TOOLBOX AQUACULTURE

PML | Plymouth Marine Laboratory

Caged Finfish waste and sea-lice anti-parasitic treatment dispersion-degradation tool

SUGGESTED USERS	PLANNING PROCESS	TYPE OF AQUACULTURE
Aquaculture producers Regulators Spatial planners	Location Pre-application EIA	Marine fish pens

SUMMARY

This example uses a coupled hydrodynamic-OrganicMatter dispersion model consisting of the Finite Volume Coastal Ocean Model (FVCOM) and a purposed designed Finfish organic matter waste and anti-parasitic dispersal and degradation model built within the Framework for Aquatic Biogeochemical Models (FABM).

The tool is suitable for impact assessments at the waterbody scale with the potential to consider interactions between different aquaculture facilities.

The information can help policy makers and producers better regulate and adapt the mode and frequency of in-feed sea lice treatments as well planners for evaluating site suitability with respect to organic matter pollution.

DESCRIPTION

The approach shown here provides detailed description of the time and spatial evolution of Organic Matter (OM) associated with fish farms and the fate of sea-lice in-feed chemical treatments as well as describing the potential interactions between farms.

The tool simulates dispersion of fish waste arising from a combination of faecal production and feed waste subjected to sinking, resuspension, deposition and degradation. In-feed anti-parasitic treatments have a high tendency for adsorption onto OM undergoing both solid particle dynamics and diffusion when in solution. They have different degradation constants when dissolved and in the sediment.

Because sea lice are a major challenge for the salmon industry and one of the main limitations for expansion of the sector, the tool has been implemented in the middle region of the Hardanger Fjord in Norway. We have considered 5 farms that have between 6 and 12 cages of 50 m in diameter and about 50-100 m away from adjacent cages.

As shown in the results, the highest levels of OM are found at the farm site which is to be expected. However interaction between farms was also detected and the footprint of OM depositions is highly site specific. The model reproduces the difference in behaviour of higher and lower organic carbon affinity constants, with the distribution of more reactive substance remaining close to the farms. Some farms underwent accumulation of anti-parasitic in the vicinity of the farm even after treatment finished.

A key strength of the modelling approach used in this case study is the ability to model potential cumulative impacts from multiple farms. Focusing on the waterbody rather than solely on the farm scale is particularly useful for marine spatial planning as areas at risk of unacceptable levels of organic waste and sea-lice treatment concentrations can be identified and decisions can then be made as to what production levels to approve. Alternative scenarios can be modelled to evaluate the potential consequences of different farming and treatment strategies or development of new or expanded sites, supporting licensing decisions. The outputs from the model can also be used to support development of zones for aquaculture.

THE ISSUE BEING ADDRESSED

The Hardanger is the largest fjord in Norway and it holds one of the largest concentrations of farmed salmonid fish in the world. However, sea lice are a major challenge for the industry and one of the main limitations for expansion of the sector Control of sea lice is vitally important not only for fish health and welfare but also overall management of salmon aquaculture in Norway. To control lice infections, there are a variety of treatments approved ranging from mechanical and thermal treatments to in-feed or bath chemical treatments of anti-parasitics medication.

There is a requirement for models to assess potential impact of chemotherapeutants on the environment beyond the farm-scale as in-feed treatments have far-field effects. For all production areas, there is a need to understand how chemical treatments are dispersed in the environment and identify potential risks to the environment.

THE APPROACH

While the locations of actual farms are used, the feed and fish growth scenarios and the treatments used in the modelling are not necessarily based on real events. They are what-if scenarios to show how models can be used to support aquaculture decision making. The tool can be used to estimate the dispersion and persistence of chemicals (e.g. diflubenzuron – DBZ and emamectin benzoate - EMB) and organic waste, including the interaction between both, in different locations and under different treatment scenarios and cage densities. The example is focused on a medium region of the largest fjord in Norway but can be adapted to other areas provided sufficient local information exists to setup the hydrodynamic model. Because of the spatial nature of the tool, interactions between farms are resolved. The simulations provide effective sedimentation rates of OM, short and long-term variability of waste deposition and fate of sea-lice chemical treatments in the water and sediment.

