AQUACULTURAL WASTE DISPERSION MODELLING IN EASTERN LIGURIAN COASTAL WATERS

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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. Many political and social conflicts can arise from the contrast between the high turistical pressure and the need for an appropriate management of natural resources. 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 following dispersion of pollutants from recorded point sources (*Henderson et al., 2001*). Although a number of aquaculture models has been developed for cold water areas (e.g. *Gowen et al. 1989; Gillibrand e Turrell 1997; Panchang et al. 1997; Dudley et al. 2000; Cromey et al. 2002*), models for Mediterranean Sea are generally lacking. Nevertheless, the prediction of pollutant dispersion and deposition in density/wind driven Mediterranean systems is one of the key question currently asked for modeling the environmental effects of fish cage farming.
The POM2D-LAMP3D numerical model has been developed at the University of Genova in order to simulate the dispersion of aquacultural wastes on the basis of coastal wind driven circulation and feed input (*Doglioli et al., 2004*).
A new tool has now been added to the POM2D-LAMP3D code in order to take into account the biodegradation of settled matter.
In the numerical simulations the dispersion of faecal matter and feed waste, released from the fish farm (see Fig.1), was evaluated in different water circulation scenarios and by changing the sinking rates. Estimates of the dispersion patterns of organic carbon have been calculated using a high resolution local grid.

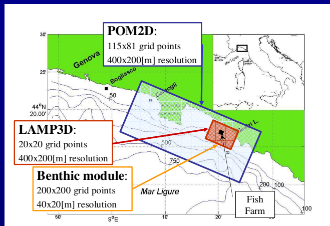

Fig. 1. Location of the fish farm respect to the numerical grids

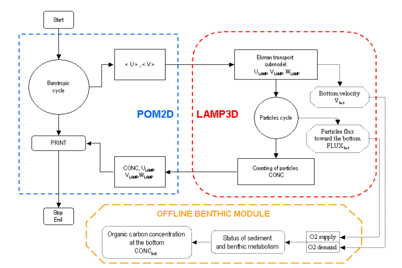

Fig.2. POM2D-LAMP3D flow chart with the new benthic module

METHODS

The Lagrangian Assessment Marine Pollution three-dimensional model, LAMP3D, is a single particle Lagrangian model. At each time step a particle with a velocity *v* moves from its position to a new one. The total velocity *v* is constituted of two contributions:

$$v = U + v'.$$

- *U* is the flow field representing the mean of the averaged transport process, calculated in barotropic approximation by the Princeton Ocean Model, POM (*Mellor, 1998*);
- *v'* is a stochastic fluctuation which is related to the turbulence intensities and characteristics of those smaller eddies that are not included in the *U* field.

Furthermore, LAMP3D is able to provide vertical profiles by using POM vertically averaged flow field to compute a theoretical vertical profile of the finite bottom Ekman spiral.
Specific properties can be assigned to each single numerical particle. Since numerous studies have demonstrated alterations of the benthos beneath and proximal to net-pens (*see Brown et al., 1987, for reviews; Findlay and Watling, 1997, and citations within*), in this work, settling particles above all have been considered.
Following *Findlay and Watling (1997)*, the benthic metabolism has been related to the ratio *O2sup/O2dem*, where *O2sup* is the oxygen supply calculated using modeled flow velocity at the bottom and *O2dem* is the oxygen demand due to the modeled carbon flux to the sediment for the settled matter mineralization (see Fig.3).
At this purpose, a high resolution grid module has been added offline to the POM2D-LAMP3D code (see Fig.2).

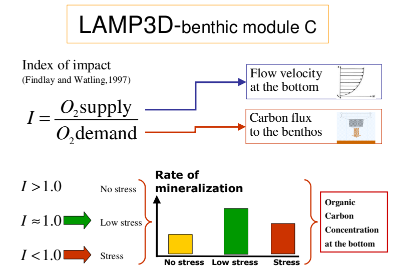

Fig.3. The benthic module for the organic carbon

Three different conditions of the benthos are then identified: if I is more then 1 there is a status of no stress, if it is about 1 there is low stres, finally if it is less then 1 there is condition of stress.
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 (see Fig.3).

