Coastal Water Council - Stakeholder Board Meeting

Ringkøbing, December 8th, 2023

Modelling of Ringkøbing Fjord to support policy-makers for compliance with the EU Water Framework Directive

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Model achievements

- Catchment model (SWAT+): nutrient exports from land
- Hydrodynamic model (Delft-3D): water circulation in the fjord
- Vegetation model: seagrass and epiphyte growth
- Shellfish model: sand mussel (*Mya arenaria*) growth
- Ecological model: general biogeochemistry

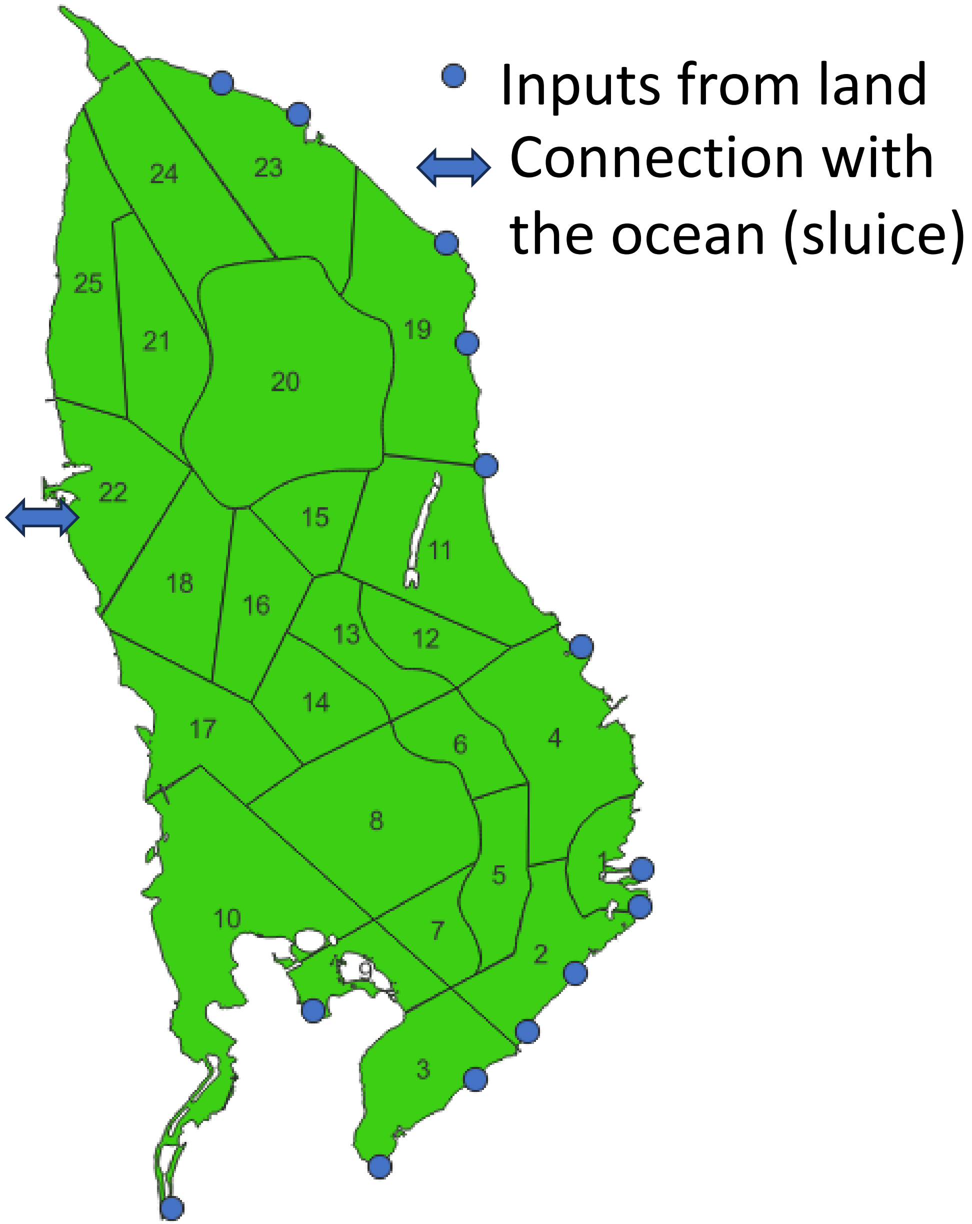
All these components are now integrated in an ecosystem scale model applied to the Ringkøbing Fjord (EcoWin).

EcoWin model setup

Ringkobing fjord is divided into 50 boxes (25 upper and 25 lower boxes).

