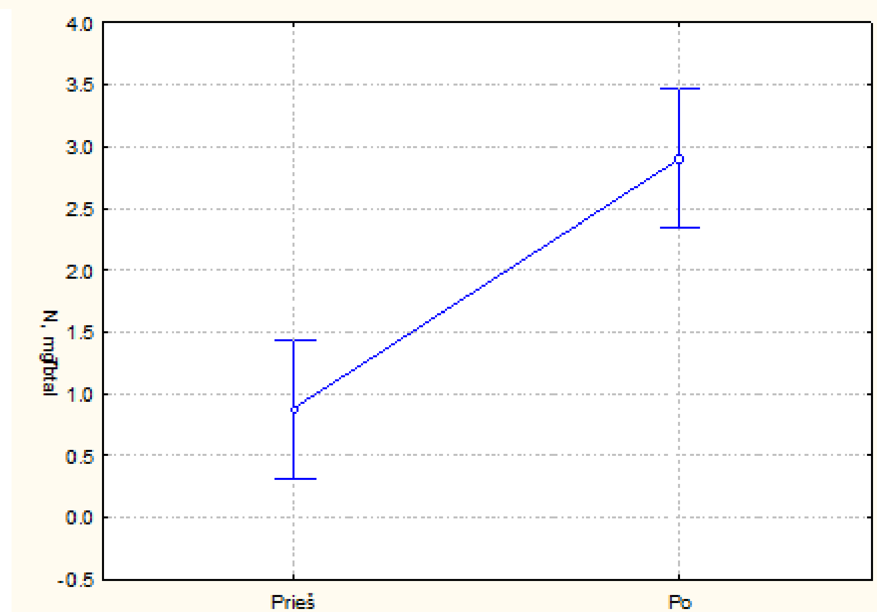
Results

Immediate changes after the experimental resuspension

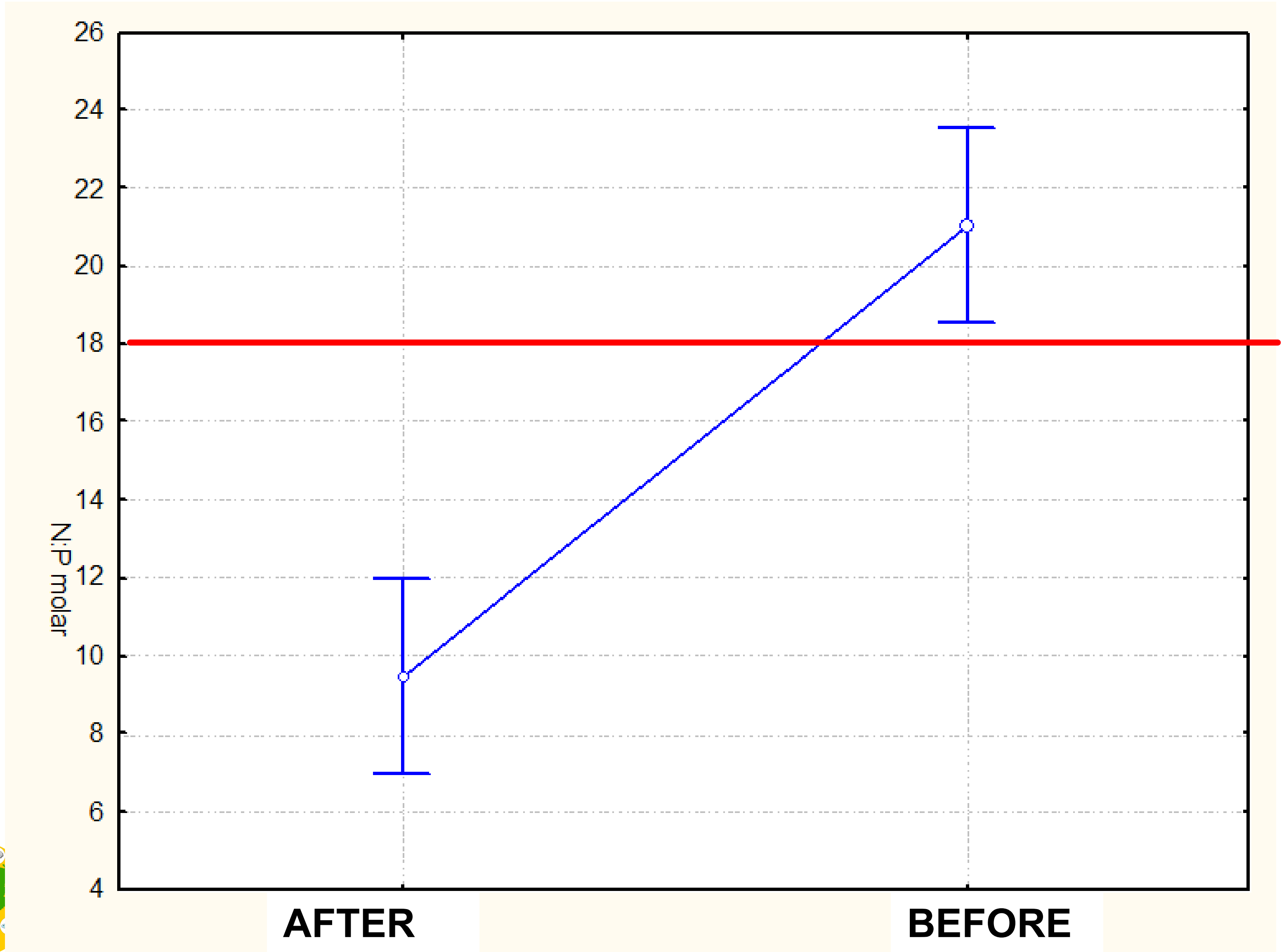




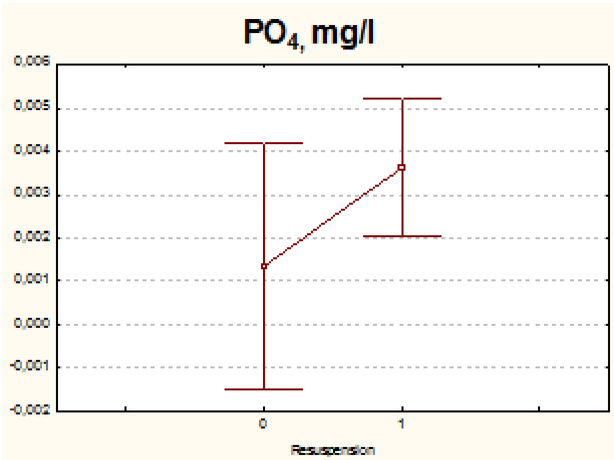


