Numerical Analysis of Eutrophication in Mikawa Bay, Japan by using Ecological Model: Prediction and Analysis on Response of Ecosystem to Various Nutrients Loading

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1. INTRODUCTION

Mikawa Bay is a semi enclosed bay located in the middle of Japan and approximately 700.000 people live near the watershed. The watershed area is used intensively for agricultural and livestock production, where nutrient from the land area is loaded through two major rivers Toyokawa and Umedagawa, and the municipal waste water treatment at Noda and Nakashima.

In the last four decade, the increased water pollution accompanied by red tides and oxygen-depleted waters has been frequently observed in Mikawa Bay. These phenomena are said to be related to the increase in the coastal nutrient supply and to a decrease in the func tion of the tidal flat, Suzuki et al., (1997). In the previous study, Anggara and Kit ada (2004) analyzed the eutrophication mechanism in Mikawa Bay using a hydrodynamic and water quality model. In that study, like most of other numerical models for coastal marine ecosystem, the model consisted of pelagic system, and the benthic variables were given as boundary condition. In this study, we developed a new model by including the benthic system to the eutrophication model, which has been used in the previous study.

The objective of this study is to examine the response of water quality in the bay to various nutrients loading from land area and sediment re-suspension using the new model. The result on the water quality response will be quantified by comparing the calculated chlorophyll-a and dissolved oxygen among the cases and basic case.

2. METHOD

2.1 Grid segmentation

In this study, the water body of Mikawa Bay, as shown in Fig. 1 is simplified in 2-dimensional space where the longitudinal directions is the line connecting monitoring points A13, A10, A5, A7 and A14 at which various data are periodically acquired by local and national governments. The water body along the longitudinal line is discretized into 30 equally spaced longitudinal segments and 24 vertical layers. Each segment has the same length of 855 m and each layer has uniform thickness of 1.1m. The depth of each segment varies from 6.6 m to 24 m.

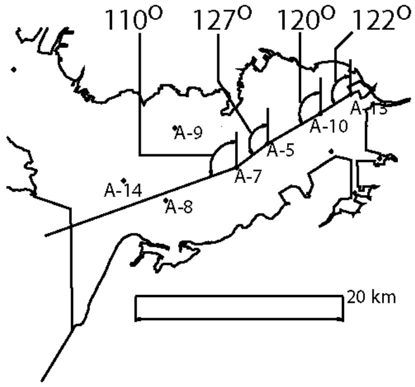

Figure 1 The segmentation model of Mikawa Bay, the thick solid line indicates longitudinal axis in two-dimensional model.

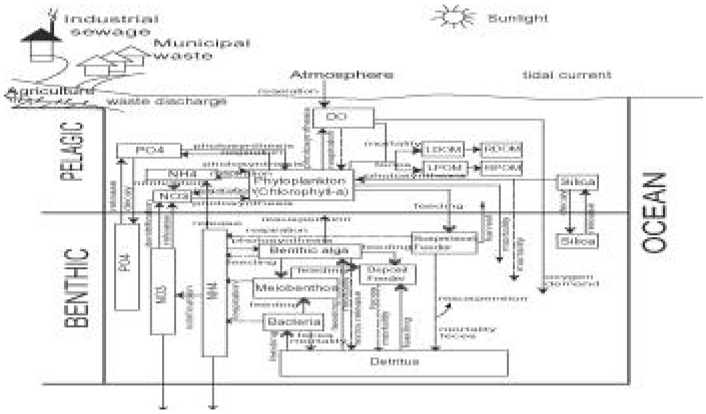

Figure 2 Block diagram showing relationship among state variables in pelagic and benthic system.

2.2 Pelagic and benthic equation

CE-Qual-W2 is a coupled hydrodynamic and water quality model. In the model, water quality algorithm incorporates 23 constituents, 13 of which were used in this application. Detailed description of the fundamental equations used in the model can be found in Cole and Wells (2000). Pelagic and food-web structure of ecological model is shown in Fig. 2. These food-web models and the benthic equation were modified based on the tidal flat model of Tokyo Bay used by Nakata and Hata (1994). Each box represents one model state variable. In the food web, double-arrow lines and dotted lines represent predation and decomposition process, respectively.