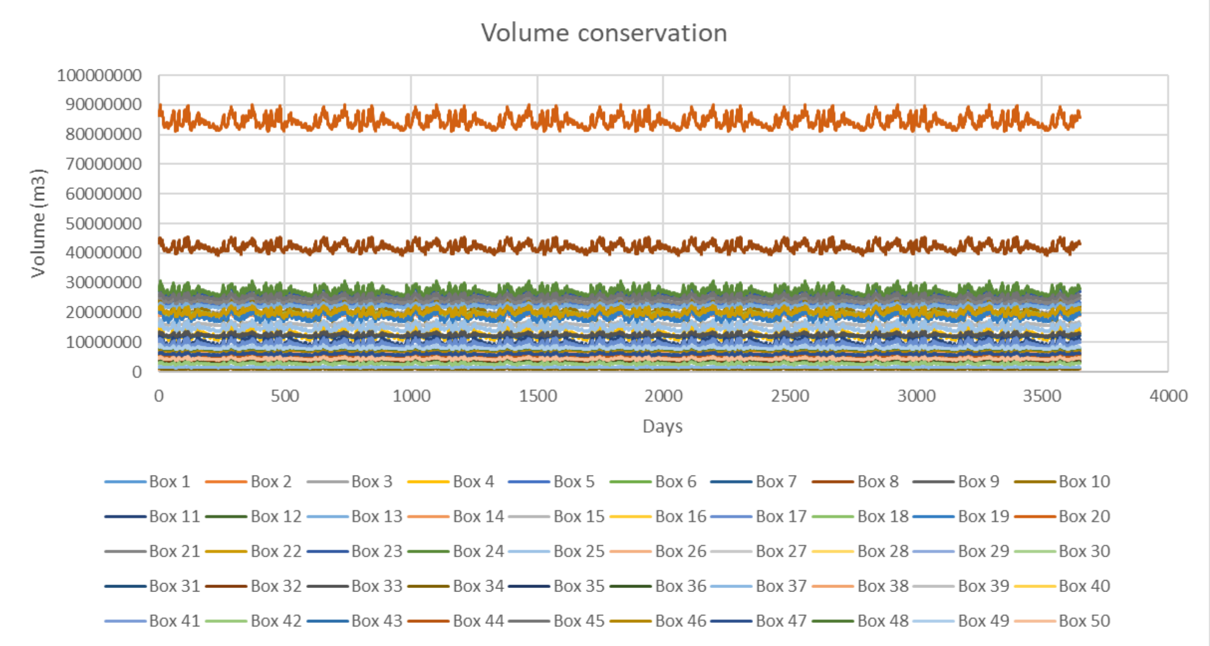
Boundary conditions include:

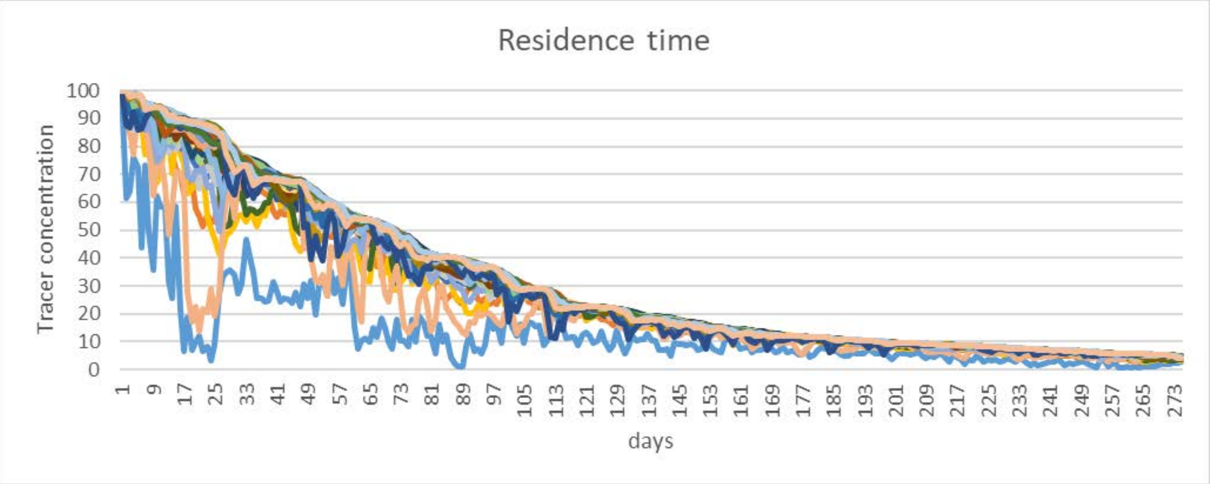
- the connection with the ocean (sluice model)
- loadings from the catchment



The box delineation allows the simulation of the impacts of different pressures on the ecosystem at a high resolution.