We use a nested domain approach to modelling the Hardanger fish farms under consideration. The full Hardanger (**parent domain**) is modelled first at a coarser resolution while the area with the fish farms (**nested domain, see figures at the end of this fact file**) is subsequently used at a higher horizontal and vertical resolution (by a factor of approximately 3) driven by the parent domain solution at the boundaries. This approach enables a better representation of the behaviour of point releases of sinking particles such as organic matter waste.

The final parent domain grid contains 210,885 calculation elements with sizes ranging from 5000m at the open boundaries to 250m along parts of the nearshore zone; the surface area of the domain is 8256 km2 with an average volume of 2000km3. The nested domain grid contains 33,328 elements, with a resolution ranging from 80m to 300m near the shared boundaries with the parent domain. The vertical discretisation of the water column uses 15 vertical levels in the parent domain grid and 25 in the nested domain grid.

The model setup requires data from a variety of sources to perform the simulations, ranging from detailed local bathymetry to river fluxes, atmospheric conditions (e.g. wind, air temperature, irradiance) and hydrodynamic conditions at the model boundaries such as depth resolved temperature, salinity and currents.

The approach can provide detail description of the time and spatial evolution of OM associated with fish farm operations as well as the fate (transport and degradation) of chemical compounds with high OM affinity. The methodology resolves the interactions between farms supporting an integrated zone management needed for the sustainable development of the industry.

THE RESULTS

As shown in the results, the highest level of OM and chemicals are found at the farm sites. The accumulated OM deposition within the farm footprints (1.5km) ranges between 60% to 120% of the farm inputs, the latter figure indicates OM inputs from a neighbouring farm. The model has a spatial resolution of 80 m at the farms, which may not be fine enough to capture the fine spatial variation of OM and chemicals under and near farm sites, particularly in locations where salmon aquaculture is operated at more shallow depths such as Scotland and

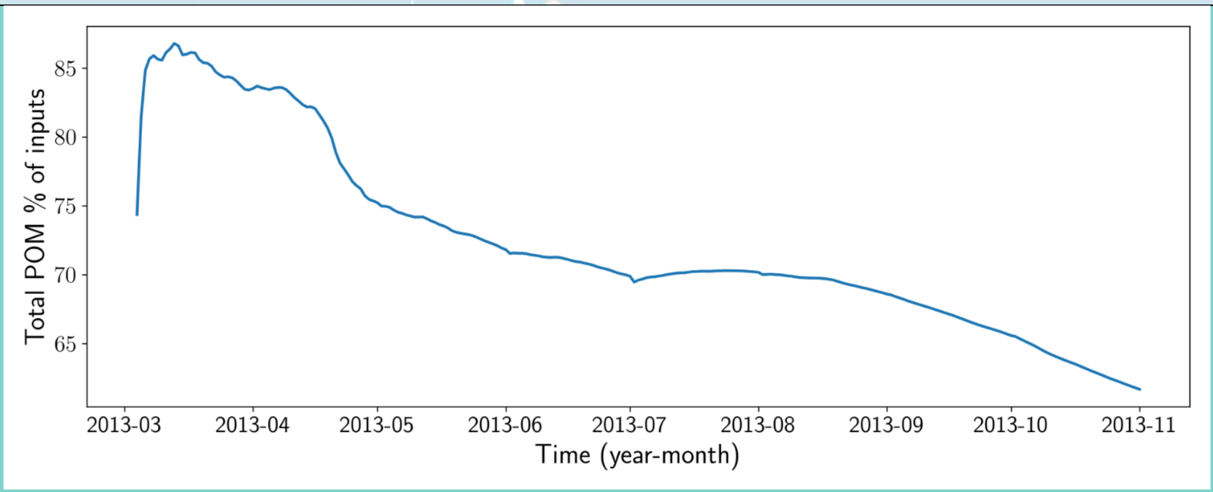
Ireland. In these areas perhaps a combined approach is necessary where far-field modelling approaches such as the one demonstrated here are used together with farm scale models with a horizontal resolution of 1 to 10 m.

