Project information

Keywords
Sustainable/green aquaculture, hydrodynamics, biogeochemistry, modeling, remote sensing, public and industry service

Project title
Development of MODel for prediction of Eutrofication and SedimenTation from fish cage farms (MODEST)

Year
2016

Project leader
Ole Anders Nøst

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
Osterfjorden – 60.5 N, 5.5 E Sagfjorden – 68.0 N, 15.5 E

Participants

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Flagship
MIKON

Funding Source

Fram Centre and Cermaq Norway

Summary of Results

In this project, MODEST, we are working to develop a model for predictions of eutrofication and sedimentation from fish cage farms. The model will be implemented for two fjord systems. One is Osterfjorden which is a deep and narrow fjord with limited exchange with the surrounding ocean. The other fjord was originally intended to be Altafjord in Finnmark, but we will change this and model Sagfjorden in Steigen, Nordland. The reason for this change is that we receive extra funding from Cermaq Norway to model the carrying capacity of this fjord. Sagfjorden is well ventilated against Vestfjorden and therefore works well as a contrast to Osterfjorden.

We have setup the hydrodynamic model FVCOM in both Osterfjorden and Sagfjorden (The model grid and modelled surface temperature for Osterfjorden is shown in Fig. 1). The assembly of available current meter and hydrographic data is ongoing and hydrodynamic model validation will be done in the end of November and December.

The modelling of sedimentation of organic waste from the fish cages has received a lot of attention during 2016. Initially we had three different options for modelling the physical sedimentation processes: 1) the Depomod model where the newest version should be possible to use with 3D model velocities. 2) FVCOM's built in sediment model. This model is basically made for river discharges of sediments, but can be changed to be used for sedimentation from fish cages. 3) The third option is to formulate our own model within the framework of FABM (Framework for Aquatic Biochemical Models, Bruggeman and Bolding, 2014). We have chosen to go for option 3. Depomod is not good because it does anyway not work with 3D velocities as promised. The FVCOM sediment model could work, but it is made for river discharges of sediments and needs re-coding to work with fish cages. The FABM option is the most practical because the biochemical models are coupled to FVCOM via FABM. To construct a sedimentation model within FABM will ease the communication to the biochemical models.

The sedimentation model has already been partly developed. The organic waste is modelled as one or more tracers with a prescribed settling velocity. The waste consists of several fractions with different settling velocities and each fraction is modelled by a tracer. We have now implemented the tracer model with a specified source at a chosen location, and the tracer is sinking through the water column with specified velocity. Fig. 2 shows an example of a tracer sinking through the water column and accumulating in the bottom layer. The next step is to make the tracer deposit at the bottom, and we will also consider resuspension of material from bottom and into the water column by high bottom currents. We aim towards finishing the implementation of the sedimentation model during January 2017.

An important part of this project is the biochemical modelling to predict effects of organic waste. We have started the development of this model by using FABM to couple the hydrodynamic model (FVCOM) with Oxydep (Yakushev et al., 2013), which has a simplified representation of the marine ecosystem. Here we present some preliminary model results from a location near Lindesnes, southern Norway. The seasonal variability of oxygen in the water column (Fig. 3a) is connected with the lateral flux and exchange with atmosphere. This exchange depends on temperature, which explains why the oxygen content in the surface layer is higher during winter. Photosynthesic production of oxygen is of secondary importance (at lease at the runs performed, see phytoplankton variability at Fig. 3d). This model run reproduces the situation when an increased dissolved organic matter flux from the bottom (Fig.3 c) leads to a decrease of the bottom oxygen concentrations to hypoxic (< 88 uM) and even suboxic (< 20 uM) levels (Fig.3a). That in turn leads to nitrate reduction (NUT decrease in the bottom layer, Fig 3b).

References:

Bruggeman, J., Bolding, K.: A general framework for aquatic biogeochemical models. Environmental Modelling &

Software. 2014.

