Aquaculture Impact Modelling in Eastern Ligurian Coastal Waters (Mediterranean Sea)

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Introduction

The eastern Ligurian coastal waters are a precious resource for several human activities: navigation, tourism, fishing and, more recently, aquaculture. In this framework, an understanding of the local sea water circulation and its impact on transport and dispersion is of great relevance in order to correctly manage the maritime and coastal activities of the area.

Mathematical models are a useful tool in evaluating the environmental impact of fish cage farming and a number of aquaculture models has been proposed for cold water areas [e.g. Gillibrand and Turrell 1997; Panchang et al. 1997; Cromey et al. 2002].

The POM2D-LAMP3D numerical model has been developed in order to simulate the dispersion of Mediterranean aquacultural wastes on the basis of coastal wind driven circulation and feed input [Doglioli et al. 2004].

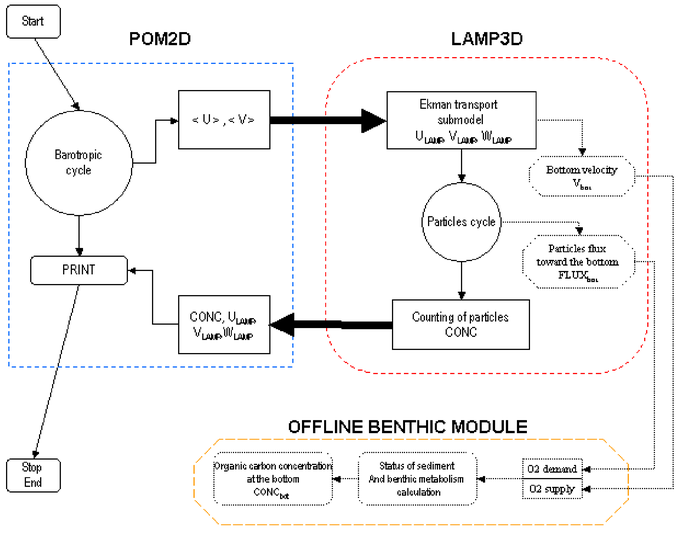
A new tool has been recently added to take into account the biodegradation of settled matter. Furthermore, physical properties of uneaten feed has been measured in laboratory [Vassallo et al. 2006].

In the light of new data, sensitivity tests have been performed with the last version of our model.

Model Description

The Lagrangian Assessment Marine Pollution three-dimensional model, LAMP3D, is a single particle Lagrangian model. The Princeton Ocean Model [Mellor 1998] in barotropic approximation, POM2D, and LAMP3D have been coupled and run together. POM2D provides the depth averaged current field to LAMP3D. The dispersion model contains a submodel based on the Ekman transport and on the mass conservation, to obtain a 3D field for the three components of the velocity [Doglioli et al. 2004].

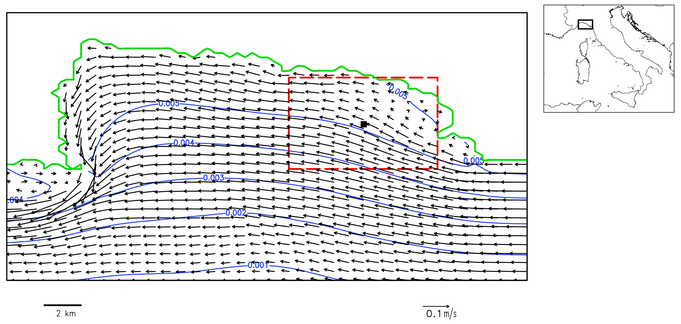
Specific properties can be assigned to each single numerical particle, in particular N, P, C contents and settling velocity. The benthic tool reproduces the benthic metabolism that has been related to the ratio O2supply/O2demand [Findlay and Watling 1997]. O2supply depends on bottom current and O2 demand depends on C flux toward the bottom. On the basis of calculated status of sediment (not stressed, low stressed, stressed), three different rates of organic carbon mineralization are taken into account to calculate the element concentration at the bottom. At this purpose, a high resolution grid module has been added offline.



http://www.ifremer.fr/lpo/doglioli/lamp.htm

Model Configuration

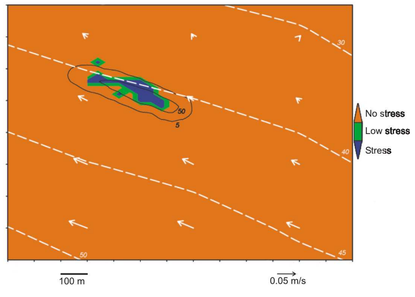
The AQUA fish farm is located offshore Lavagna (Ligurian Sea, NW Mediterranean) on the 40-m isobath. The model is forced prescribing at the western boundary an annual timeseries for the alongshore component of the coastal current. These timeseries have been calculated from historical measurements.



