DISTRIBUTIONS OF NITROGEN COMPOUNDS TO SUSTAIN AQUACULTURE ACTIVITIES IN JEPARA WATERS, INDONESIA

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Abstract

Fishing industry (e.g., shrimp pond culture) has been rapidly developed in some part of the Indonesian coastal zones, especially in Jepara waters located at the northern coast of Central Java. In addition to meet the domestic demand, the aquaculture farm products are also exported to other countries. Therefore, the products provide a valuable income for the Indonesian government and its society. However, the harmful effects of society on this resources such as marine pollution (e.g., organic wastes, heavy metals, and pesticides) and poor control of fisheries management have resulted in documented cases of reduced yields in the region. To overcome this problem, an understanding of relationships between the physical environment and marine ecology is required. In this study, we address to investigate the effects of accumulation and diminution of organic matters (i.e., Nitrogen compounds) and also by making clear their final fate in the fish and shrimp pond culture environment located around Jepara waters using a coupled hydrodynamical-ecological model for regional and shelf seas (COHERENS). The components of nitrogen compounds for distributions investigate are: organic nitrogen, ammonium, nitrate, microplankton-N, zooplankton-N, detrital-N.

Keywords : organic nitrogen, ammonium, nitrate, microplankton-N, zooplankton-N, detrital-N

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1. Introduction

Jepara is a part of North Java coastal region that has aquacultures as one of its major economic activities (Hartoko, 2000). Geographycally, this region is located between the latitudes 06°39’30“ S - 06°44’40“ S, and longitudes 110°34’40“ E - 110°38’20“ E (as shown in Figure 1). Along the coast lines, there are fish and shrimp pond cultures about 805.717 ha with 9 canals used as both for inlet and outlet of sea water.

In addition to meet the domestic demand, the aquaculture farm products are also exported to other countries, especially Japan. Therefore, the fishing industry has provided thousands of jobs and significant revenue for Indonesia, especially for the Jepara region. Unfortunately, the harmful effects of society on this resources such as marine pollution and poor control of aquatic environment and of fisheries management have resulted in documented cases of reduced yields in some of the major commercial fisheries (Annual report of Fisheries in Jepara regency, 1996-1999). To overcome this problem, an understanding of relationships between the physical environment and marine ecology is required.

Marine pollution (e.g., organic wastes, heavy metals, and pesticides) and poor control of fisheries management around aquatic environments have resulted in decreasing of the quality and quantity of the fishing products. In addition, if the level of toxicity of specific pollutants exceeds an acceptable level, the fishing products will be dangerous to be consumed. In this study, we address to investigate the effects of accumulation and diminution of organic matters, and also by making clear their final fate in the fish and shrimp pond culture environment. Here, we focuses on the prediction of organic waste distributions related with nutrient cycling in Jepara waters, especially along the coast of Serang River and Bokor Patch Reef (Figure 2) where many fish and shrimp pond cultures exist in the region.

The nutrient cycling considered in this study is nitrogen both as inorganic and organic compound. A coupled hydrodynamical-ecological model for regional and shelf seas called ‘COHERENS’ from Luyten *et al*., (1999) was used to predict the water dynamics and distribution of nitrogen in the Jepara Waters.

2. Model Descriptions and Its Application

2.1. The Hydrodynamic Model

To predict nitrogen distributions in coastal waters, we need to acquire a better understanding of the hydrodynamics. Based on the previous study carried out by Kastoro (1987), it is recognized that tidal current is dominant along the Coast of Jepara and Bokor Patch Reef. Mixed, mainly diurnal tides predominate in the region. Therefore, we used tides as the main forcing for the model. Because tidal elevations imposed at the open boundaries are not available at the model domain (marked C in Figure 3), we extend the domain to be an area indicated by A in Figure 3. The nested model technique (Supangat, *et al.*, 2001) was then used to simulate water circulation along the Coast of Jepara and Bokor Patch Reef.