Yakushev, E.V, E.I. Debolskaya, I.S. Kuznetsov, and A. Staalstrøm, Modelling of the Meromictic Fjord Hunnbunn (Norway) with an Oxygen Depletion Model (OxyDep), E.V. Yakushev (ed.), Chemical Structure of Pelagic Redox Interfaces: Observation and Modeling, Hdb Env Chem (2013) 22: 235–252, DOI 10.1007/698_2011_110, Springer-Verlag Berlin Heidelberg 2011, Published online: 20 July 2011

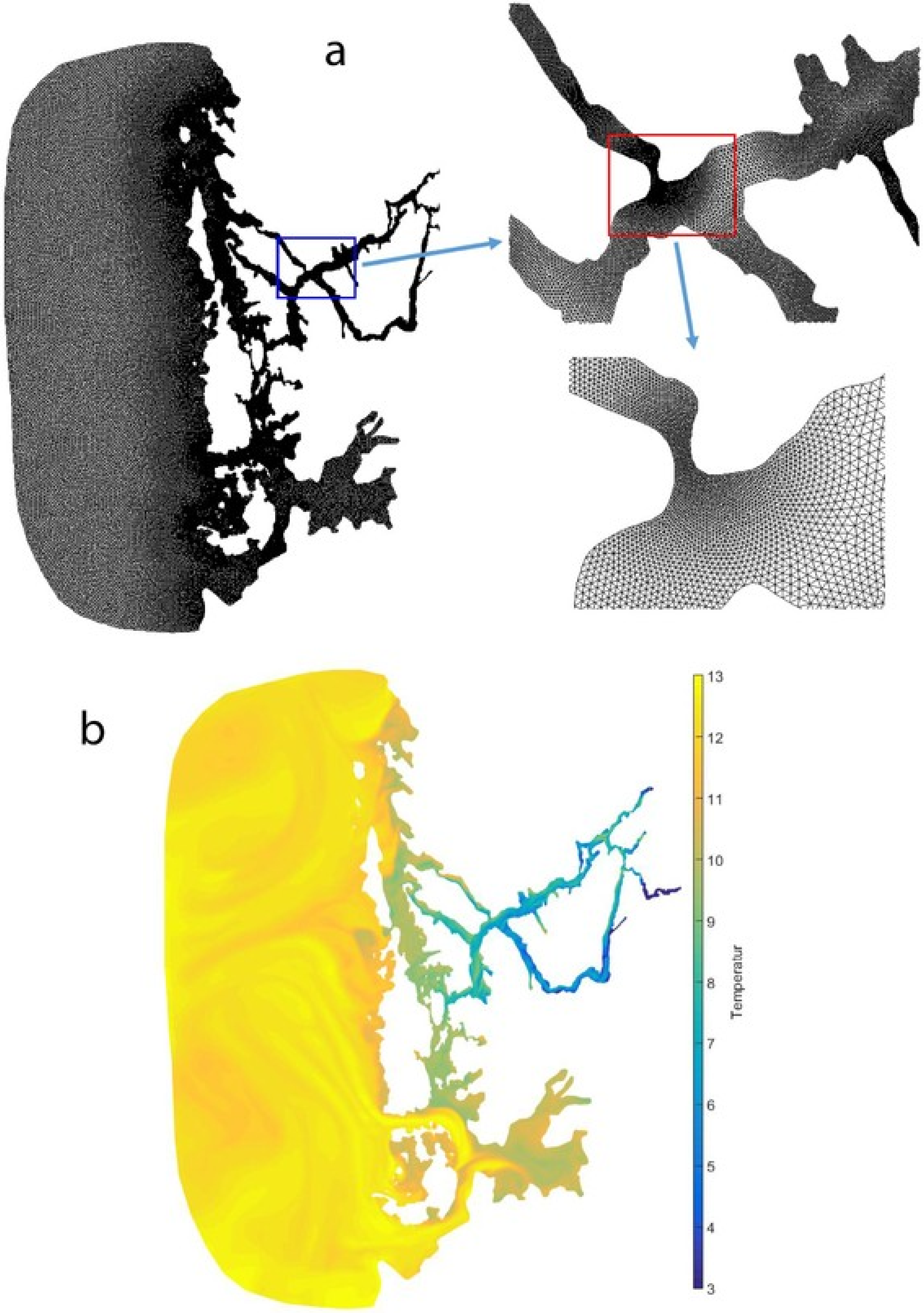

Figure 1. a) Model grid with details in the entrance to Osterfjorden. b) Modelled surface temperature for October 2013.

