TOOLBOX AQUACULTURE

NIVA Norwegian Institute for Water Research

BROM/2DBP: Biogeochemical O-N-P-Si-C-Mn-Fe-S Bottom RedOx model coupled with 2-dimensional vertical transport model considering water column, BBL and upper sediments in one model domain

SUGGESTED USERS	PLANNING PROCESS	TYPE OF AQUACULTURE
Aquaculture producers Regulators Certifiers	Location License Pre-Application EIA Decision	Marine fish pens Freshwater fish cages

SUMMARY

BROM/2DBP offers a detailed treatment of water column redox biogeochemistry and a high-resolution, integrated treatment of matter transport in the water column, benthic boundary layer, and upper sediment. It is therefore particularly well suited to studying impacts on concentrations of dissolved oxygen, nutrients, organic matter, and carbonate chemistry in areas that may be subject to deoxygenated conditions, or where interactions with the sediments are important.

DESCRIPTION

BROM-2DBP is a fully-coupled benthic-pelagic model consisting of two modules, biogeochemistry and transport, combined using the Framework for Aquatic Biogeochemical Modelling (FABM, Bruggeman & Bolding, 2014). Biogeochemical processes are modeled with the Bottom RedOx Model (BROM, (Yakushev et al. 2017)) that has a special focus on deoxygenation and redox biogeochemistry in the sediments and Benthic Boundary Layer (BBL). The BROM biogeochemical model is coupled with a 2-Dimensional Benthic-Pelagic transport model (2DBP) that considers vertical and horizontal transport in the water column and vertical transport in the upper cms of the sediments. This allows simulation of the effects of fish farm emissions on water column and sediment biogeochemistry.

The BROM/2DBP model may be useful for both the planning of new farms and the management of existing farms. It can be adapted relatively easily to other areas, although the 2D approximation is likely to work best in areas where current vectors are largely confined to a single depth-horizontal plane (most likely in coastal areas).

BROM/2DBP was applied to analysis of the fish farming consequences in the Hardangerfjord (Norway) with a developed aquaculture industry.

The BROM/2DBP model may be useful for both the planning of new farms and the management of existing farms. It can be adapted relatively easily to other areas, although the 2D approximation is likely to work best in areas where current vectors are largely confined to a single depth-horizontal plane (most likely in coastal areas).

BROM/2DBP simulates processes in the water column, BBL and upper sediments simultaneously and predicts changes in redox conditions first of all at the sediment surface taking into account effects of OM mineralization in low oxygen conditions using other electron acceptors (nitrate, metal oxides, sulphate).

THE ISSUE BEING ADDRESSED

The overall aim was to develop and apply a model for quantifying effects of fish farm emissions on water column and sediment biogeochemistry. We employed a fully-coupled benthic-pelagic model which consisted of two modules to model biogeochemistry and transport of organic matter.

THE APPROACH

The model is calibrated using field data collected in Hardangerfjord, one of the largest salmon farming areas in Norway, in August 2016. During the field surveys, water-column biogeochemical characteristics were measured in a gradient extending from a fish farm (20 m from the net) to a control site over 1000 m away. Porewater biogeochemical profiles were also performed in bottom sediments at 100 m and 500 m from the farm.

Biogeochemical processes are modeled with the Bottom RedOx Model (BROM, (E. V. Yakushev et al. 2017)), which has a focus on deoxygenation and redox biogeochemistry in the sediments and Benthic Boundary Layer (BBL). In this work, BROM is coupled with a new 2-Dimensional Benthic-Pelagic transport model (2DBP) that considers vertical and horizontal transport in the water column and vertical transport in the upper cms 5 cm) of the sediments.

THE RESULTS

We demonstrate the model's ability to predict consequences of increased fish farm emissions on biogeochemical conditions in the water column and upper sediments, and discuss how this can be used to estimate the carrying capacity of water bodies with respect to fish-farming.

