ID21- MULTISCALE APPROACH FOR NUMERICAL MODELING OF AQUACULTURE

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Abstract - Fish farming activities are a relevant economic resource in coastal waters, which have grown in a significant way in recent decades, often with deleterious environmental effects. The sustainability of the activity requires proper management and especially an appropriate site selection, which avoids use conflicts and considers adequately the potential effects before they occur. For this purpose numerical modeling is a key tool for a sustainable aquaculture.

Aquaculture is a complex activity that has environmental effects at different scales and influences and it is also influenced by the surrounding environment. Therefore the correct modeling of the activity must consider the different scales at which the aquaculture could influence, as well as the effect of environment on the activity and the interference of cultured fish over themselves.

This work describes the application of a modeling protocol to assessing the carrying capacity of fish culture in marine waters. It is a sequential process which consider the critical condition for environmental factors and culture characteristics.

Keywords: Marine aquaculture, Carrying Capacity, Environmental Impact, Coastal Management, Modeling

INTRODUCTION

Worldwide the increasing demand for fish protein over the last decades has led to a significant intensification of aquaculture production. This aquaculture intensification resulted in a deterioration of coastal marine systems and their living resources in many cases.

The Carrying Capacity evaluation related to marine farming is imperative in the context of sustainable aquaculture. According to the terminology proposed by the NIWA, Productive Carrying Capacity (PCC) evaluates from the point of view of the viability and welfare of the culture and Environmental Carrying Capacity (ECC) is the ability of the medium to assume the impact of the activity.

One of the key issues in the context of the ECC, is the understanding of the impacts of aquaculture and the identification of the scale on which they appear. Although the waste input from a single fish farm can be treated as a point source, some of it may contribute to ecological pressures at a distance from the source. It is thus important to consider the spatial extent of the ecological pressure and its impact (Table 1). Although these depend on farming method and local environmental conditions. Three zones around a polluting point source can be distinguished: Local scale (Zone A: few meters to hundred meters); Zone B (hundred meters to kilometers) and Regional scale (Zone C: many kilometers).

Thus ECC analysis should be performed on the three spatial scales mentioned above. For PCC the scenarios should be related to different culture scales (cultured biomasses, cage sizes and its spatial configurations).

METHODS

The carrying capacity is evaluated sequentially, based on the predictions of different environmental scenarios. When the analysis requires it, the simulation scenarios are nested at different levels of spatial resolution:

- A first analysis of the rate of water renewal establishes the productive capacity of the area.
- Subsequently the assimilative capacity of the benthos is determined by means of sedimentation rates of particulate waste from aquaculture.
- A second dispersion simulation analyzes different possibilities of grouping cages in production units and determines the number, spacing and distribution of cages for an optimal grouping. The criteria used in this case are the risk of hypoxia in the culture and toxicity by the discharge of ammonia.
- Finally a hydrodynamic and ecological model analyzes a realistic case of facilities distribution.

Extreme environmental conditions were simulated, those which produce most damage to the environment when a culture is simulated in the situation of maximum production.

DICUSSION AND CONCLUSIONS

Results on productive capacity must be compatible with the quality objectives established for the water column. According to the results for the two first steps, size, depth and fish density of a cage culture are sized for each facility. The third step modifies the internal organization of cages within a facility to accomplish culture welfare. The last model takes into account interactions with other sources of discharge and its impact on the environment at different nested scales.

The use of extreme conditions in simulations ensures a huge margin of security to use model predictions on aquaculture management.

Simulation models are so powerful that provide an excellent opportunity to apply this kind of approach. The protocol developed here uses several of them and is an ideal framework for this type of study. It is a sequential approach that follows a scheme that progressively applies various criteria by an increasingly restrictive and complex order. Thus allowing the reserve of the most complicated tasks (hydrodynamic simulations, 3D dispersion studies) for more specific scenarios (suitable area, number of cages, type, depth, etc.) and avoiding also the need to perform a considerable

Pressure	Impact	Spatial Scale
primary sedimentation of organic particles in regions of low or moderate dispersion	increased organic input to seabed, increased oxygen demand, smothering of fauna, consequent anoxia and change in benthic community structure	zone A
sedimentation in regions of high dispersion and resuspension	the same (but less intense)	zone B, C
primary oxygen depletion (by fish-generated BOD)	changes in behavior wild animals, mortalities, benthic community change if oxygen falls below EQS	zone A, B, C
nutrient enrichment	potential risk of eutrophication	zone B, C
chlorophyll enhancement resulting from nutrient enrichment	potential risk of harmful blooms, increased sedimentation, increased shading	zone B, C
change in N:Si or N:P ratios	change in balance of organisms, especially, diatoms: flagellates: cyanobacteria	zone B, C
increased primary production resulting from chlorophyll and nutrient enhancement	more food for plankton, but also more risk of increased secondary sedimentation	zone B, C
decreased water transparency resulting from increased chlorophyll	decrease in light available to seagrass communities, etc	zone B, C

Table 1. Ecological pressures generated by the aquaculture in floating cages, and consequent impacts on ecosystems