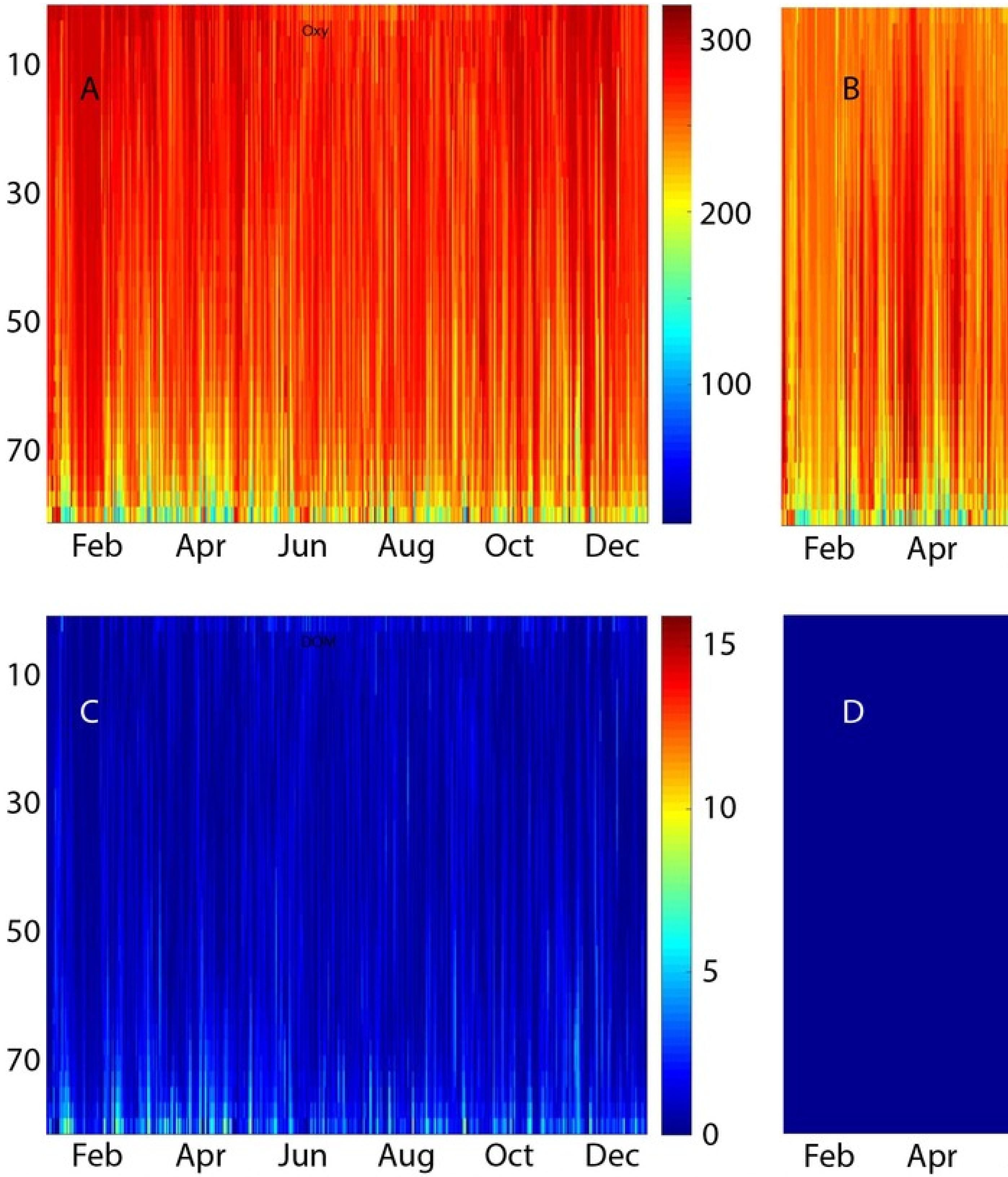

Figure 3. Results from coupled FVCOM-Oxydep simulations in a locatior
Norway. Seasonal variability of modeled dissolved oxygen (A), nutrient (
and phytoplankton (D) in the water column.