Model stability and residence time

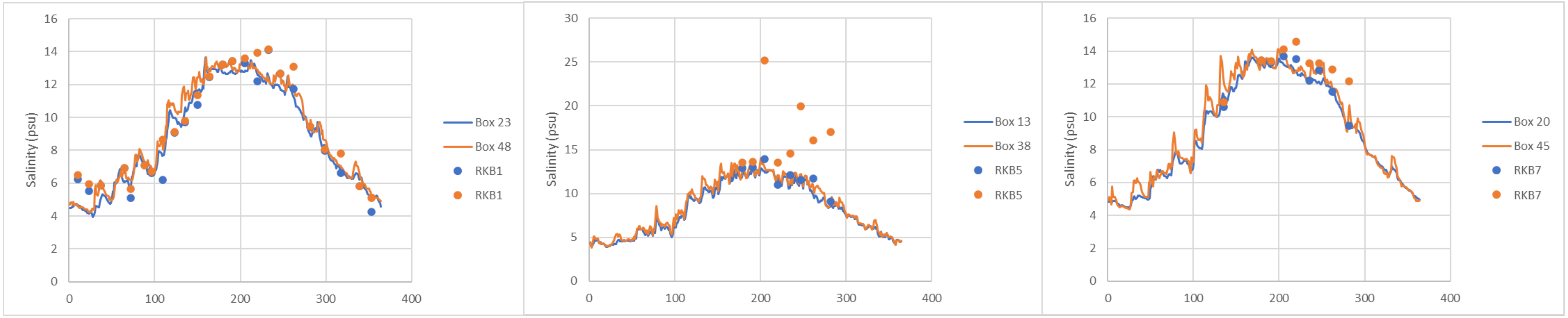




- Hydrodynamic models take a very long time to compute and can only be run for 1 year.
- In EcoWin, a reference year (2017) is run cyclically for a 10 year period to ensure the stability of the physical and biogechemical processes.
- Residence time can be estimated looking at the decay of a conservative tracer. It ranges from 36 to 95 days. It is shorter for the box at the mouth of the Skjern river (13 to 18 days).

Volume conservation was verified for each box: upscaling from the hydrodynamic model to the ecosystem-scale model is validated.