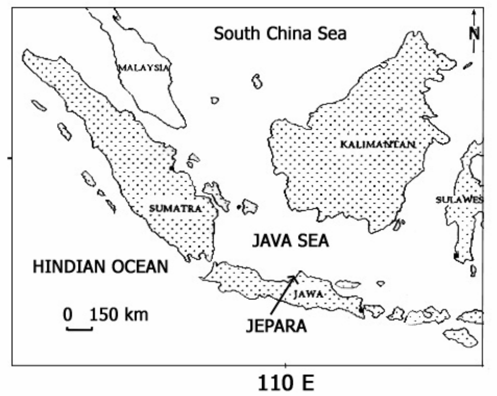

Figure 1. Location of Jepara waters as part of the Indonesian archipelago (Source: Supangat, 1998)

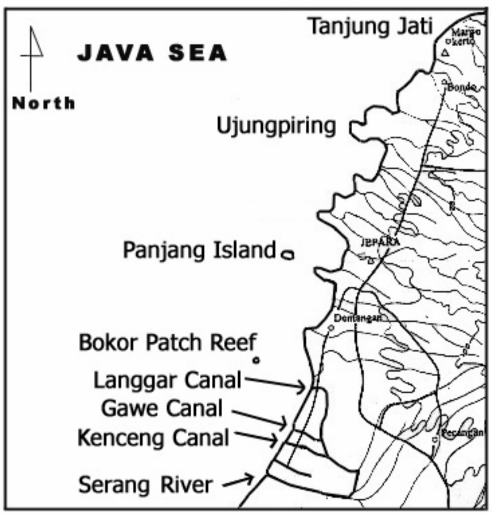

Figure 2. A detailed sketch of Jepara waters around fishpond culture area, scale 1 : 250,000 (Source: Kamiluddin, *et al.*, 1998).

The simulation was carried out in three stages, namely a coarsest grid model, a finer grid model, and a finest grid model, indicated by A, B, and C in Figure 3, respectively. Furthermore, description of this paper will focus on the finest grid model since we concern at study area located along the Coast of Jepara and Bokor Patch Reef (marked C in Figure 3). The model domain is 11 km x 8 km covered by 100 x 80 grid cells at approximately 100 m resolution. In the study area, there are 1 river and 3 canals serving as freshwater runoff and nutrient input, namely Serang River, Kenceng Canal, Gawe Canal, and Langgar Canal (marked by S-1, S-2, S-3, and S-4 respectively in Figure 18).

In this study, we used the 2D mode of the COHERENS. The model was run from March 1 to April 15, 2001. Tidal elevation imposed at the open boundaries for the coarsest grid model derived from a global tide model of ORITIDE (*Ocean Research Institute, University of Tokyo*).

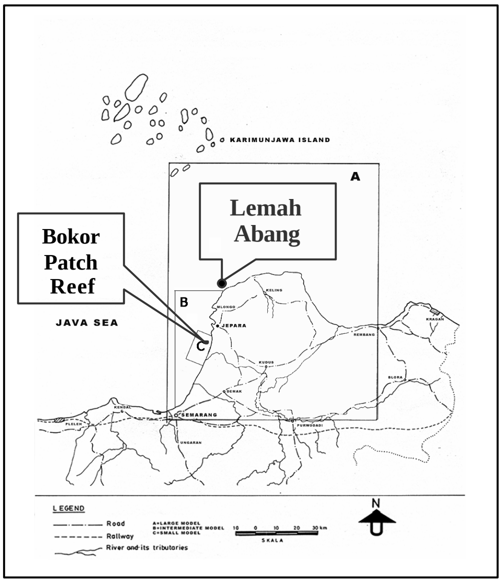

Figure 3. Model study area (A = the coarsest grid model, B = the finer grid model, C = the finest grid model). (Source: Mihardja, *et al.*, 1996).

2.2. The Nitrogen Model

A main process of the biological model of the COHERENS is a mutual interaction among 2 compartments (i.e., microplankton and detritus), and nutrient exchanges between the water column and the sediment (fluff) layer. Nitrogen is simulated by the nitrification process, in which nitrifying bacteria are assumed to be abundant at all the times.