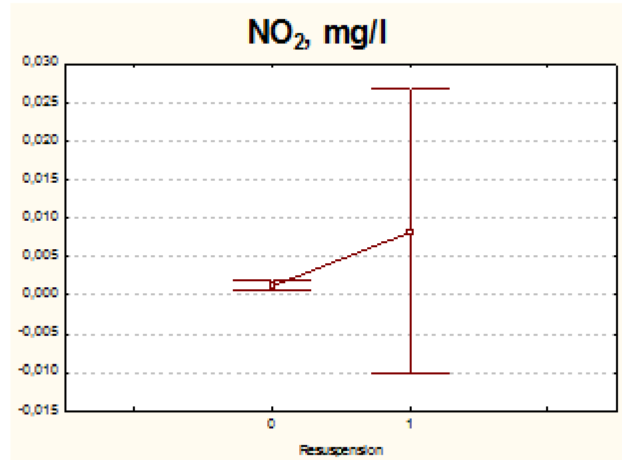


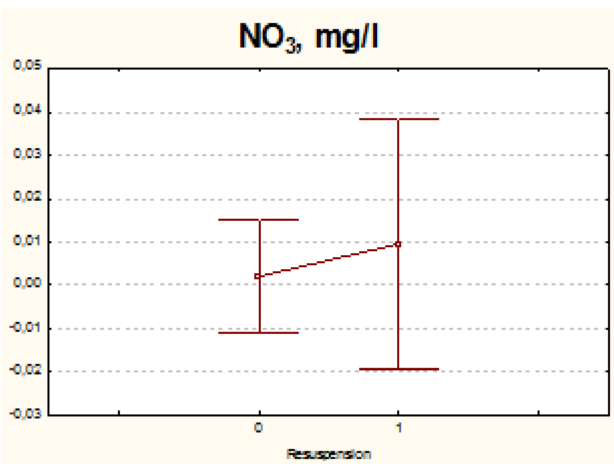
Immediate changes in total N:P ratio after the artificial resuspension