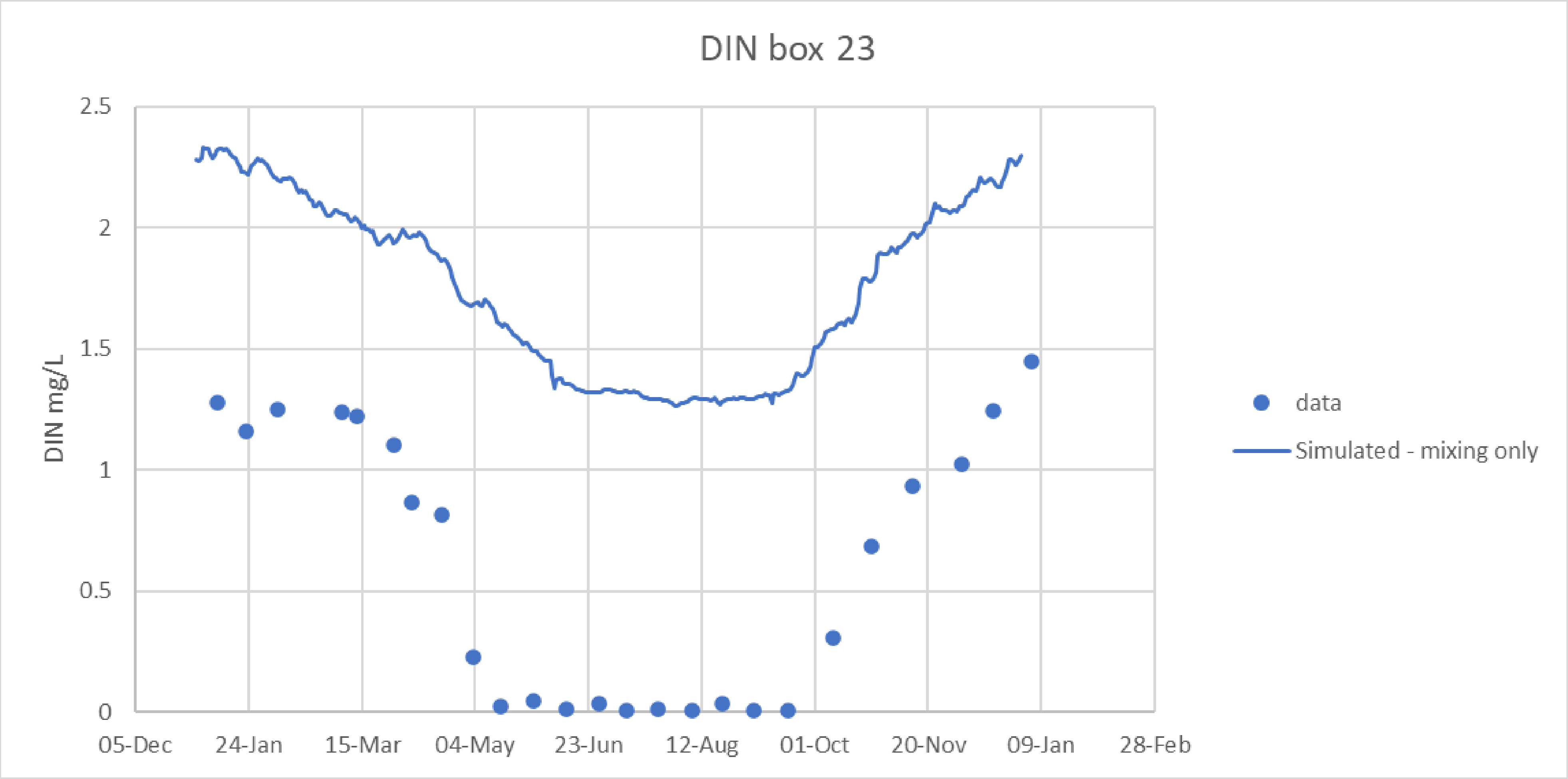
Salinity



- Salinity seasonal patterns are well reproduced for all the boxes where data for comparison are available
- Stratification observed in boxes 13/38 is not well reproduced by the model because the large size of the boxes in EcoWin makes small-scale process like stratification difficult to reproduce
- This issue is not expected to impact the biogeochemical processes simulated at the ecosystem scale

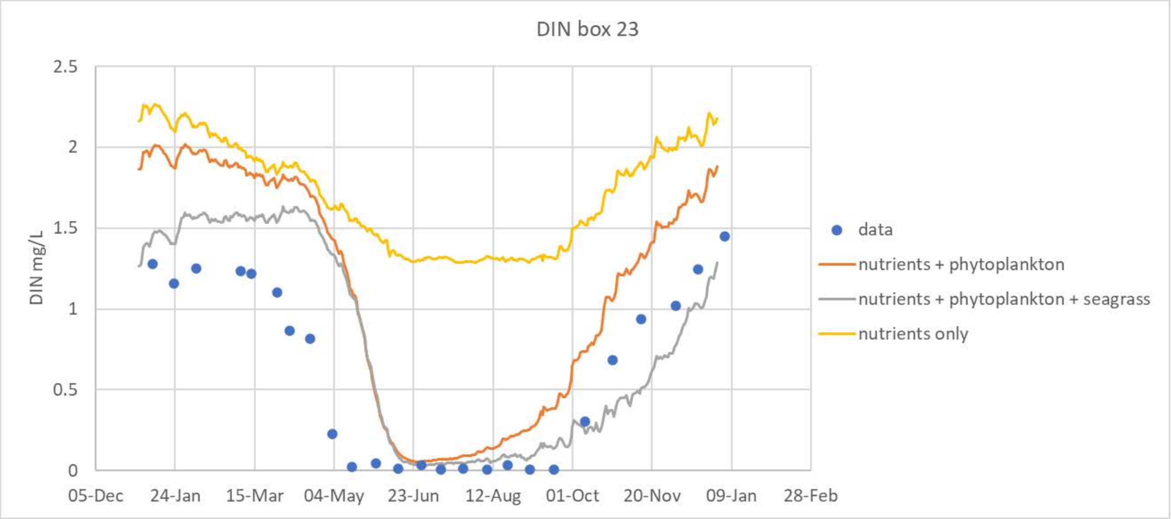
The circulation of water and mass simulated by the hydrodynamic model is well reproduced by EcoWin model.