In the following we will outline parameters used in the model. Reference values of temperature and salinity were obtained from observation, namely 29°C and 33‰, respectively. Solar radiation was 3651,3 watt/m^2 taken from a literature for tropical waters (Lalli & Parsons, 1993). Autotroph basal respiration value was 0,04 day^{-1} obtained from a literature for *Skeletonema costatum* (Richardson, *et. al*., 1983). Meanwhile, grazing rate value was 0,05 day^{-1} obtained from Tett & Walne (1995).

Initial values of parameters used for the nitrogen model were obtained from field measurement. The parameters are organic nitrogen, ammonium, nitrate, microplankton, detritus, zooplankton, and oxygen. Meanwhile, Serang River, Kenceng Canal, Gawe Canal, and Langgar Canal were point sources of nitrogen compound (as shown in Table 1).

Table 1.
Initial values of parameters used in the model

No.	Parameters	(mg/l)	References
1.	Microplankton Carbon	0,0267	Supriyanto (1994)
2.	Microplankton Nitrogen	0,0048	Supriyanto (1994)
3.	Detrital Carbon	0,021	Observation
4.	Detrital Nitrogen	0,044	Observation
5.	Ammonium	0,012	Observation
6.	Nitrate	0,390	Observation
7.	Zooplankton Nitrogen	3,814	Observation
8.	Oxygen	7,00	Observation
9.	Organic Nitrogen	0,022	Observation

3. Results and Discussion

3.1. Current Simulation

The simulated current circulation pattern in the study area can be seen in Figures 6 and 7. During spring ebb condition, the current flows toward the northeast (Figure 6), whereas it flows southwestward during spring flood condition (Figure 7). Tidal prediction at Bokor patch reef was chosen as the reference time of the flood and ebb condition. The maximum current speed calculated by the model is 0,235 m/s.

The model results were validated by comparing the predicted and computed values of sea surface elevation and the observed and computed values of currents. The sea surface elevation used for model verification was also obtained from the ORITIDE. Verification of sea surface elevation was carried out at Bokor patch reef (Figure 4). The general agreement betwen the computed results and predicted value of sea surface elevation is reasonably encouraging.

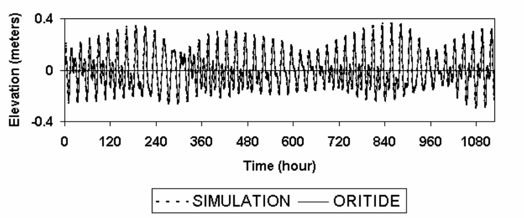

Figure 4. Model verification of sea surface elevation.

Verification of currents was carried out at the site spot of Lemah Abang (110°48'00" E and 6°25'12" S), which location as shown in Figure 3, because observation data are available at the region. The verification was only performed in the coarsest grid model because the Lemah Abang region does not exist in the finer and finest grid model. Figure 5 shows the verification of the components of current for *x*- and *y*-direction, respectively. The simulation results of *x*-direction current (*u*) vary from –0.399 m/s until 0.394 m/s, in which 20% bigger than the observation values. Meanwhile, the component of current in *y*-direction (*v*) shows generally good agreement with the observation data.

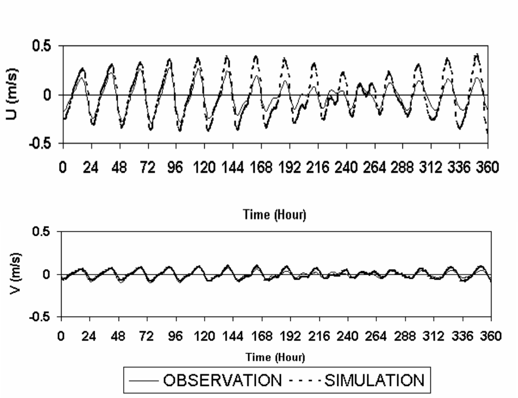

Figure 5. Model verification of the components of current in *x*- and *y*-direction, namely *u* and *v* respectively.

3.2. Distribution of Nitrogen Compounds

The simulation results of the nitrogen model along the Coast of Jepara and Bokor Patch Reef are shown in Figures 6 – 17. The results present that distribution pattern of nitrogen compounds is consistent with the current circulation pattern.