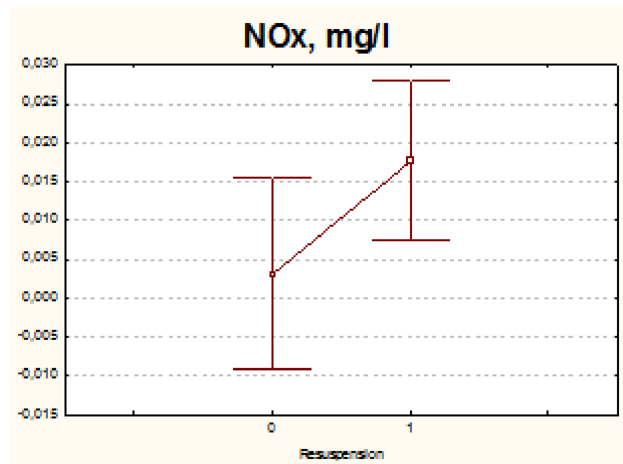


Wind induced natural resuspension effects

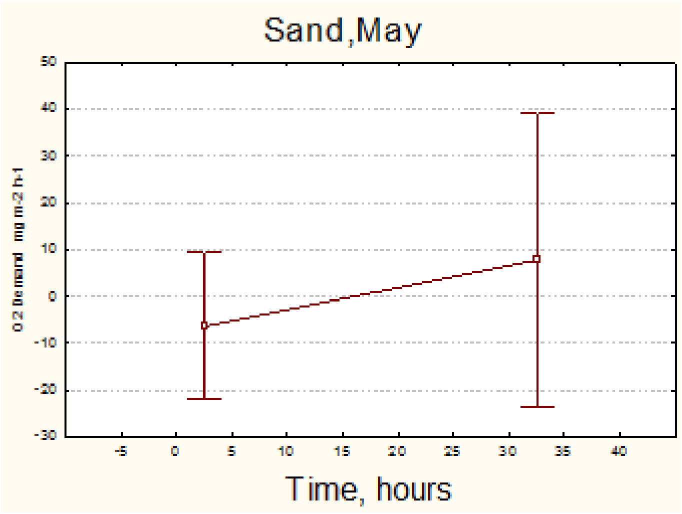


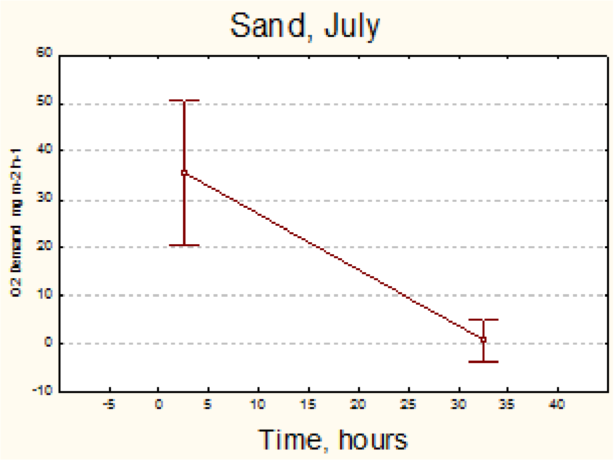