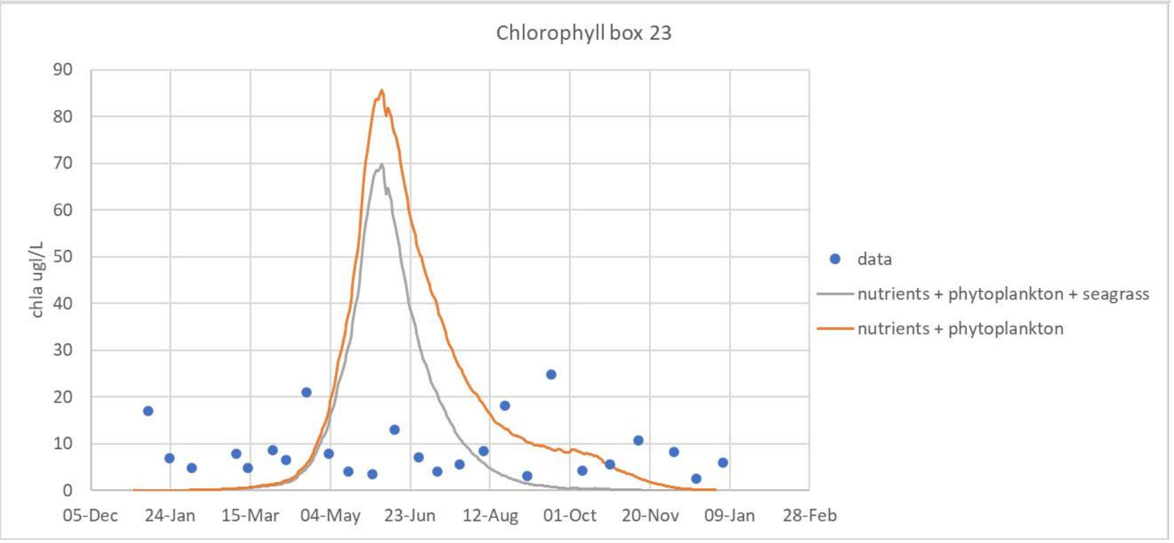
Dissolved Inorganic Nitrogen (DIN)



Nutrients are not conservative: they are affected by biogeochemical processes occurring in the fjord and cannot be reproduced only by combining inputs from the catchment and from the ocean.

Dissolved Inorganic Nitrogen (DIN) and chlorophyll a

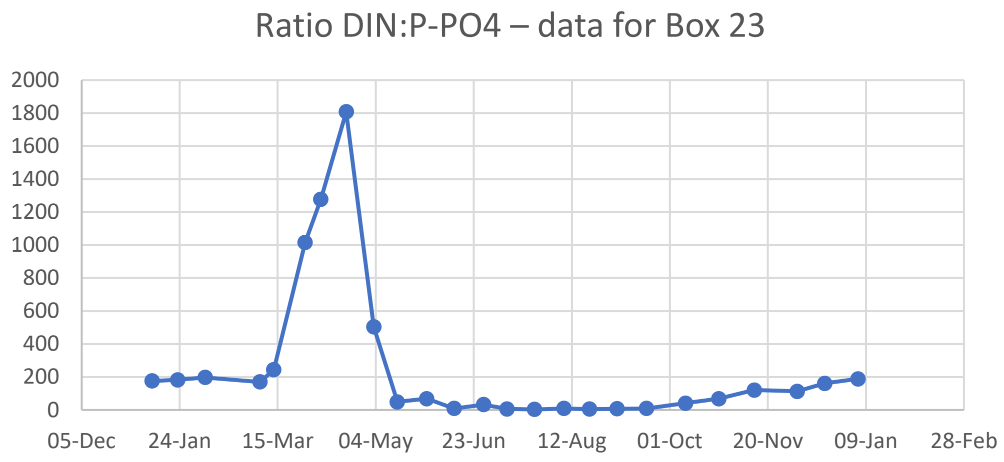


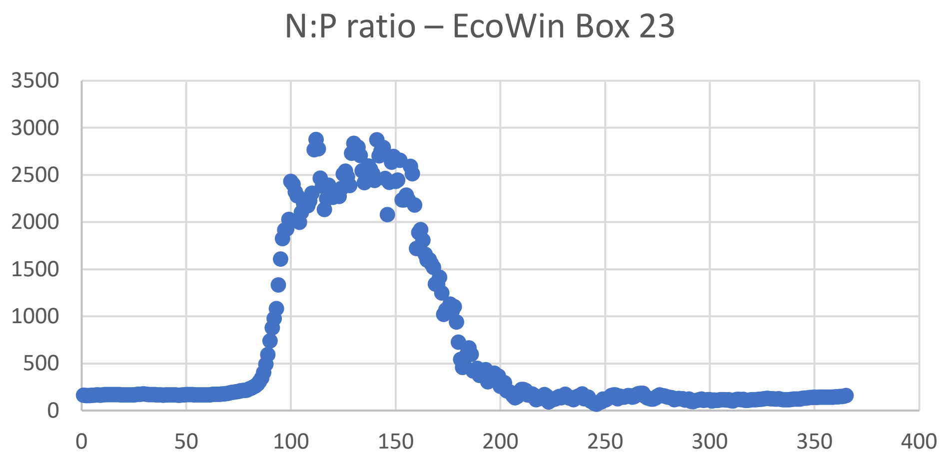


- Main processes simulated by EcoWin are:
  - Pelagic primary production (phytoplankton)
  - Benthic primary production (seagrasses and epiphytes)
  - Benthic secondary production (sand mussel)

- Limited data availability to calibrate each process individually
- When adding those processes we correctly reproduce DIN pattern but simulated chlorophyll a peak is too high