In general, concentrations of nitrogen compounds simulated by the model are: 0.003 - 0.072 mg/l for organic nitrogen, 0.002 – 0.066 mg/l for ammonium, 0.002 – 1.055 mg/l for nitrate, 0.001 – 2.290 mg/l for microplankton-N, 3.814 – 4.710 mg/l for zooplankton-N, and 0.035 – 1.498 mg/l for detrital-N.

Figures 6 to 11 show the horizontal distribution of organic nitrogen, ammonium, and nitrate during the spring ebb and flood tide condition. High concentrations can be seen around the mouth of river and canals (around marked by S-1, S-2, S-3, and S-4 in Figure 18). The concentration of organic nitrogen, ammonium, and nitrate decreases in offshore direction. These results indicate that the mouth of river and canals serve as a nutrient trap area where high concentrations of nutrient take place (Odum, 1971). Sources of the nutrient are fishpond cultures and domestic waste. However, the range of simulated concentrations still meet the water quality standard for marine organism issued by Indonesian government.

Distributions of microplankton-N, zooplankton-N, and detrital-N during the spring ebb and flood tide condition can be seen in Figures 12 to 17. Low concentrations exist around the mouth of river and canals (around marked by S-1, S-2, S-3, and S-4 in Figure 18), and the concentrations subsequently increase in offshore direction. It happens because the mouth of river and canals are ones of eutrophic areas that have high concentration of nutrient. However, concentrations of microplankton and zooplankton are low in the region (Harris, 1986; Baretta-Bekker, *et. al.*, 1992). The microplankton-N used in this study was *Skeletonema costatum* (Phylum Diatoms or Bacillariophyta), which has euryhaline characteristic. It means that the species can adapt high ranges of osmotic pressures (Abercrombie, *et. al.*, 1997). So, its habitat is estuaries and seas, in which high abundance exists in the sea (Isnansetyo & Kurniastuty, 1995).

In the biological model of COHERENS, zooplankton-N is associated with variable accumulation of potential losses of microplankton-N at second trophic level. It means distribution of zooplankton-N influenced by microplankton-N abundances.

Detrital-N is a part of organic detritus, in which its composition consits of death organism, organic waste, and pools of bacteria, protozoa and microbes (Abercrombie *et. al.*, 1997; Baretta-Bekker *et. al.*, 1992, Luyten *et. al.*, 1999). So, abundance in mouth of rivers and canals are higher than in the sea. However, the simulation results showed a different phenomenon. This might be happen because the initial condition of ratio between carbon and nitrogen used in the model is 30%:60% (Parsons, *et. al.*, 1984). This ratio was greater than the default value of detrital-N quota of the COHERENS. Therefore, the remineralisation of nitrogen proceeds faster than the degradation of carbon. Eventually, detritus becomes more refractory with the increasing time, so that concentration of detrital-N in the mouth of river and canals tends to be low.

3.3. Verification of the simulated Nitrogen Compounds

Comparing the simulated results with observation data of March 19, 2001 carried out the verification. The verified parameters were organic nitrogen, ammonium, and nitrate (see Table 2 to 4).

Stations for verification were mouth of Serang River, mouth of Kenceng, Gawe, and Langgar Canals, which are named as stations 1 to 4, respectively. Meanwhile, station 5 to 8 are located at an offshore distance of 700 m from mouth of Serang River, of 900 m from mouth of Gawe Canal, and of 700 m from mouth of Langgar Canal, respectively (marked by V-1 to V-7 in Figure 18).