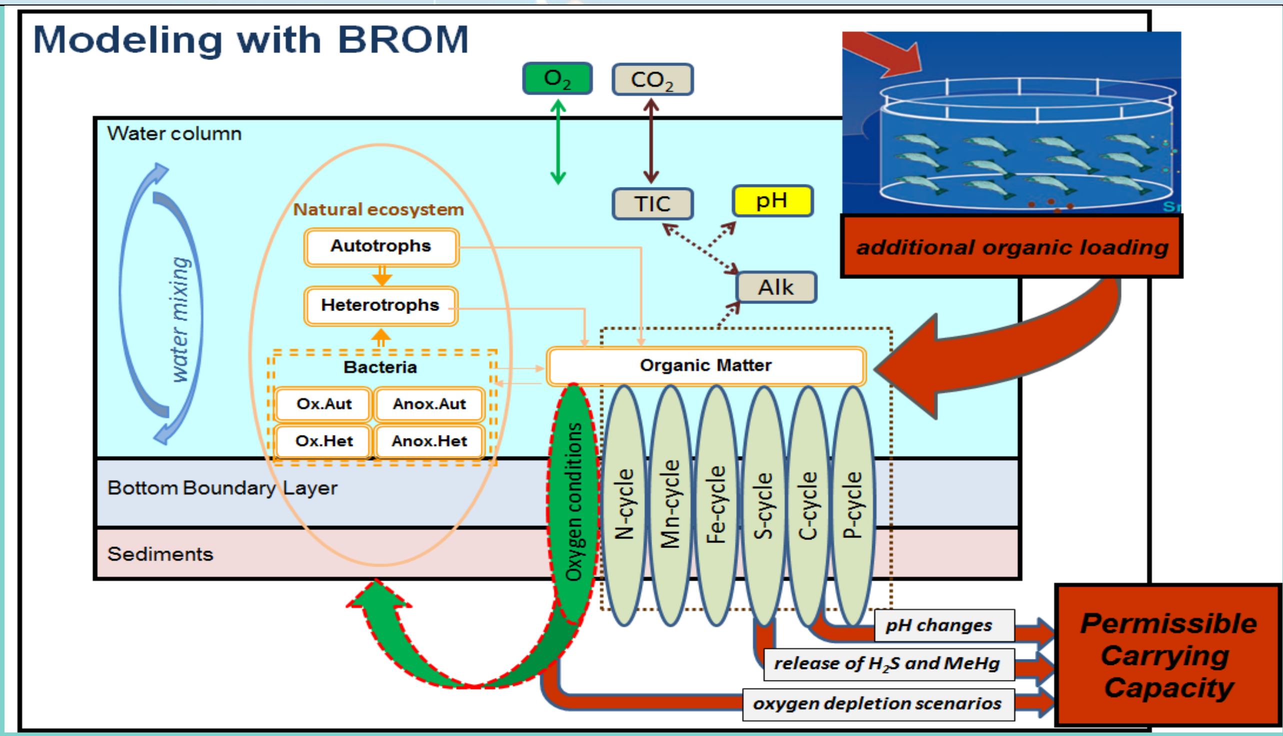
The example application herein suggests that the BROM/2DBP approach can reproduce the mechanisms of changes in pelagic and benthic biogeochemistry due to the emission of organic matter from a fish farm. In particular it allows predictions of:

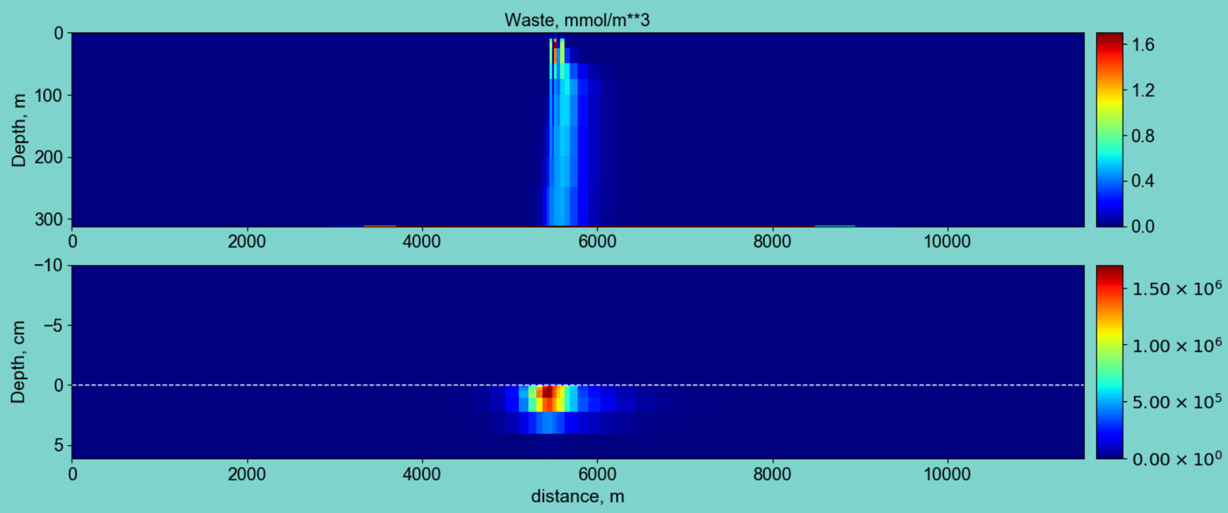
- volume of water affected
- area of the bottom affected
- extreme concentrations of substances in relation to allowed permitable levels
- changes in redox-dependent transformation of pollutants (i.e. heavy metals)