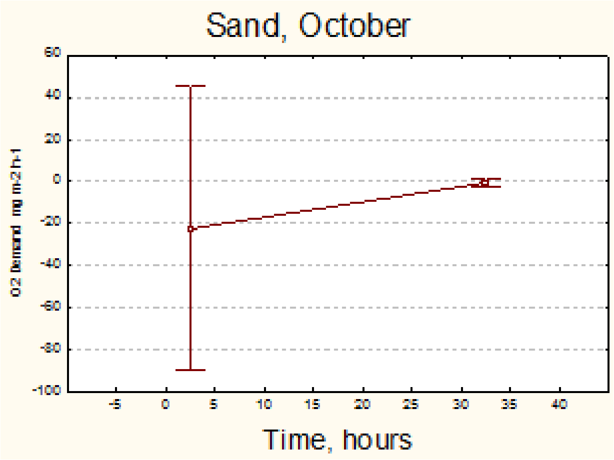




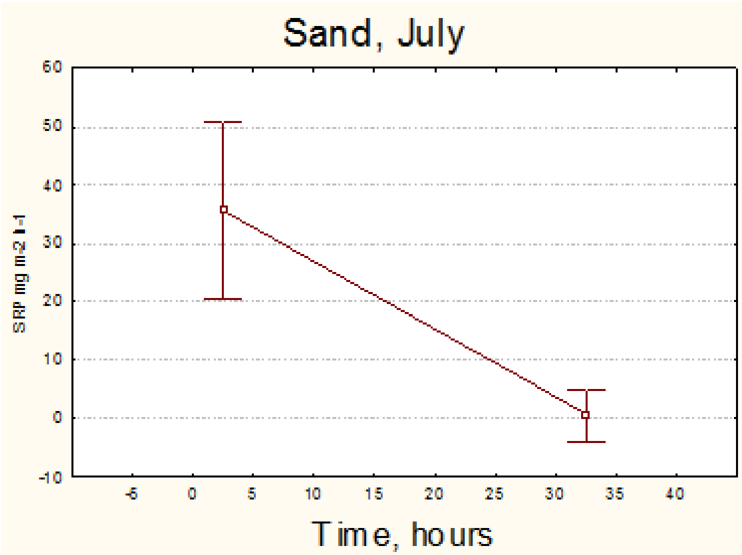
Oxygen demand changes during the incubation experiment