Table 2.
Verification of organic nitrogen concentrations

STATION	ORGANIC NITROGEN (mg/l)	
	OBSERVATION	SIMULATION
1.	0,072	0.072
2.	0,060	0,061
3.	0,066	0,066
4.	0,044	0,044
5.	0,044	0.043
6.	0,072	0,062
7.	0,056	0.040

Table 3.
Verification of Ammonium concentrations

STATION	AMMONIUM (mg/l)	
	OBSERVATION	SIMULATION
1.	0,002	0,003
2.	0,019	0,024
3.	0,011	0,015
4.	0,012	0,014
5.	0,024	0,023
6.	0,015	0,017
7.	0,012	0,015

Table 4.
Verification of Nitrate concentrations

STATION	NITRAT (mg/l)	
	OBSERVATION	SIMULATION
1.	0,880	0,881
2.	0,360	0,366
3.	0,255	0,265
4.	0,320	0,327
5.	0,773	0,883
6.	0,390	0,217
7.	0,840	0,238

In general, the simulated results have mean relative errors about 6.50 %, 24.55 %, and 22.36 %, for organic nitrogen, ammonium, and nitrate, respectively.

4. Conclusions

The study of nitrogen compound distributions in the Jepara waters, Indonesia, especially along the coast of Jepara and Bokor

Patch Reef, was carried out using the COHERENS model.

Range of the simulated concentrations of organic nitrogen and ammonium are 0.003 – 0.072 mg/l and 0.002 – 0.066 mg/l, respectively. They are about 0.002 – 1.055 mg/l for nitrate and 0.001 – 2.290 mg/l for microplankton-N. Meanwhile, range of the simulated concentrations of zooplankton-N and detrital-N are 3.814 – 4.710 mg/l and 0.035 – 1.498 mg/l, respectively. The concentrations of nitrogen compounds simulated by the model still meet the water quality standard for marine organism recommended by Indonesian government. Therefore, the Jepara waters are still suitable regions for fish and shrimp pond cultures.

Acknowledgements

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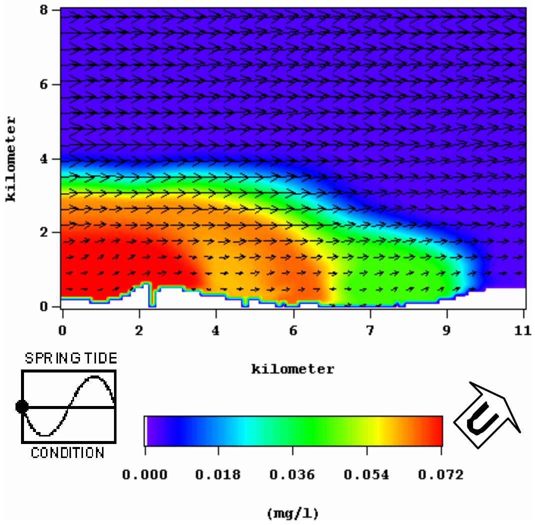


Figure 6. Distributions of organic nitrogen during spring ebb tide.

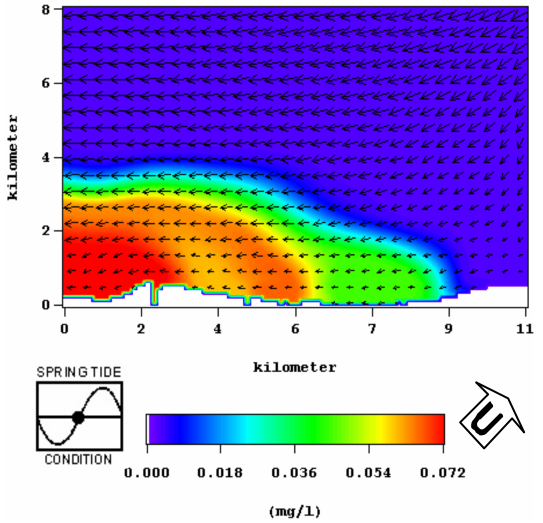


Figure 7. Distributions of organic nitrogen during spring flood tide.