A key strength of the modelling approach used in this case study is the ability to model potential cumulative impacts from multiple farms. If multiple farms are treating with chemicals, then there may be additive or synergistic effects that would be unknown if the farms are modelled on their own. Our results indicate that both DBZ and EMB require a minimum of 10 days to reach the sediment (in depths of ~200m) and that there was exchange of chemotherapeutants between farms. This could result in a build-up of chemicals beyond established environmental quality standards. However this is difficult to predict without the use of a modelling approach that includes consideration of the hydrodynamics of the area.

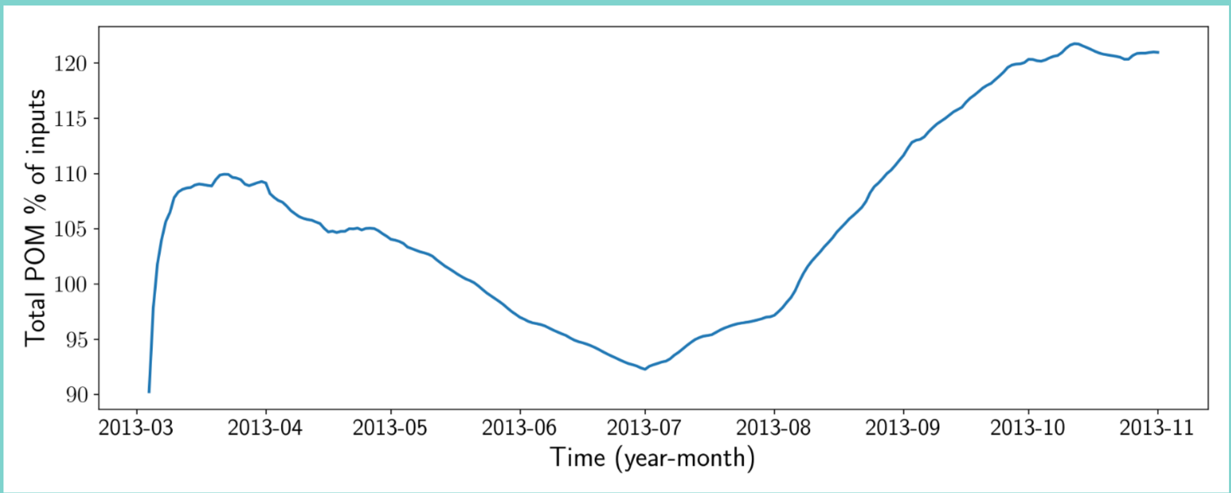
Focusing on the waterbody rather than solely on the farm scale is particularly useful for marine spatial planning as areas at risk of unacceptable levels of chemical can be identified and decisions can then be made to alter treatment regimes, use alternative products or use non-chemical approaches such as mechanical treatment. Alternative scenarios can be modelled to evaluate the potential consequences of different farming strategies or development of new or expanded sites, supporting licensing decisions. The outputs from the model can also be used to support development of zones for aquaculture, disease management areas and coordinated treatment strategies. This is of benefit to the industry as control of sea lice requires consideration beyond individual farm level.

THE BROADER APPLICABILITY

The tool is applicable to regional areas of high finfish production densities with the potential for cumulative impacts arising from the interaction among neighbouring farms. The approach is particularly suited to offshore or deep environments (> 30m) where tides are not the dominant flow regime. Because of the requirement for expert knowledge, transferability to different geographical regions is possible but time consuming. However, because of the possibility to simultaneously consider multiple farms the approach can be cost effective. The tool can be kept up to date by the addition of new chemotherapeutants as they are adopted by the industry.



(a)



(b)

Figure 1. Evolution of sediment OM as a proportion of total farm OM input within 1.5km of the centre of farm a) 1 and b) 5. Note farm 5 (b) accumulates non-local OM waste.