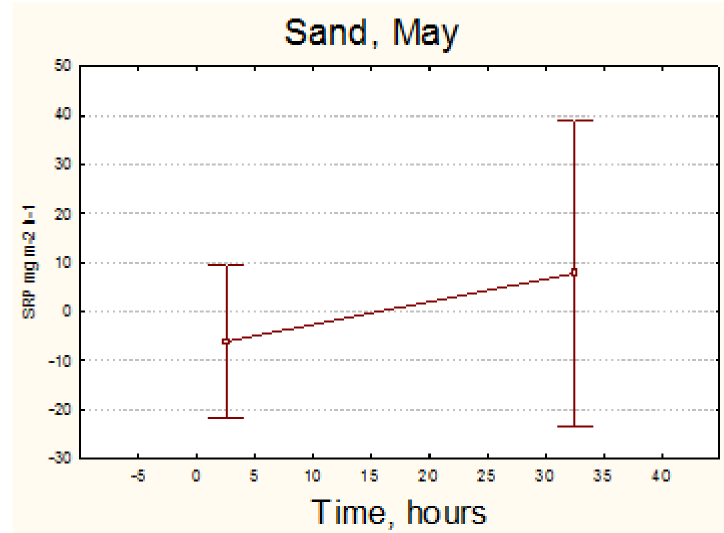


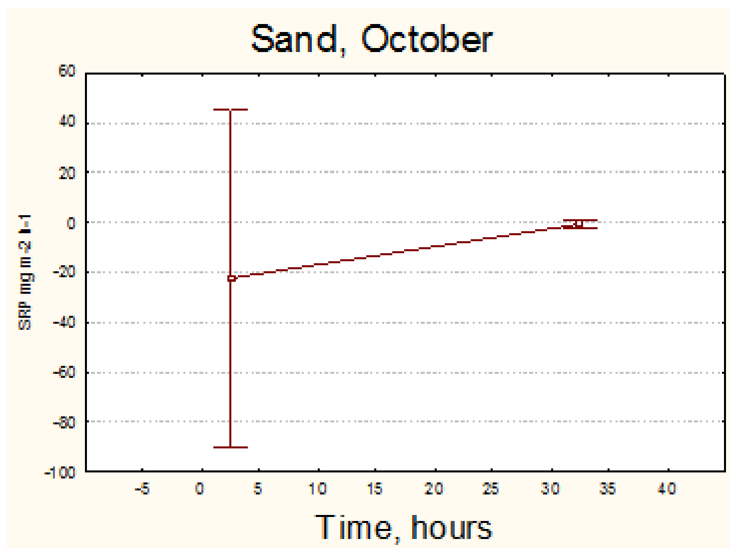




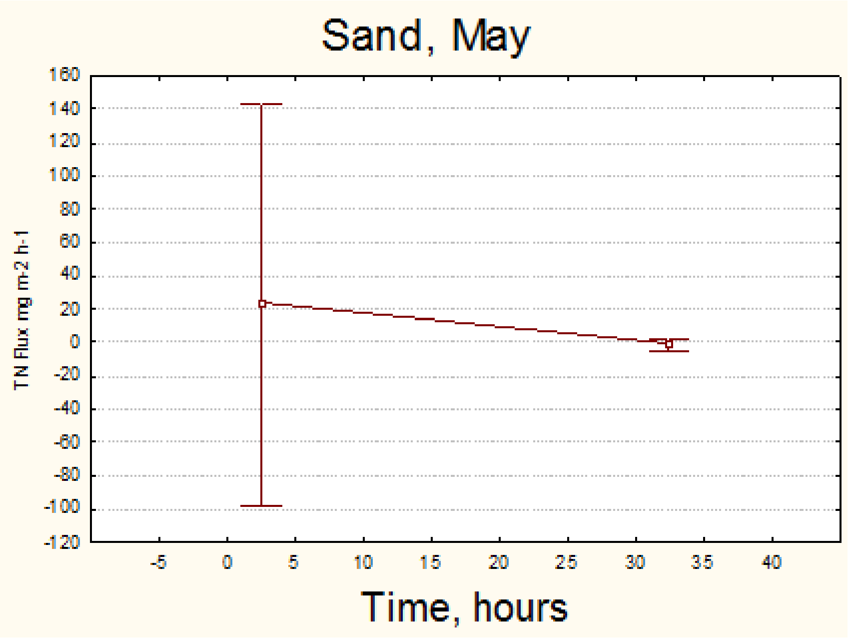
SRP flux changes during the incubation experiment

