Assessment of Ecosystem Response in Pujada Bay by Water Quality Model Combined with Species Competition Model

47-176817　李 天野　　(Graduation: September 2021)
Department of Environment Systems　　Supervisor: Professor Shigure TABETA

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1. Background and objectives

Pujada and Mayo Bays in southeastern Mindanao are important convergence points for the Pacific Ocean and Celebes Sea bioregions. To elucidate the type and volume of agrochemicals used in the surrounding areas as well as other pollutants that have leached into the bays to possibly cause marine pollution, this project named Development of a Comprehensive Coastal Ecosystem Modelling, Mapping and Monitoring Systems (CCEMMMS) is carried out in collaboration with the Davao Oriental State College of Science and Technology, Philippines. Against this background, the main part of this research is to make a physical-ecosystem model for understanding the current situation of water quality and its changing mechanism in Pujada Bay and try to develop a tool to assess the ecosystem response due to the water quality change. As a goal, this research is expected to be used to recommend adequate, practical, practicable, and crucial management interventions and to support conservation practices. We hope some results from this research can help to identify areas or factors that require the most urgent attentions and raise awareness among the coastal communities close to the affected areas about the real status of their coast to implement needed interventions.

2. Research flow

This research has two main sections, reproduce the basic water quality and ocean current movement of the bay, and establish a rational link between human activities, water quality changes and ecosystem changes. The processes are broken down into following four steps:

- Collection and modification of relevant input data.
- Assume reasonable values for partial missing input data and conduct numerical simulations in Pujada Bay during certain time period to reproduce the environment.
- Introduce a coral-algae competition sub model to the water quality model.
- Based on the result of coupled model simulation, try to investigate the relevant response of ecosystem to human activities through scenario setting.

3. Introduction of models

In this research, a physical-ecosystem model, MEC Model (Marine Environmental Committee Model) is chosen as numerical model. The fundamental components of MEC Ocean Model are physical sub model and NPZF ecosystem sub model. Because physical disturbances play a vital role in nutrient diffusion and in sequence affects the distribution of aquatic living creatures, the former sub model is aimed to deal with the hydrodynamic conditions and water state. Then it is followed by a sub ecosystem model dealing with the chemical and biological features of research targets, which is a more direct index for environmental evaluation. After reproducing the water quality and ecological environment of Pujada Bay, a coral-algal competition model was introduced for the first time into the MEC model, which was used to predict the ecosystem trends under different conditions.

4. Simulation conditions

Pujada Bay is a U-shaped bay with an opening that faces towards the south-southeast and small islands are found at its mouth (Fig. 1). It has several freshwater tributaries (Magum River, Matiao Creek and Pahamutang Creek). It encloses an area of 168 square km shared by 10 coastal barangays of Mati, Davao Oriental. The computational simulation area was a rectangle range between 6.74~6.98°N and 126.14~126.35°E, with 30-degree rotation. The only open boundary was located at the lower side of this area, and the whole area was divided into 200m-size meshes (66×115) horizontally. The grid data is shown as Fig.2.The three marked points are local observation sites, which are located at the mouths of the rivers entering the bay, so these three positions were also used to locate the river outlets.

Fig. 1 Map of Pujada Bay bathymetry

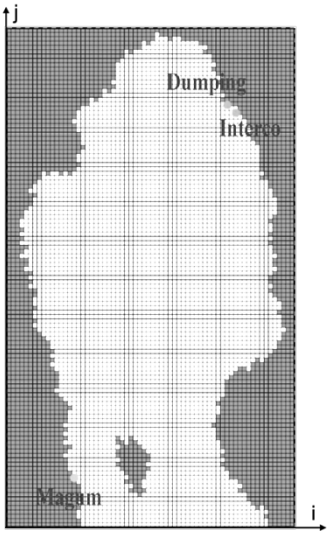

Fig. 2 Grid map for simulation

In vertical direction, the area was divided into 31 layers. Considering that currents near the ocean surface are more influenced by meteorological factors such as wind and solar heat, the layers near the surface were divided more compactly. Since the depth variation of Pujada Bay is very large but considering that the deep sea is less affected by human activities and will reduce the stability of the model simulation, the part with depths greater than 400m was ignored. The grids at the edge of the shoreline were also finely adjusted for the MEC-NEST model by ignoring or unifying the depth of some grids that are too shallow. The various data involved in this research, like climate, wind, open boundary and river data, were partly obtained from reports of the Davao Oriental State College of Science and Technology, Philippines. Other missing data were filled in via CMEMS and SOLCAST. Considering the stability and comparability of the simulation， two separate time periods were simulated in this research, July 1 to July 30 in 2020 (wet season), and September 1 to 30 in the same year (dry season). Since the main objective of this research is on predicting and assessing the possible impacts of future human activities on the bay, two output points were selected for the demonstration of the MEC-NEST model simulation results, where were close to the largest city along the coast, Mati.