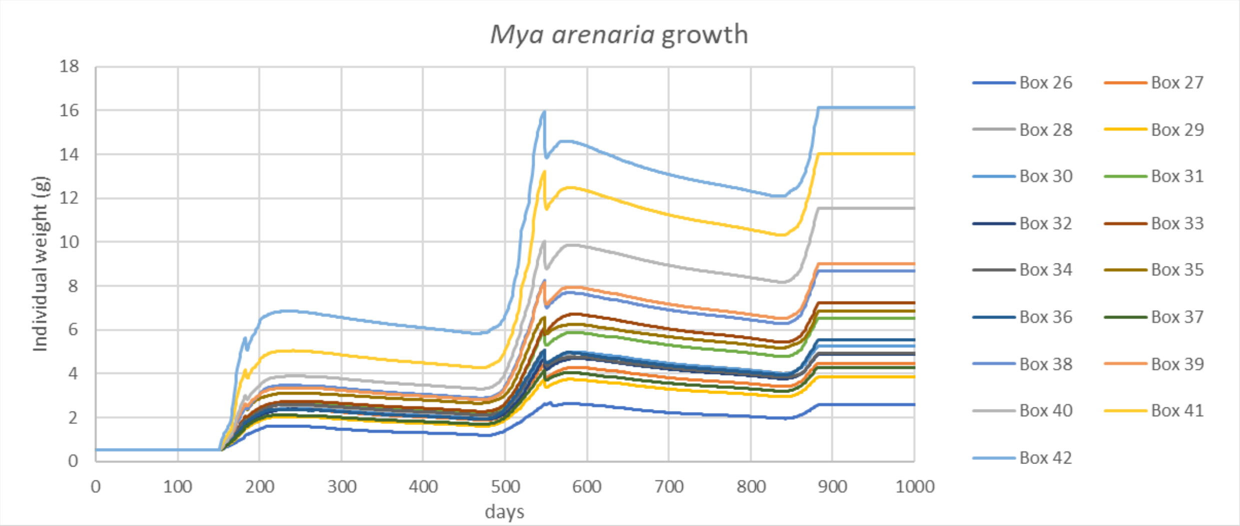
Nitrogen and phosphorus ratio – model analysis

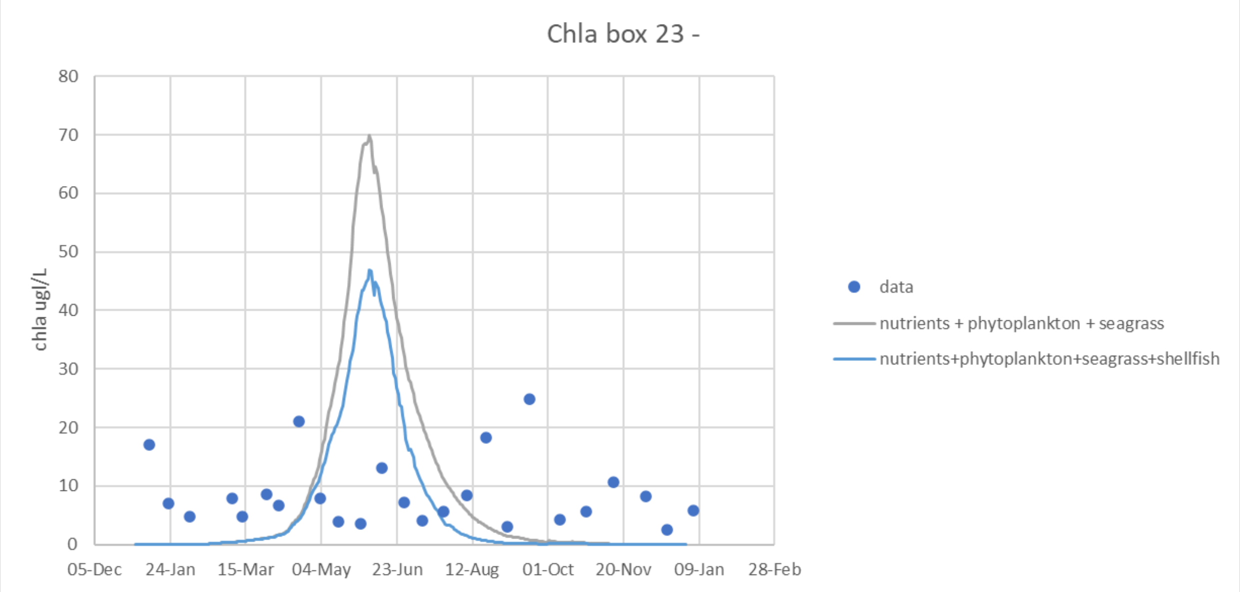




- The ratio DIN:P-PO4 is often higher than the Redfield ratio (16:1 in atoms)
- In parts of the year, primary production in the fjord may be limited by phosphorus
- Bottom boxes show quite strong nitrogen limitation, maybe due to seagrasses and epiphytes