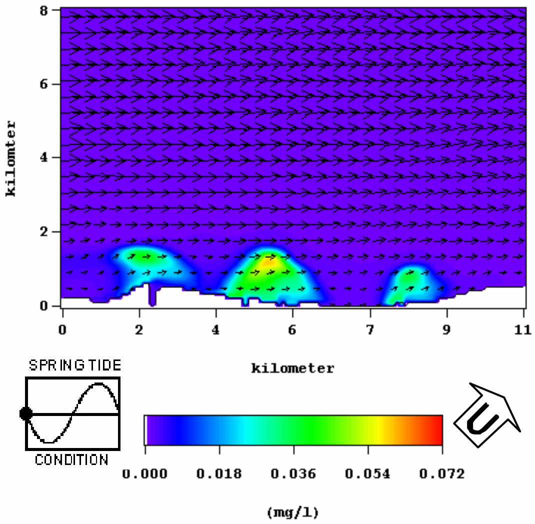


Figure 8. Distributions of Ammonium during spring ebb tide.

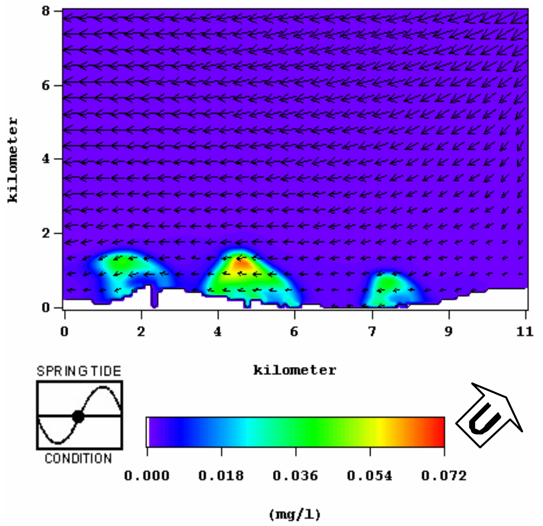


Figure 9. Distributions of ammonium during spring flood tide.

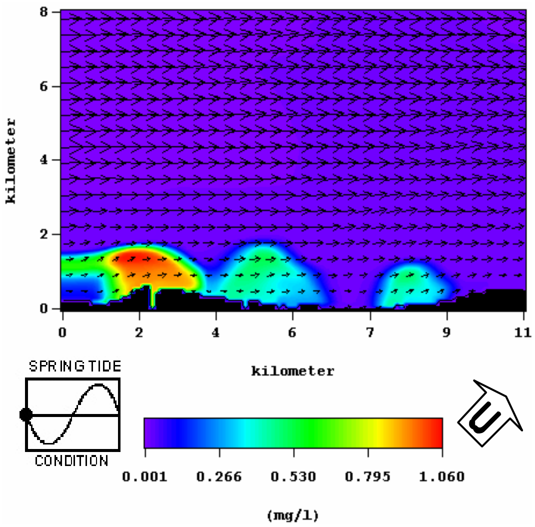


Figure 10. Distributions of nitrate during spring ebb tide.

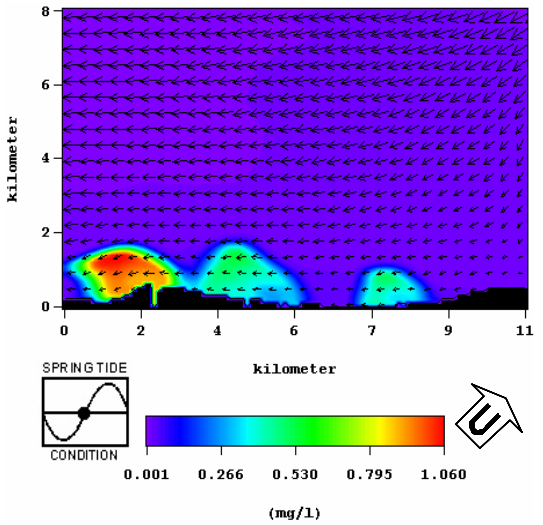


Figure 11. Distributions of nitrate during spring flood tide.

