Simulating the impact of fish farm wastes on the environmental status in an Allocated Zone of Aquaculture in the Eastern Mediterranean Sea

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

SUMMARY

Use of AIM, a 3-D coupled hydrodynamic/biogeochemical model, to examine the impact of aquaculture wastes on the environmental status of an AAZ under different scenarios (fish production, changing climate).

DESCRIPTION

The Aquaculture Integrated Model (AIM, Tsagaraki et al., 2011; Petihakis et al., 2012) can be used in an Aquaculture Allocated Zone (AAZ) (e.g Argolikos gulf, Greece) to examine the fate of seabass/seabream aquaculture wastes under different scenarios (e.g fish production, changing climate) and assess their potential impacts on the surrounding ecosystem, in terms of good environmental status. The modelling tool consists of a high resolution 3-D coupled hydrodynamic/biogeochemical model, with a mass balance model (Tsapakis et al., 2006), being used to calculate nutrient inputs from the fish cages, based on fish feed data. A series of nested models is used to consistently downscale the hydrodynamics and biogeochemistry from the coarser resolution (~few kilometres) model of the wider area to the high resolution model (~few tens of meters) of the fish farm area. The model is validated against available satellite (Chl-a) and collected in situ (Chl-a, nutrients, mesozooplankton) data. The tool has been implemented to assess the present environmental impact of the fish farms in the Argolikos AAZ and to

investigate the system carrying capacity through additional scenarios adopting an increased fish production. The tool was also implemented to investigate the potential changes in the AAZ environmental status due to climate changing conditions (i.e. increase of temperature/stratification etc), under future scenarios for 2030-2050 and 2080-2100 time windows.

THE ISSUE BEING ADDRESSED

The input of dissolved inorganic nutrients from fish farms may affect the ecological regime of the surrounding areas. The dispersion of waste and build-up of nutrients within the marine environment depends on the hydrography and physical conditions in the area of the fish farms. The areas, where many aquaculture farms operate together, are called Allocated Zones for Aquaculture (AAZs), and, in these areas, the environmental impact of fish farms wastes may be complex. Consequently, planning and licensing of cage aquaculture can be complex and decision makers need help to assess if a site is suitable for cages and determine acceptable biomass limits.

THE APPROACH

AIM consists of a 3-D coupled hydrodynamic/biogeochemical model that can be used to simulate the effect of aquaculture wastes in an Aquaculture Allocated Zone (AAZ) area. The use of a comprehensive biogeochemical model, such as ERSEM allows investigating the complex food web response, triggered by the nutrient inputs. The high resolution (~50m) of the hydrodynamic model and its progressive downscale through nesting with coarser models allows a realistic simulation of circulation, which is crucial for the correct dispersion of aquaculture effluents. Once setup and validated, the coupled model can be used to examine the impact of existing aquaculture units in an AAZ area, in terms of good environmental status and ecosystem functioning. More importantly, it can be used by means of scenario (e.g farm location, production etc) simulations as a management tool for the spatial planning and licensing of new farms or the increase of production for existing farms. The model produces maps of near surface currents, Chl-a and dissolved inorganic nutrients (phosphate, nitrate, ammonium, silicate) that can be used to calculate environmental indicators (i.e. Environmental Index E.I.; Primpas et al., 2010) describing the environmental status in the area and assess the AAZ carrying capacity.

THE RESULTS

The tool has been implemented for an AAZ in Argolikos gulf in the Eastern Mediterranean Sea assessing the impact of fish farm wastes on the environmental status of the area, under different scenarios. The results suggest that the environmental conditions in the AAZ were “good” during winter well mixed period and “moderate” to “poor” during more stratified periods, particularly summer. The environmental conditions in the vicinity of different fish farms were found to be correlated to the fish farm production, as well as the predominant current speed. For instance, there were cases of fish farms presenting relatively better environmental conditions, despite their high fish production, due to the stronger prevailing currents, resulting in the more efficient off-shore dispersion of fish farm wastes. Changes in the food web structure were mainly characterized by an increase of dinoflagellates that are generally considered as an indicator for eutrophication and also nanophytoplankton and microzooplankton. A scenario simulation, adopting a double fish production was performed, investigating the carrying capacity of the AAZ. An additional increased production scenario was performed, allocating more

production in fish farms characterized by better environmental conditions. In this case the deterioration of conditions in fish farms was more balanced, avoiding extremes.

Different case studies of the AIM tool are available in Ecological Modeling Tool in the link of Lifewatch Greece Portal (https://portal.lifewatchgreece.eu/).

THE BROADER APPLICABILITY

The tool can be relatively easily adapted for other fish farm areas in the Mediterranean, to help stakeholders determine if a site is suitable for fish cages and/or determine acceptable biomass limits. The main limitation of the modelling system is that it is computationally demanding, due to the high resolution of the model. Therefore, overall the use of AIM as a management tool requires some effort and expertise (scientific for the model output interpretation and technical for the model implementation), but future plans include the dynamic model implementation through a web application that will make this tool more user-friendly.