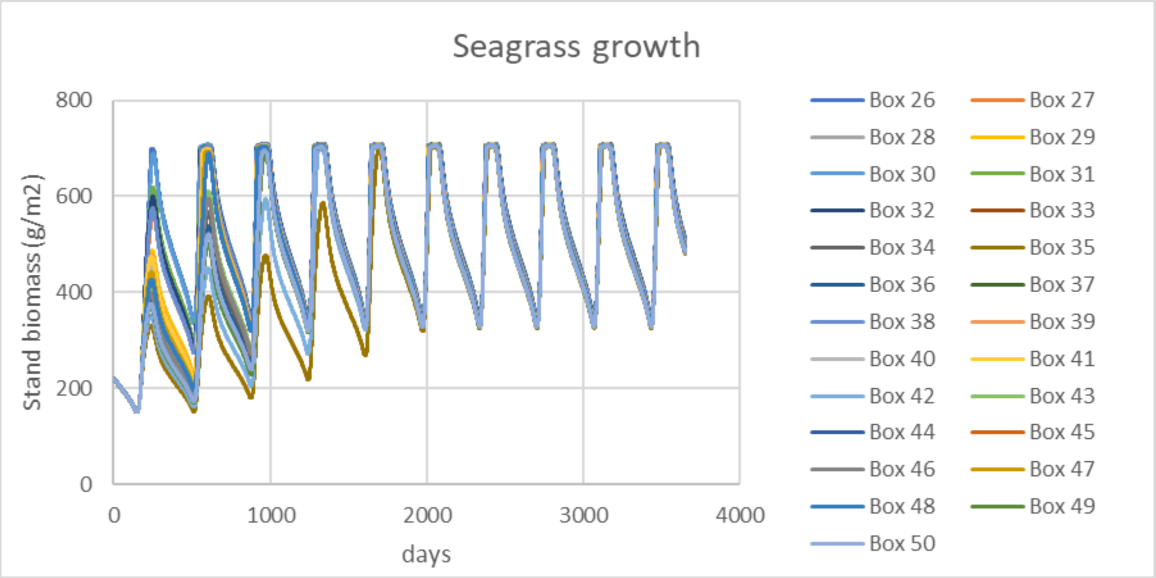
Sand mussel - Mya arenaria

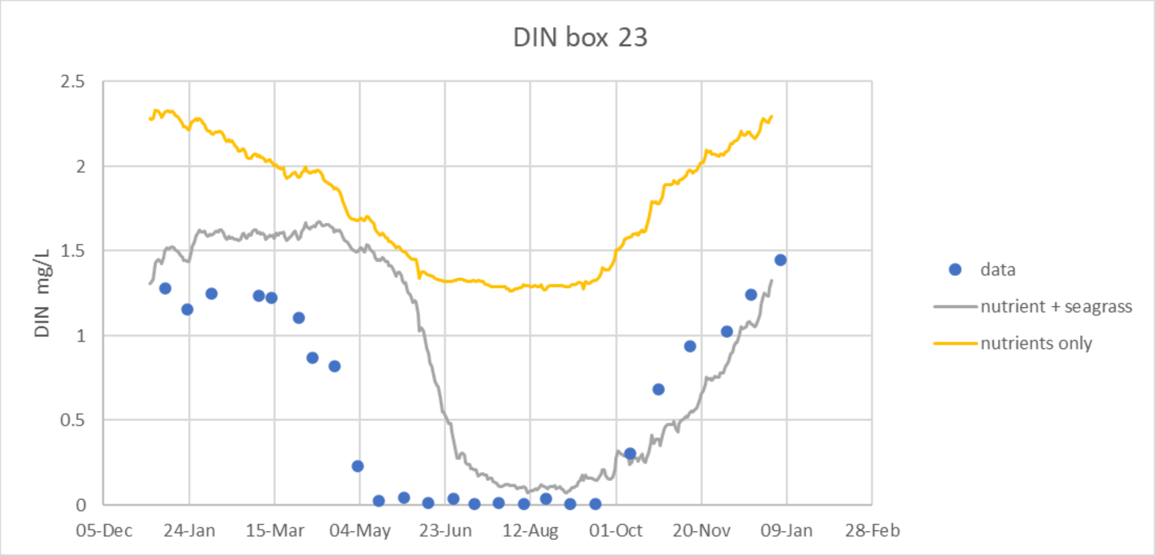




- Limited data availability (density, geographical distribution)
- Introduction of *Mya arenaria* decreases chlorophyll a concentrations in the fjord
- It has almost no impact on nitrogen concentrations