Depth averaged velocity (arrows [m/s]) and elevation field (contour lines [m]) show typical westward transport but storms can induce inversion in the current direction. Furthermore topographical forcing induces local recirculations in the lee of the headland. The dashed red line rectangle represents the high resolution LAMP3D grid around the fish farm (filled rectangle).

Impact Evaluation

The offline benthic module provides the level of stress of the benthos (shaded colors) and the organic matter concentration on the bottom (contour black lines). During westward current periods alongshore pattern is observed. When the current intensifies the stress decreses and bottom concentration can also decrease for periods longh enough. Higher stress is observed when current is low.



Settling Velocity Measurements

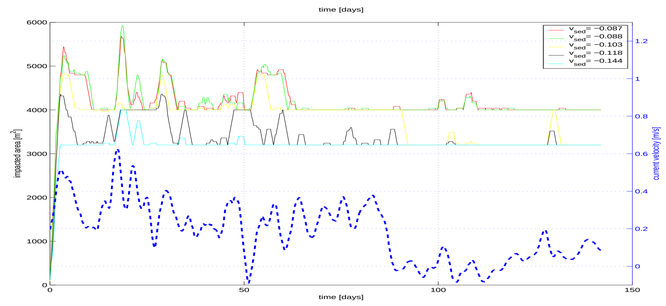
Numerical experiments confirmed that settled uneaten feed causes the most intense impact under sea cages and settling velocity represents a key parameter for the waste dispersion model. We measured the physical properties of feed pellets involved in typical Mediterranean rearing (i.e. Gilthead Sea Bream *Sparus aurata L.* and Sea Bass *Dicentrarchus labrax L.*) and in Mediterranean Sea conditions (i.e. temperature, salinity) [Vassallo et al. 2006]. Both extruded and pelletized feed pellets has been studied during laboratory experiments. Results are reported in the following table where asterisks refer to extruded pellets.

Nominal diameter (mm)	3	3.5*	4.5	5*	6
v_{set} mean [ms^{-1}] (std)	0.087 (0.008)	0.118 (0.008)	0.103 (0.009)	0.144 (0.011)	0.088 (0.030)
τ_{float} mean [s] (std)	69 (50)	73 (77)	29 (40)	2 (7)	12 (35)

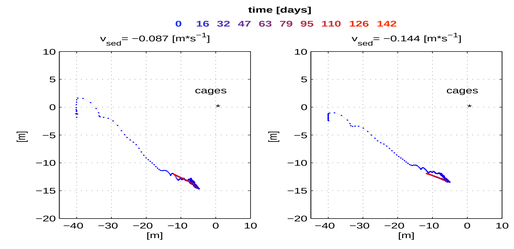
Variations in settling velocities v_{set} have been found to be related to pellet's size, water temperature and salinity. Furthermore the time the particles spend at the surface before settling, τ_{float}, has been found to represent a key parameter in determining the settling velocities. Our results are in part different from previous ones relating to cold waters and could play a role in evaluating and modelling Mediterranean aquaculture environmental impact.

Sensitivity analysis

Aiming to assess the sensitivity of our numerical model we performed a number of different simulations changing the pellet settling velocities v_{set} while maintaining the same flow field.



Simulations brought to slightly different results in wideness of the impacted bottom area. Area timeseries are compared with the forcing alongshore current timeseries (dotted line). When in summer current intensity decreases, the impacted area does not suffer any more variations reaching an equilibrium between organic matter inputs and decomposition rate of the bottom. Furthermore, smaller pellets are more diffused.



Nevertheless, the barycenter of the impacted area does not vary noticeably between slowest and fastest particles. Validation of numerical results with field data [Doglioli et al. 2004] is confirmed.

Outlooks

These results suggest to devote attention to the settling velocity parameter when inferring prediction on waste dispersion from aquaculture. New numerical experiments are forseeable for an evalution of feacal pellets impact in the light of new data [Magill et al. 2006]. Modelling both uneaten feed and feacal pellets fluxes toward the bottom, will allow us to better evaluate the environmental state of the impacted bottom area and to predict its evolution.

Acknowledgments

The authors would warmly thank Patrizia De Gaetano for the help with numerical simulations and data collection. A. M. Doglioli is currently supported by SHOM, under contract number CA 2003/03/CMO (Contact: Alain Serpette).

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