We have chosen as wastes indicators the concentrations of nitrogen, phosphorus and organic carbon in uneaten feed, faecal matter and in excretion products.
Nitrogen and phosphorus are thus present in both soluble and sedimentable form.
The organic carbon is only in sedimentable form.
Other input parameters are shown in Fig.4.

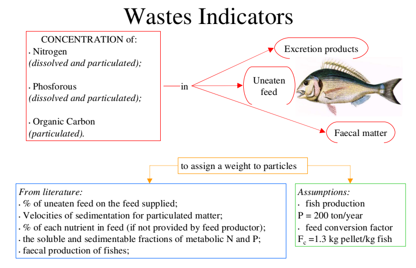

Fig.4. Wastes indicators

RESULTS

The AQUA fish farm is located offshore Lavagna (Ligurian Sea, NW Mediterranean) on the 40-m isobath (see also Fig.1). The wind driven nearcoast circulation has been simulated forcing the model with climatological data obtained by a fair statistical treatment of wind data taken by the Italian Air Force since 1963 to 1996 at the Genoa airport (*Ravasco, 2000*). The analysis clearly shows the presence of three wind trends in the sectors of North-East (NE), South-East (SE) and South-South-West (SSW). The NE wind is more frequent than the other two directions during the whole year, mainly in winter, while the SSW wind is the strongest.
With NE and SE wind the current follows the coast moving westward (see Fig.6). In contrast, with SSW wind the nearshore current intensifies as a consequence of water accumulation toward the coast and it is possible to have a reversal of the current direction for short periods.
The numerical results are in good agreement with field data taken in the area (see *Doglioli et al., 2004*).

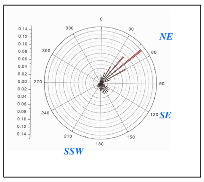

Fig.5 Annual frequency for the wind direction

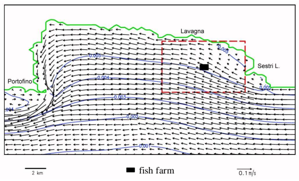

Fig.6 Depth averaged velocity (arrows [m/s]) and elevation (contour lines [m]) fields calculated for NE wind on the POM2D grid. The dashed line rectangle represents the high resolution LAMP3D grid around the fish farm (filled rectangle).

Below the cages the current intensity decreases almost linearly with depth and the different rates of decrease in speed depend on wind intensity and direction. Settling particles remain mainly confined in the fish farm area and readily sink, being almost insensitive to settling rates.
As a consequence, higher organic carbon concentrations correspond to most stressed sediment (Fig.7). Nevertheless, simulations with time varying wind forcing (both in direction and intensity) suggest the ability of the sediment to respond well and to change quickly to the environmental conditions.
Patterns of field sediment nutrients experimental data agree with model observations under westward transport and daily loading rate between field and modeled data are also in agreement.

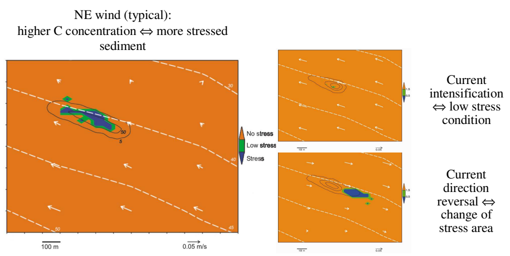

Fig.7 Organic carbon concentration at the bottom (solid isolines [mmol/m2]) and status of sediment (shaded colors). Arrows indicate bottom velocity and dashed lines isobaths in [m].

CONCLUSIONS

LAMP3D model, upgraded with benthic module, improved its capability to help fish farm management and decision making. As regards the studied case, modeled concentrations of elemental wastes resulted low in sediment compartment and never exceeded the superior bound warned in environmental risk assessments. However field measurements of Mediterranean environment carbon flux could improve the predictive capacity of the model and will permit to validate the model on a regional scale. Collaboration with farmers is essential for input parameters values and field data collection.

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