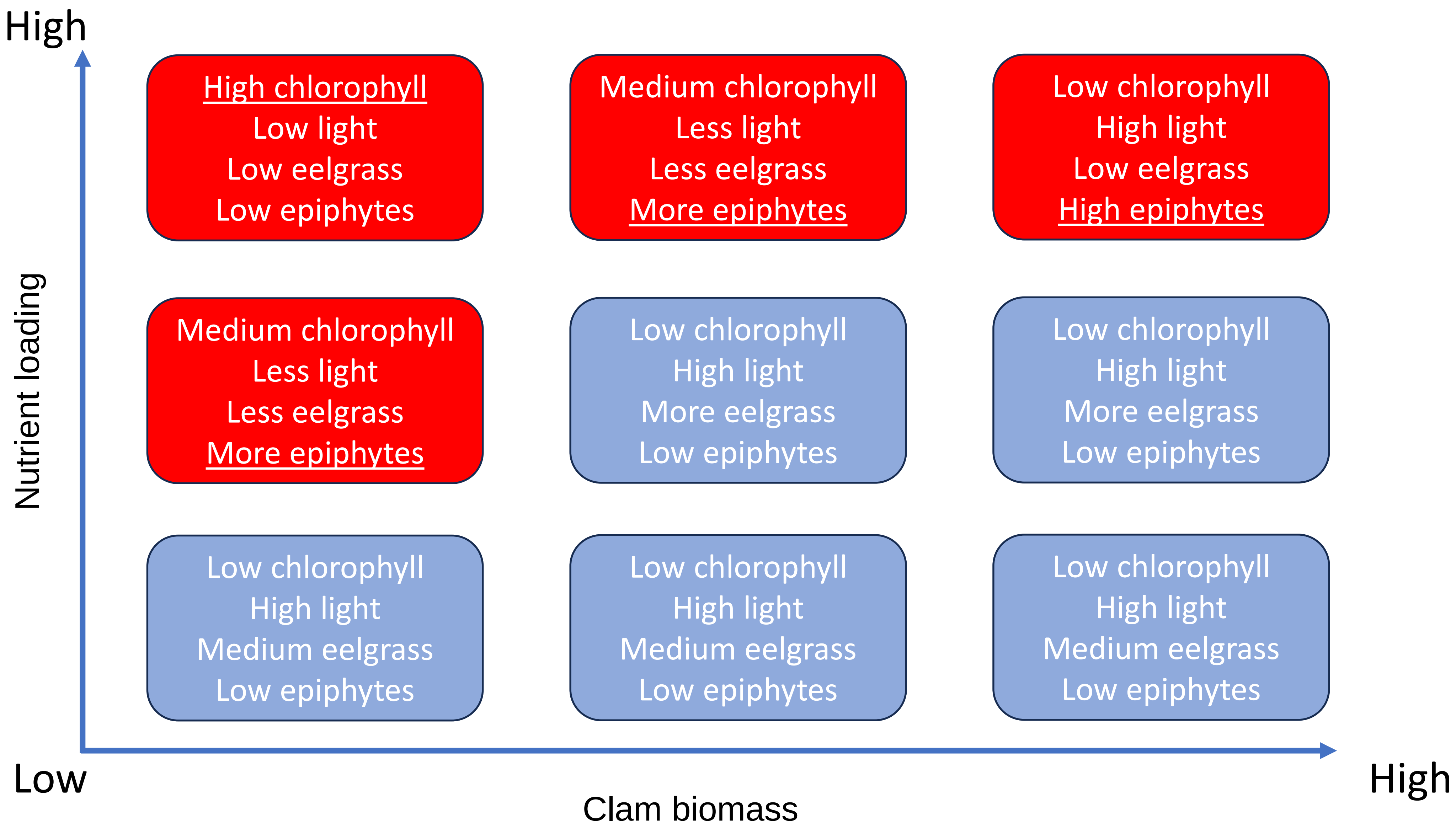
Seagrass





- Representation of the growth of seagrass and associated epiphytes.
- High potential for nutrient uptake but difficult to calibrate.
- Limited data availability (biomass, geographical distribution).

Conceptual model for epiphytes – Risk analysis



Synthesis

- The EcoWin model integrates all the component models developed for Ringkøbing Fjord
- It accurately reproduces the water and mass circulation of the system
- Seagrasses and associated epiphytes have a high potential for nutrient removal; however, excessive epiphyte biomass is an indicator of eutrophication
- *Mya arenaria* decreases chlorophyll in the system
- Work is being finalized to fine-tune the simulation of the processes and better represent the fjord dynamics
- The model will provide significant insights on how the fjord responds to changes in loadings from the land and changes in keystone species such as clams