5. Scenario set up

According to the related research in Manila Bay of Philippines, fish pens/cages had the highest N and P input, which were mainly due to the application of commercial feeds. Here, as similar, the waste from aquaculture, mainly from fish pens/cages, is also considered as one of the possible causes of

water quality deterioration in Pujada Bay. Currently, the coastal population of Pujada Bay is still increasing, which will inevitably lead to an increase in the production demand of aquaculture farms, and in turn to an increase in environmental pressure. Since studies around Pujada Bay are relatively sparse, there are no data related to aquaculture now. However, by comparing and calculating the data with those of similar areas, we can roughly estimate the nutrient emission. As a reference, data related to aquaculture in Manila Bay were used in this research. By comparing the distribution area of the fish cages between the two bays, the specific value of the required parameters can be estimated from the annual nutrient input from the aquaculture farms in Manila Bay.

6. Results and discussion

The simulation results were compared to the observation data. Usually, this step is expected to testify the accuracy of numerical model. However, in this research, this premise must be mentioned that the observation data used in this chapter are all from one observation site outside the bay, which was the only data source. Therefore, all observation data were used only for the reference of numerical ranges and as a compromise, this research focused on the coarse reduction of the bay overall environment and the plausibility of the simulation. Partial simulation results are shown below as Fig.3 and Fig.4.

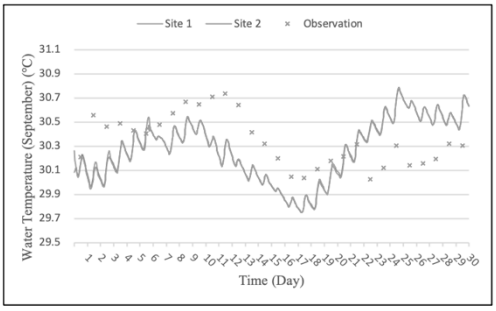

Fig. 3 Time series of the water temperature at surface in September

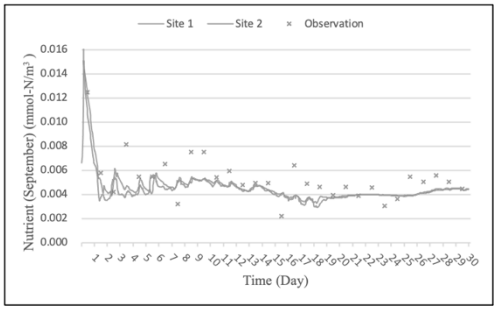

Fig. 4 Time series of the nutrient at surface in September

As conclusions: 1) The physical environment of water temperature and salinity in Pujada Bay can be reproduced consistently and realistically by MEC-NEST model. 2) In the simulation of ecosystem environment, the model presented uncertainty in its simulation results. The ambiguity mainly came from the multiple assumptions that had to be made due to the lack of field data. 3) The simulation of the coral-algal competition model could reflect the pattern of coral and algal abundance variation in response to feedback from both nutrient supply and consumer abundance.