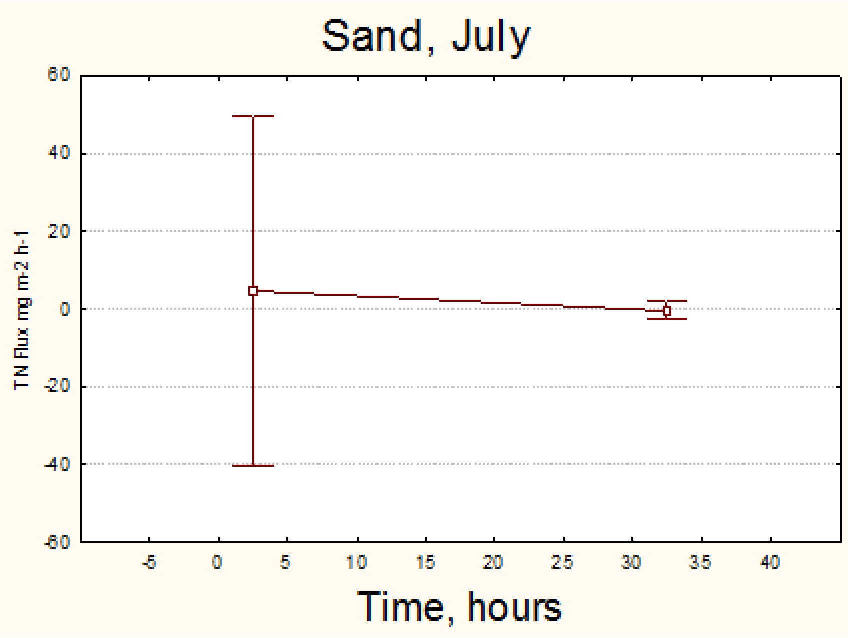




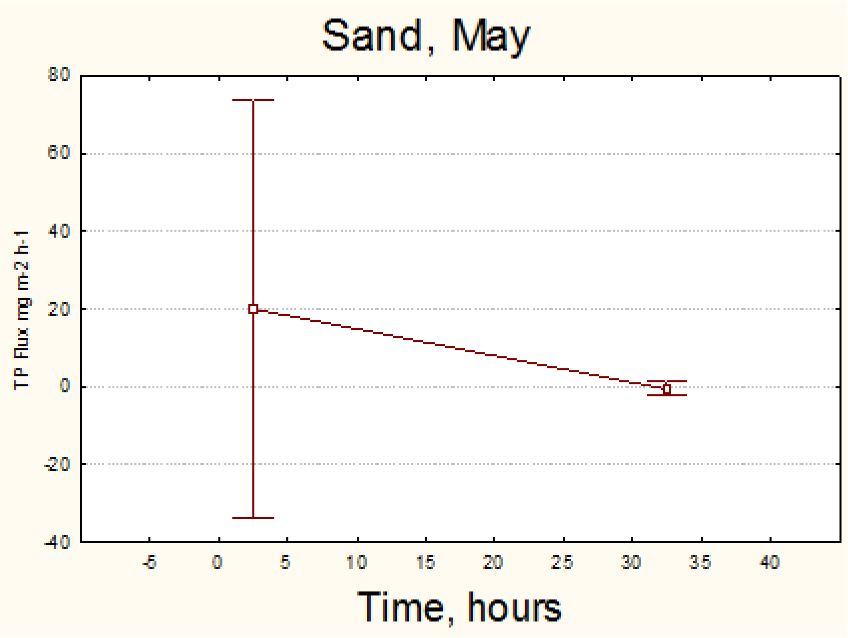


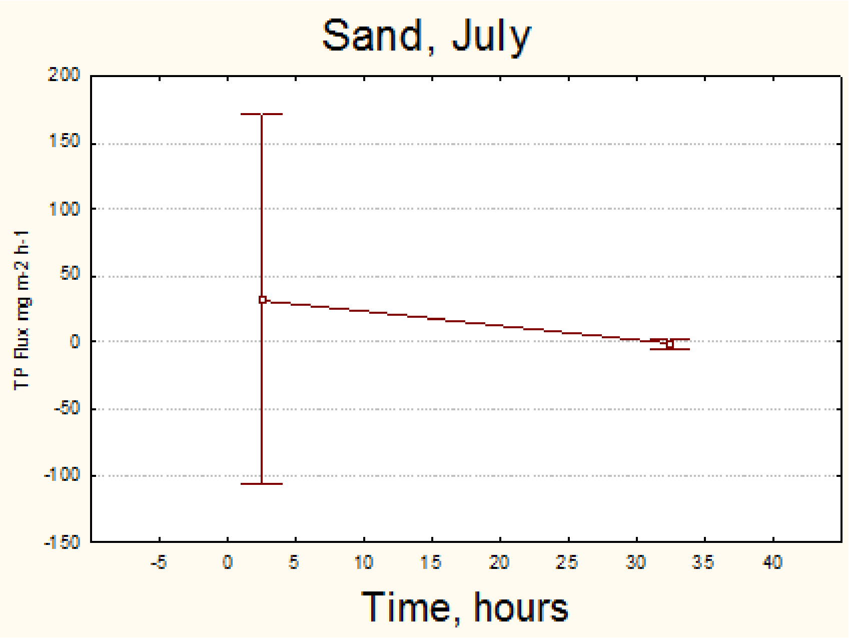
TN flux changes during the incubation experiment





TP flux changes during the incubation experiment