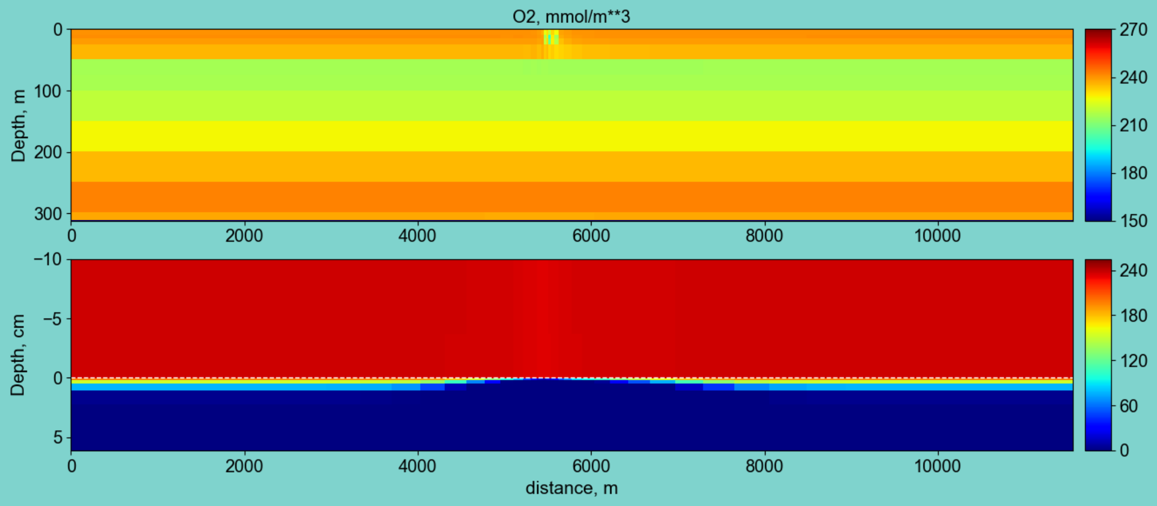
Such predictions can be used as an effective instrument for estimating the carrying capacity of water bodies with respect to fish farm aquaculture.

THE BROADER APPLICABILITY

The approach requires a moderately high level of specialist/technical expertise (compiling and running Fortran code, preparing NetCDF input files) and a moderate level of computational expense (more than a simple box model or spreadsheet approach, but much less than a 3D hydrodynamic model).


Modeling with BROM
O_2
CO_2
Water column
water mixing
Natural ecosystem
Autotrophs
Heterotrophs
Bacteria
Ox.Aut
Anox.Aut
Ox.Het
Anox.Het
TIC
pH
Alk
Organic Matter
additional organic loading
Bottom Boundary Layer
Sediments
Oxygen conditions
N-cycle
Mn-cycle
Fe-cycle
S-cycle
C-cycle
P-cycle
pH changes
release of H_2S and MeHg
oxygen depletion scenarios
Permissible Carrying Capacity


Waste, mmol/m**3
Depth, m
Depth, cm
distance, m



Modelled distribution at a transect trough the fish farm of fish waste (mmolN/m3 top) and dissolved oxygen (bottom) showing decrease of dissolved oxygen in the water column near the installation and decrease of oxygen penetration depth in the sediments

CONTACT INFORMATION	NIVA Evgeniy Yakushev, Philip Wallhead Contact email address eya@niva.no, pwa@niva.no
LINK	https://github.com/BottomRedoxModel