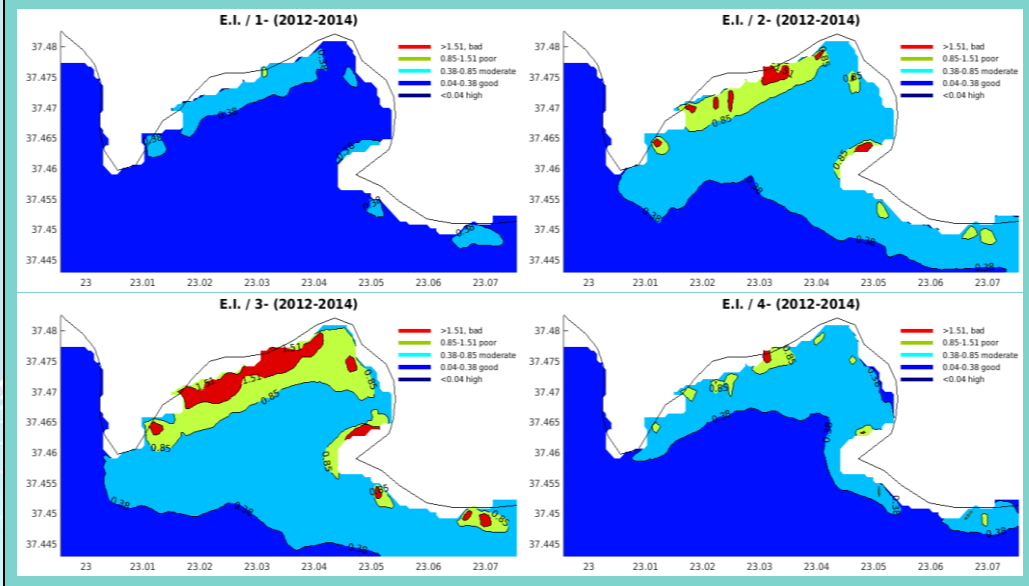

Figure 1: Seasonal variability (1=winter, 2=spring, 3=summer, 4=autumn) of simulated Environmental Index (E.I) over 2012-2014 period in Argolikos AAZ.

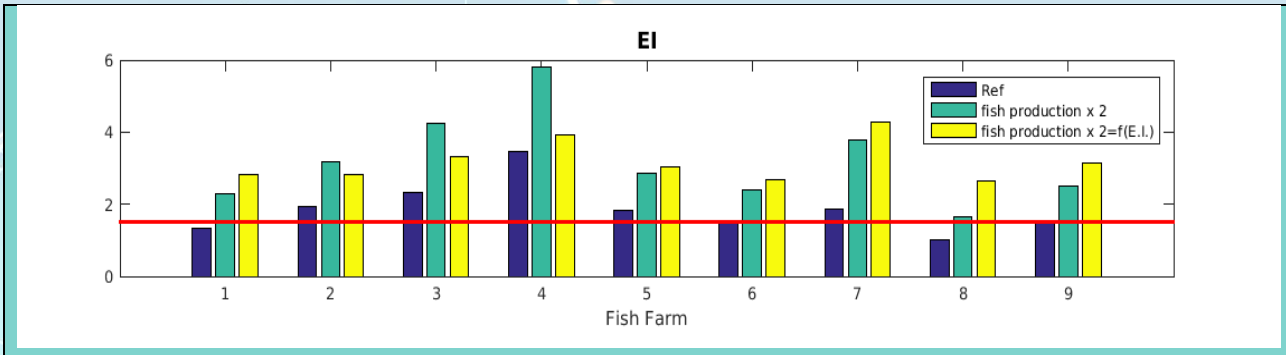

Figure 2: Mean 2013 summer simulated E.I. index in the vicinity of the fish farms in Argolikos AAZ with Reference fish production, double fish production and double fish production "optimally" distributed in different fish farms taking into account of E.I variability. The red line indicates the threshold identifying "bad" environmental conditions E.I (1.51) index.

SWOT ANALYSIS	
STRENGTHS	The tool is a comprehensive and high resolution biogeochemical/hydrodynamic model that provides realistic simulations that can be used for the spatial planning and licensing of new farms or the increase of production for existing farms.
WEAKNESSES	The model is computationally demanding, requiring a computer server, with results being produced on a time scale of days. In situ measurements, needed for the proper model validation may increase the tool cost.
OPPORTUNITIES	Can be used as a dynamic management tool through a user-friendly web application.
THREATS	The tool application is relatively demanding (initial setup, computational cost etc), which may be limiting for its broad use for licencing/planning.

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LINK	Different case studies of the AIM tool are available in Ecological Modeling Tool in the link of Lifewatch Greece Portal (https://portal.lifewatchgreece.eu/).

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