3. RESULTS AND DISCUSSION

3.1 Model comparison

Keywords: Numerical analysis, Eutrophication, Benthic system, Water quality model
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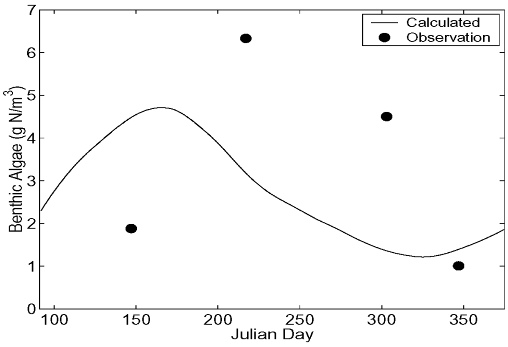
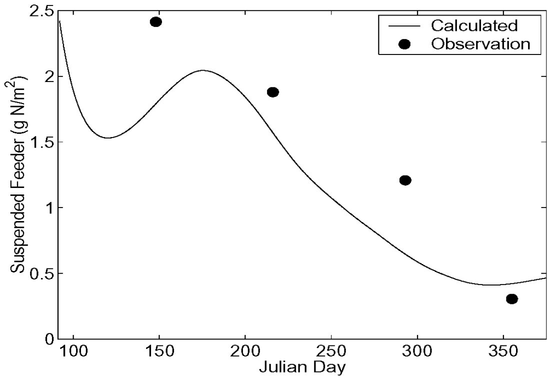
The calculated model of benthic alga and suspended feeder (fig. 3a, b) suggests that the model reproduces seasonal variation; i.e., the pattern of biomass concentration exhibits peaks that correspond to the growth of biomass in summer time. The observed data were collected only four times during the year, i.e., May, August, October and December. Thus further detailed comparison between observation and calculation was impossible.

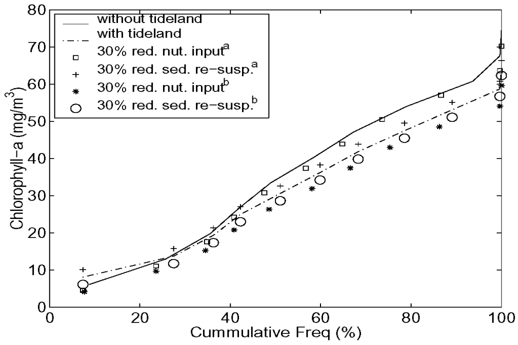


(a) Benthic alga

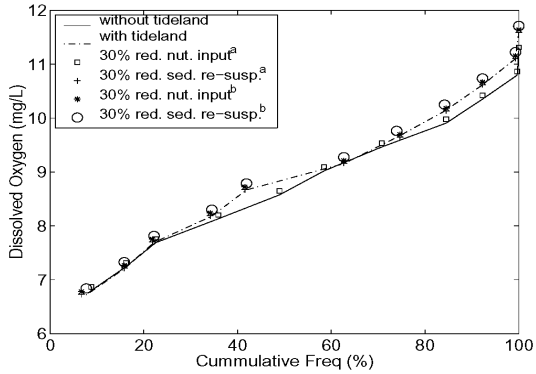


(b) Suspended feeder

Figure 3 Comparison of the model prediction and the observation on the seasonal variation of benthic organism. The horizontal axes represent Julian Day (April to March).



(a) Chlorophyll-a at measurement point A13



(b) Dissolved Oxygen at measurement point A13

Figure 4 Comparison of model calculated cumulative frequency distribution of chlorophyll a and dissolved oxygen concentration for all scenarios.

3.2 Prediction of Water Quality Improvement

Five cases were simulated to analyze the response of water quality in the bay (Table 1). The new model reduced the predicted mean chlorophyll-a about 4 mg m^{-3} and increased the predicted mean dissolved oxygen about 1 mg L^{-1} (Figs. 4a.b). Reduction in predicted chlorophyll-a concentration by the control of loading from land area was found to be relatively small if benthic system does not work. On the other hand, control of nutrient input from sediment re-suspension without benthic system gives approximately similar result in reducing chlorophyll-a concentration as with benthic system case. The response of dissolved oxygen concentrations to various nutrients inputs were found similar to the response of chlorophyll-a concentrations; only the magnitude was different.

Table 1 Calculation scenarios

Basic case	without benthic system
Case 1	with benthic system
Case 2	30% red. nut. input without benthic system [a]
Case 3	30% red. resus. without benthic system [b]
Case 4	30% red. nut. input with benthic system [a]
Case 5	30% red. resus. with benthic system [b]

[a] A 30% reduction of nutrient loading from land area. The loading from land area represents those from waste water treatment plant (WTP) and river.

[b] In the model calculation , the nutrient re-suspension rate was reduced by 30%

4. CONCLUSION

The present numerical analysis gives the following major findings: The model developed in this study numerically reproduced a realistic behavior observed in Mikawa Bay ecosystem, such as benthic alga and suspended feeder. Control of nutrient input from sediment without benthic system gives approximately similar result in reducing chlorophyll-a and increasing dissolved oxygen concentrations as with benthic system case.

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