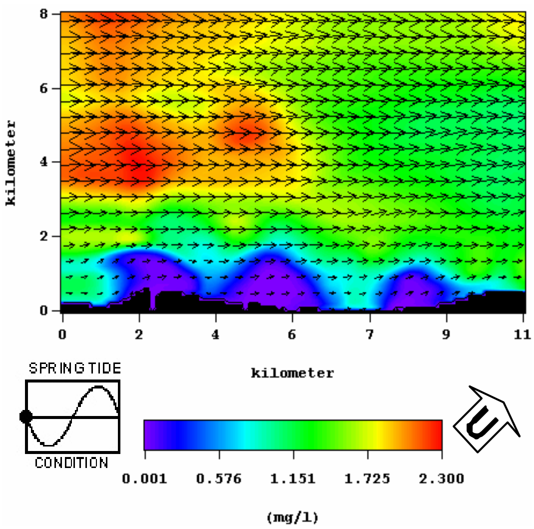


Figure 12. Distributions of microplankton-N during spring ebb tide.

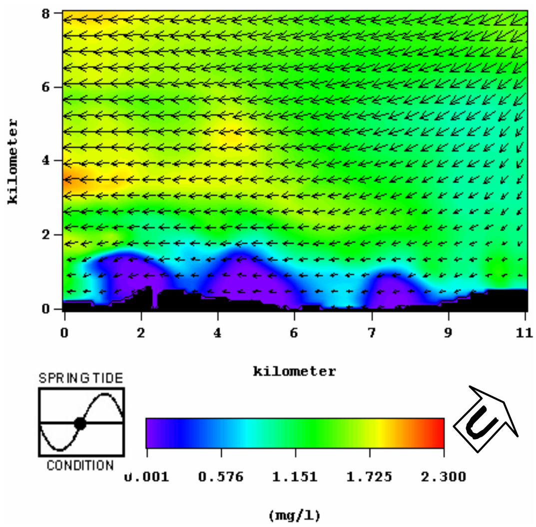


Figure 13. Distributions of microplankton-N during spring flood tide.

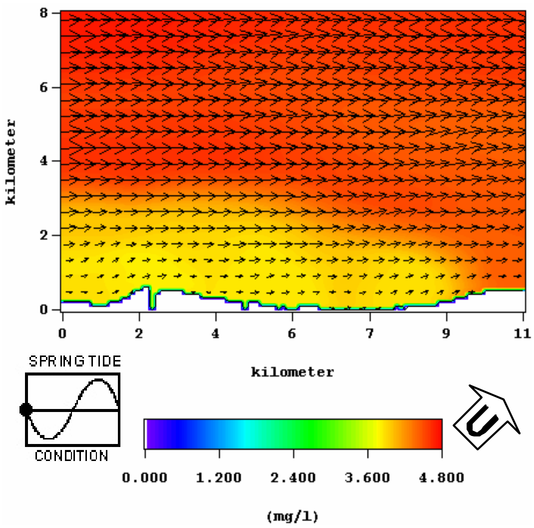


Figure 14. Distributions of zooplankton-N during spring ebb tide.

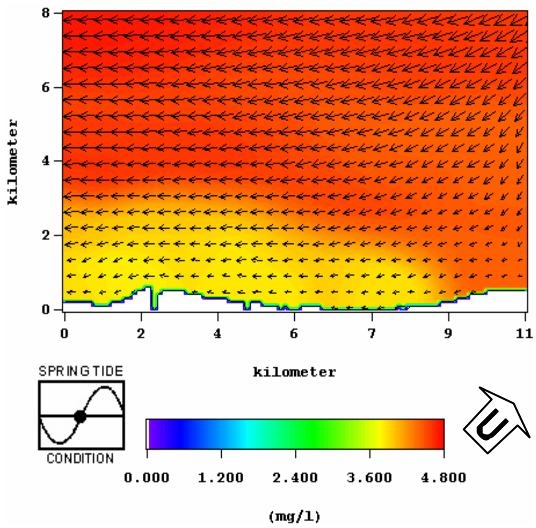


Figure 15. Distributions of zooplankton-N during spring flood tide.