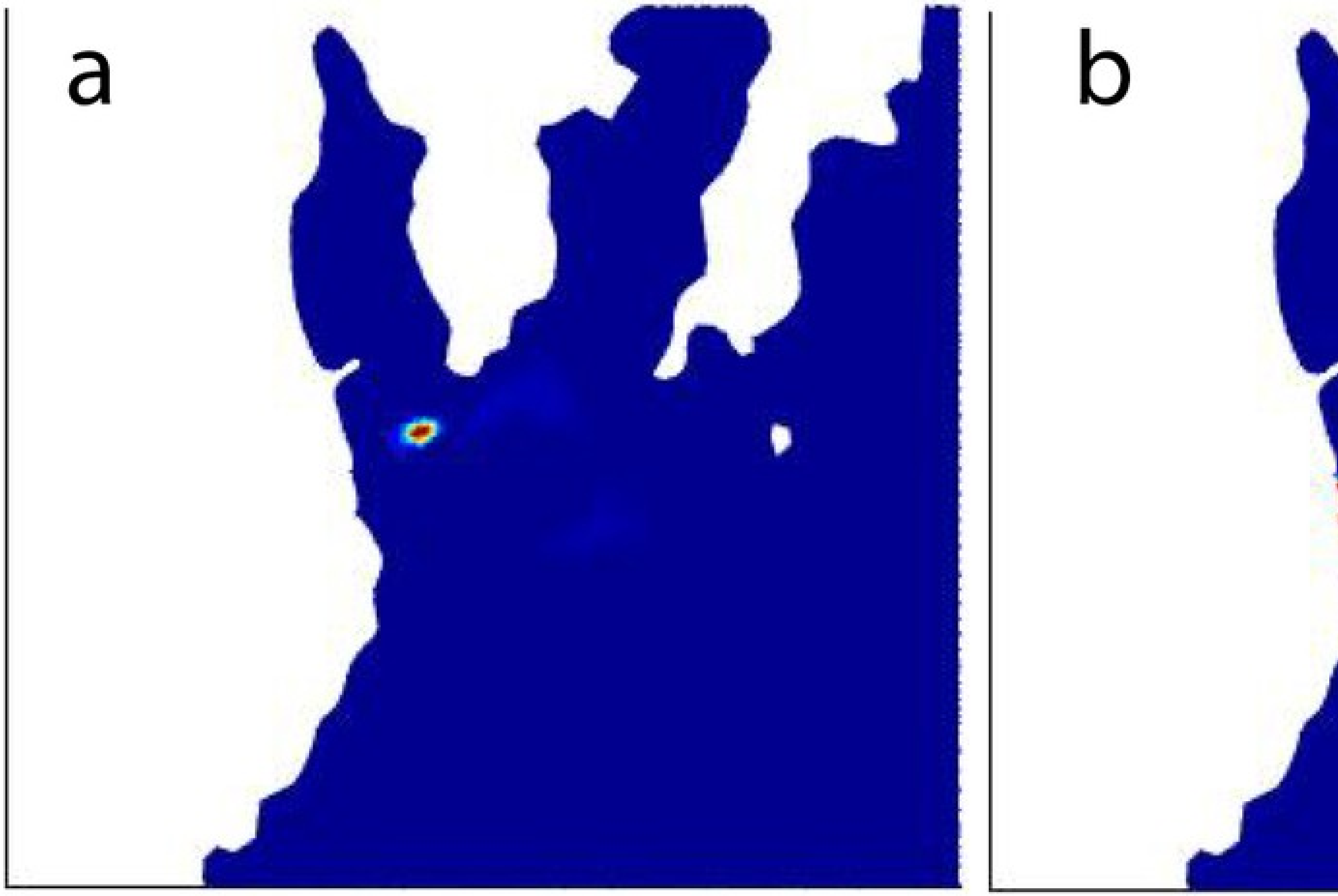

Figure 2. Tracer consentrations (units and ma
above bottom (b) and bottom (c). The experir
the tracer consentrations after 48 hours. Trace

Master and PhD-students involved in the project

Two master students will be recruited to the project within the next few month.

For the Management

Since we are still in the phase of developing models we cannot show specific results. However, the goal of MODEST and the motivation behind the project is to develop a state-of-the-art model that can be used by the aquaculture management to assess the aquaculture environmental footprint.

Published Results/Planned Publications

Planned publication: A model for prediction of eutrofication and sedimentation from fish cage farms.

We will write publications to international journals and present on workshop/conferences.

Communicated Results

At this stage of the project we are busy developing the model. Therefore, the focus is, at the moment, not on communicating results. However, when we produce our first results of the model (spring 2017) this will be communicated to users (aquaculture industry) and presented at workshops. And since this is a new, much needed, tool that does not exist in Norway at the moment, we will also communicate our results in the press.

Interdisciplinary Cooperation

In MODEST we have a strong cooperation between physical and chemical oceanographers, and the results of the project depends on this inter-disciplinary cooperation. The cooperation works well and enables us to develop a product which is highly needed in the aquaculture industry. We do not have any negatives in this respect. The project also has a strong component of biology through the cooperation with other projects doing field work near fish farms. We only see this as positive, because interdisciplinary cooperation is the only way forward to reach the goal of the project.

Budget in accordance to results