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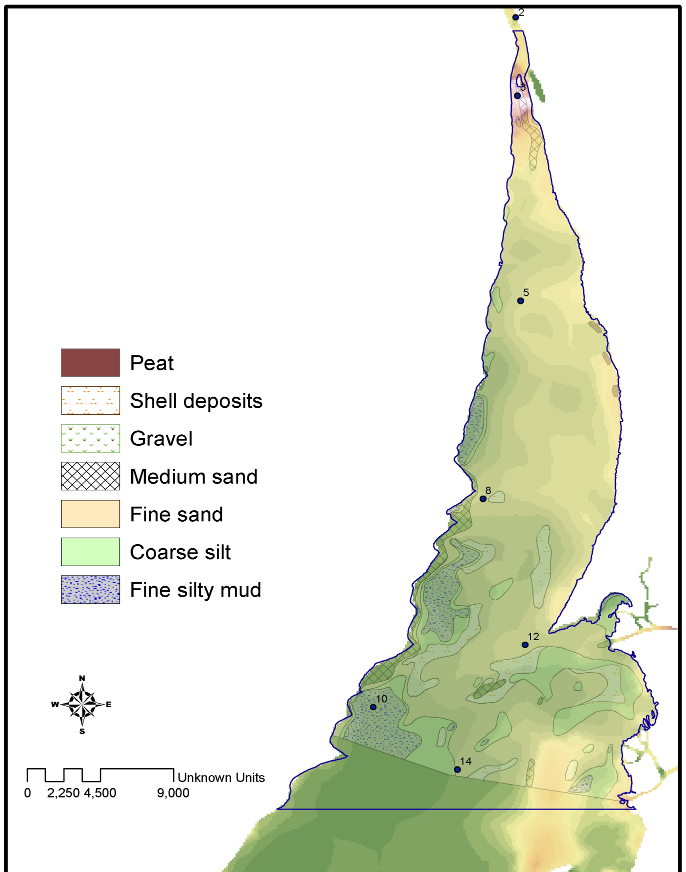
Calculated shear stress values & sediments



Calculated as for 2000 climatic conditions at study site (northern part of the lagoon)