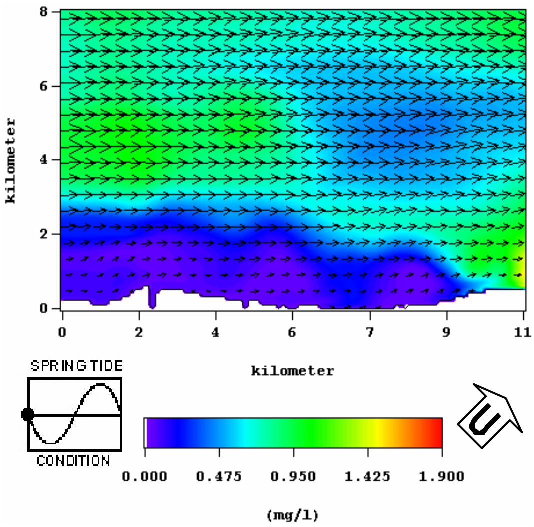


Figure 16. Distributions of detrital-N during spring ebb tide.

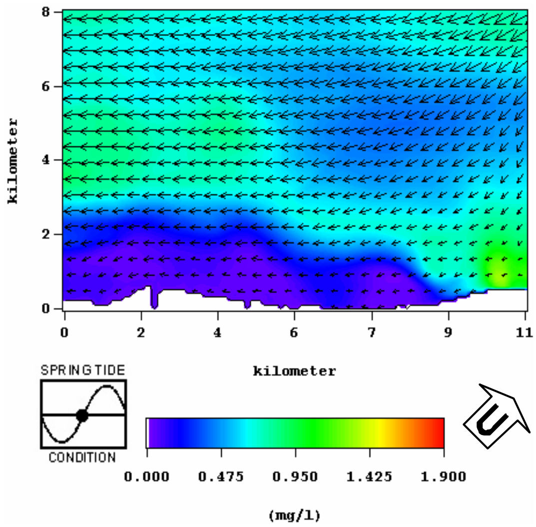
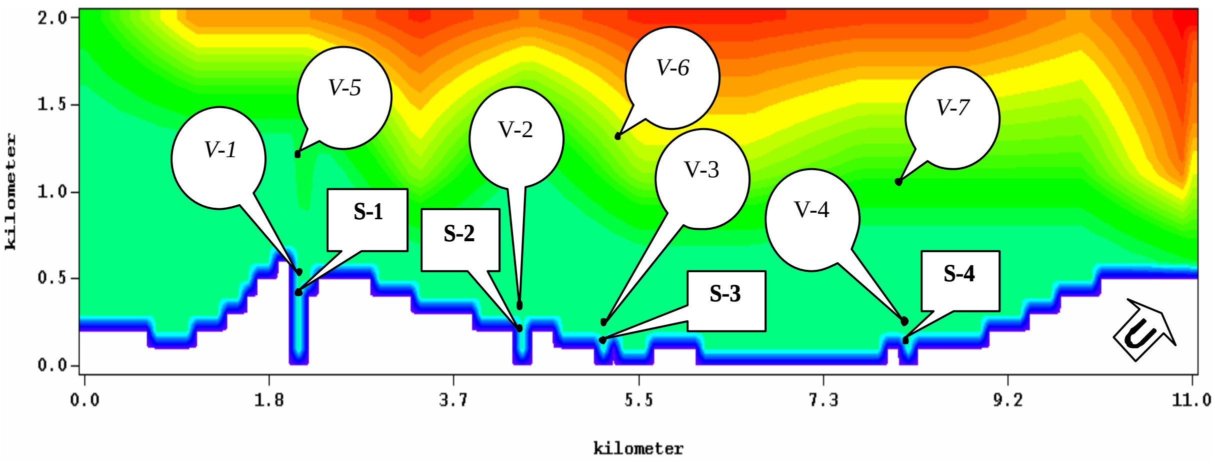


Figure 17. Distributions of detrital-N during spring flood tide.



Note:

S-1 = Source of Serang river
S-2 = Source of Kenceng canal
S-3 = Source of Gawe canal
S-4 = Source of Langgar canal

V-1 = Station 1 for Verification
V-2 = Station 2 for Verification
V-3 = Station 3 for Verification
V-4 = Station 4 for Verification

V-5 = Station 4 for Verification
V-6 = Station 5 for Verification
V-7 = Station 6 for Verification

Figure 18. The Stations are for verifications and point sources of nitrogen compounds. Sketch in the finest grid model area.