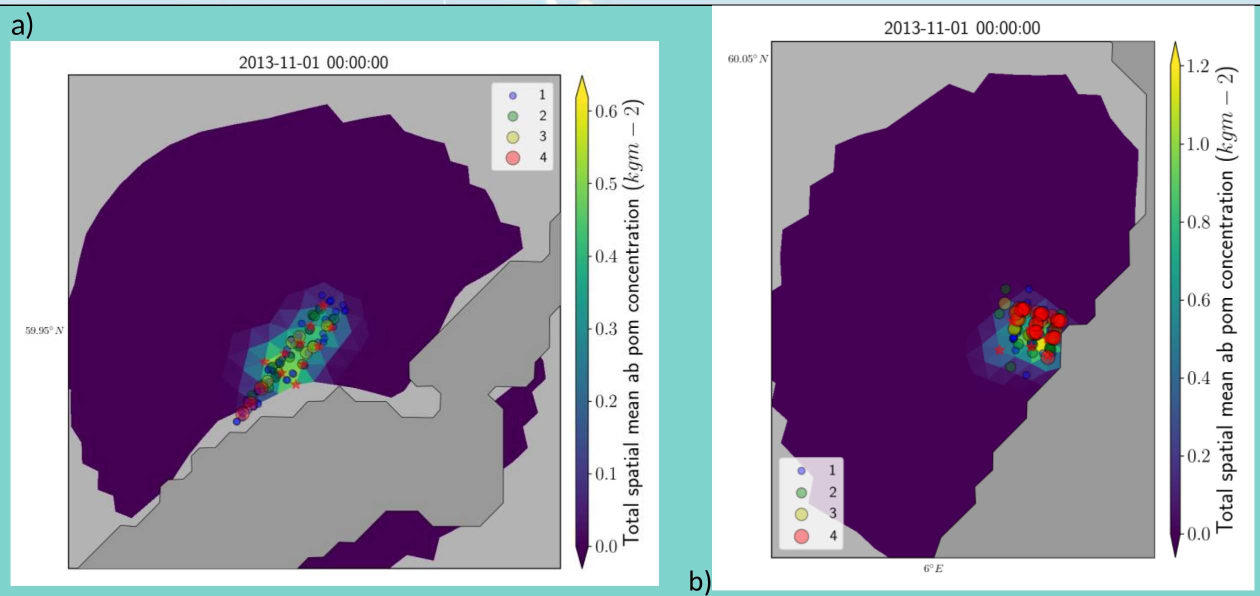
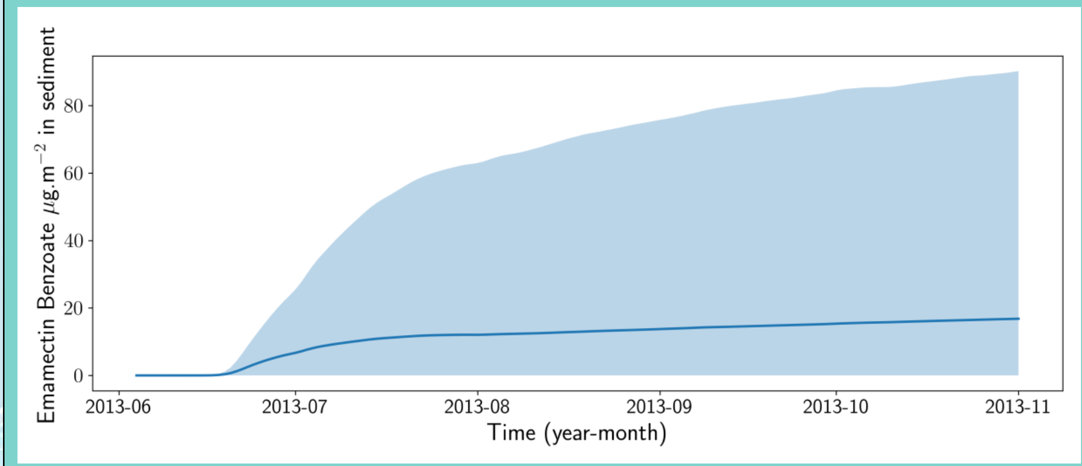
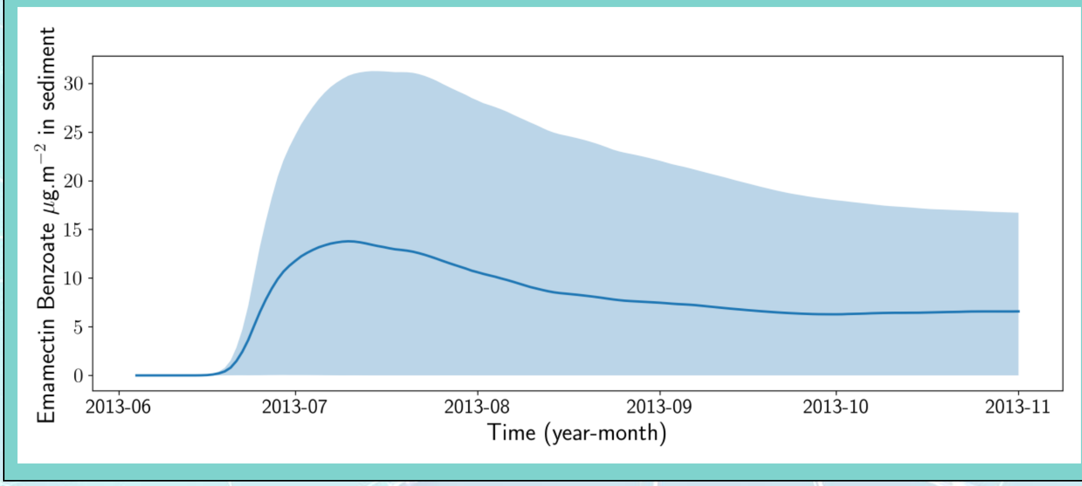