Sandy sediments 34.6 % time over critical shear stress values

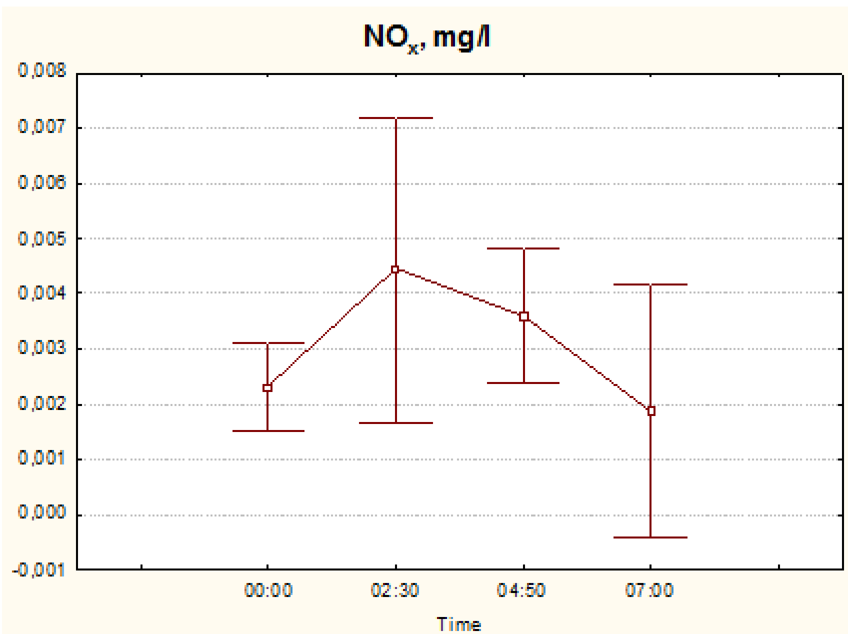
Muddy sediments 20.5 % time

over critical shear stress values

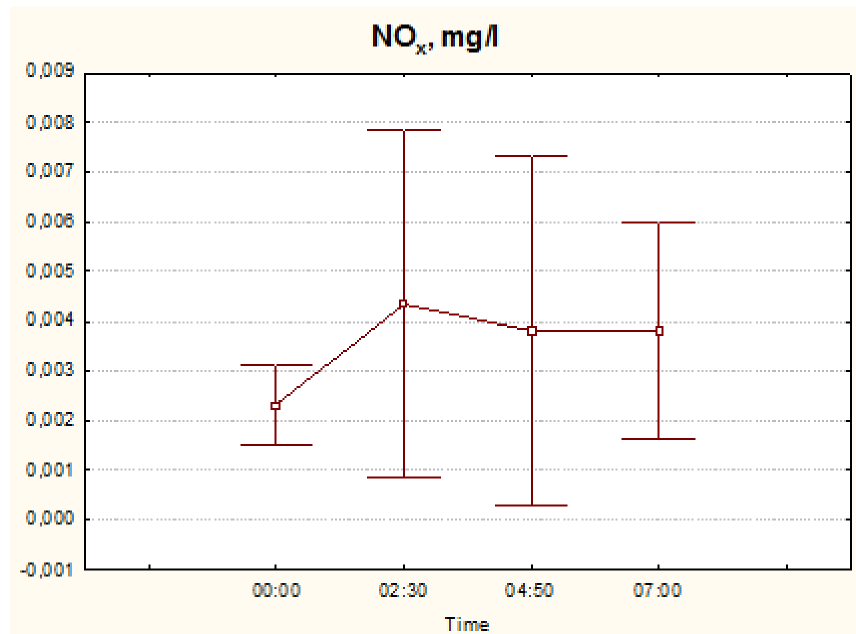
CONCLUSİONS

- Resuspension model follows quite well the sediment distribution pattern.
- Resuspension enhances significantly bentho-pelagic exchange increasing the nutrient flux (primarily organic) from bottom sediment to the water column
- İn the Northern part of the lagoon nearly 1/3 of the year shear stress values are over the critical value threshold.
- There was high interseasonal variation in the resuspension effects on the concentrations of DIN and DIP, which needs more background data on the nutrient and phytoplankton for interpretation
- There was a shift towards N limitation in the molar total N:P ratio immediately after resuspension, however, after 32 hours incubation Total N and P concentrations were as low as the pre-resuspension levels
- Variation in the experimental results was very high – could be attributed to the sediment heterogeneity in replicate samples

NOx concentration changes during the 7h incubation experiment



No nitrification inhibition



Nitrification inhibition