The funding from the Fram Centre has been vital in initializing the project. The project would not have been started without this funding. With the Fram Centre funding it has also been easier to get funding from the industry. We now have a contract with Cermaq Norway to model the effect of organic waste from fish farms in Økssundet in the outer part of Sagfjorden, Nordland.

Could results from the project be subject for any commercial utilization

Yes

If Yes

There is a need for tools that can estimate the carrying capacity of the coastal ocean to fish farming. The new standards for sea bed monitoring under marine cage farms (ISO 12878 and NS 9410, revised 2014) recommend the use of depositional models for prediction of the footprint of organic waste which is expected under marine cage farms. Furthermore, a considerable number of Norwegian salmon farms have during the years 2013 and 2014 voluntarily signed agreements with the Aquaculture Stewardship Council (ASC) and are obliged to follow the ASC standard for environmental monitoring. In this standard, predictive modelling of organic deposition under marine cage farms will become obligatory. The models developed within MODEST covers these needs, and these model tools will be commercially utilized.

Conclusions

a) As this project is still in the first of three years, it is not the time to list future research and perspectives. However, we are doing pioneering work on research on environmental impact of aquaculture, and we expect the project to lead to many new research ideas and perspectives.

b) The project shows good progress according to the original plan and we have developed/are developing new model techniques for use along the Norwegian coast. 1) We have developed "unstructured grid" ocean modelling for Norwegian coastal areas. This has large advantages along an irregular coastline because it makes it possible to vary the model resolution spatially through the model domain. 2) We are making god progress in the development of a model for sedimentation of organic waste from fish farms. 3) We have coupled our unstructured-grid hydrodynamic model to a simplified ecosystem model (oxydep) for simulations of environmental effects in the water column and bottom sediments.