Figure 2. Sediment OM concentrations after 8 months of simulation overlaid with the station score from all available B-surveys (2010-2018) for a) farm 3 and b) farm 4.





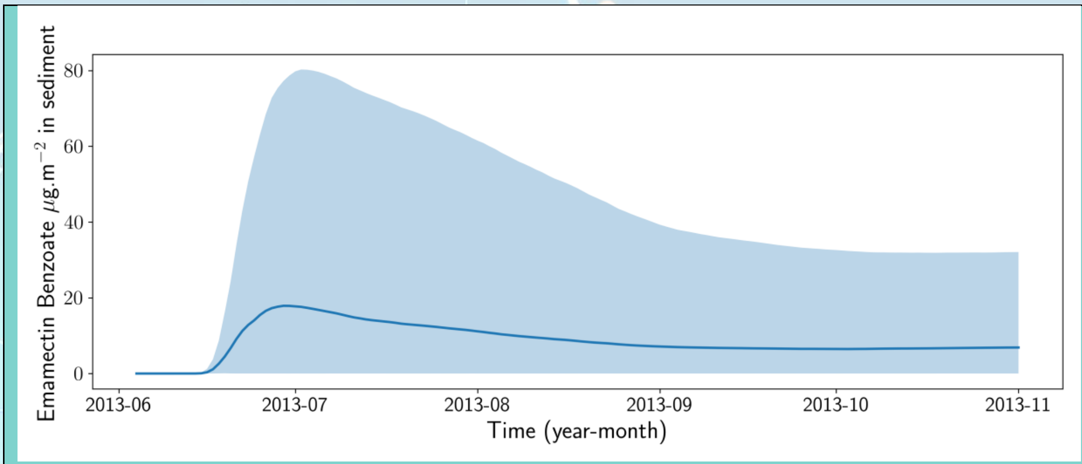


Figure 3. Time evolution of the mean sediment concentration of Emamectin Benzoate within 300m of the central farm position for farms a) 1, b) 3 and 4 c). The shaded area covers the maximum and minimum values found within the area analysed. Notice how some farms experience long-term decline in concentrations after ending the treatment while others increase during the duration of our simulations.

SWOT ANALYSIS	
STRENGTHS	The tool is suitable for long-term behaviour of OM and chemotherapeutants in intensive aquaculture areas where between farms interactions could be an issue.
WEAKNESSES	The tool requires specialist knowledge to use and it is expensive and time consuming to implement in data poor areas.
OPPORTUNITIES	The tool enables producers and regulatory bodies to better define farm treatment approaches to sea lice and enables a coordinated management approach.
THREATS	The tool requires access to large quantity of data (e.g. regional scale hydrodynamic and atmospheric model simulations) that might not be available in all regions. For European waters, these are accessible through the European Copernicus Marine environment monitoring service (CMEMS).

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