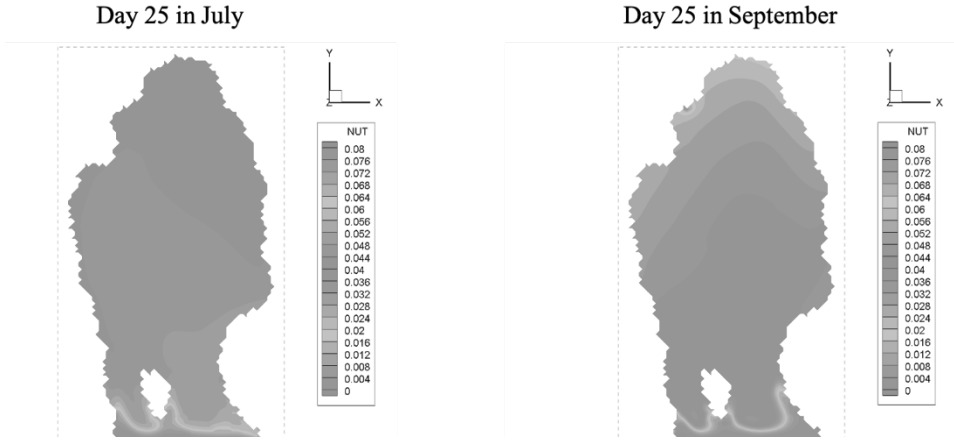

Fig. 5 Horizontal distribution of the surface nutrient changes in day 25

Fig.5 here shows the numerical changes of the before and after values of nutrient concentrations at surface layer in the bay without and with the impact of aquaculture, the gradual diffusion of nutrients in the bay over time can be seen in the figures. The simulation result for July had similar characteristics. And following Fig.6 and Fig.7 show the difference simulation result of the competition model. Cases that coral abundance reduced was increased, which implied a high probability that coral abundance would be replaced by other benthic communities under conditions of high nutrient supply.

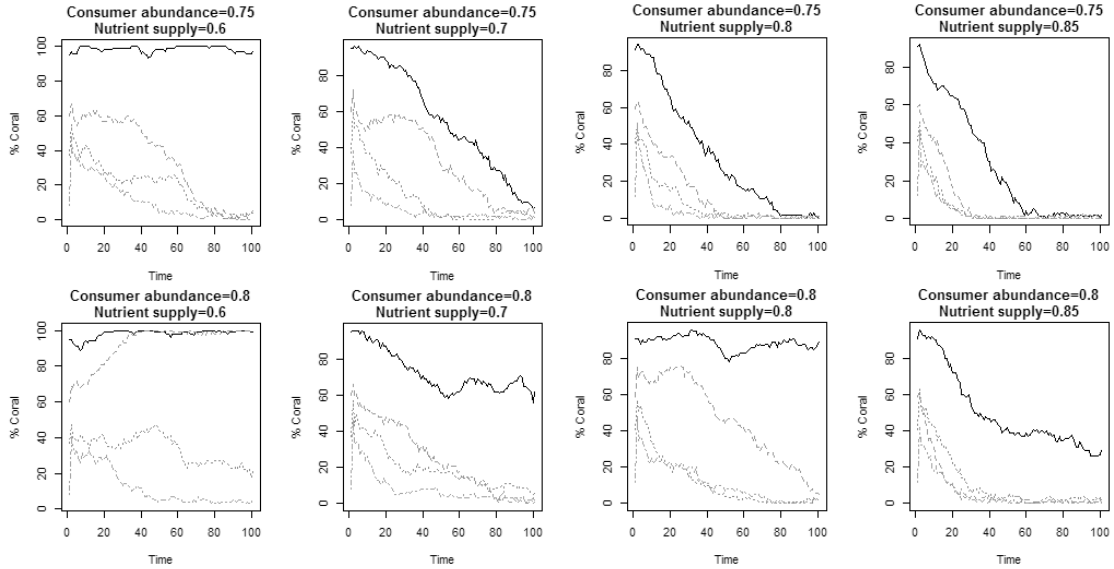

Fig. 6 Multiple results of coral abundance variation without impact of aquaculture

Fig. 7 Multiple results of coral abundance variation under impact of aquaculture

7. Summary

In this research, MEC-NEST Model has been expanded by introducing the coral-algae competition model and applied to the Pujada Bay to understand the current water quality and ecosystem environment, then further to elucidate the possible effects of aquaculture scale expansion on ecosystem. The combined model was stably run, with quantitative reproduction of physical and ecosystem environment. Although the fidelity of the model was not credibly confirmed due to practical reasons, the overall simulation results were still within an acceptable and reasonable range and showed a similar trend to the real situation. Variations in local coral and algal abundance simulated by the competition model also, to some extent, showed the ecosystem response of the bay to environmental changes. After the first section of this research was completed, scenarios associated with aquaculture were set up to further demonstrate the model's ability to respond reasonably well to possible environmental changes. After model modification and re-simulation, the validity of the model was partially proved.

8. Reference

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