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We regret for any errors or omissions that we may have unintentionally made.

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PREFACE

The International Seminar on Water Related Risk Management, held in Jakarta, Indonesia from 15 to 17 July 2011 were attended by experts, Scientiest, Practitioners and Profesionals on water resources, Coastal and other related sectors.

The discussions of the seminar had covered the entire aspects of water related risk management including risks contained in flood/drought , coastal , groundwater and urban drainage as well as socio-econonic aspects, involving likely notified profesionals with numerous models, scientific and empirical deliberation, as well as field experience exposures.

The overall presentations, discussions and debates during seminar concluded that the outputs will undoubtedly contribute to remarkable concepts, strategies, lessons learned, and sharing of experiences on the water related disastrous phenomena and it’s risks, particulary on the enviromentally sound technologies and sustainable practices on the year to come. Based on this fact, I believe that the proceeding of this seminar will be valuable document in solving the problems of water related disaster and reducing the impact of water related risk.

I would like to thank the organizing committee, reviewer and writers, seniors and all members of HATHI for enormous supports to the seminar. May God bless you all.

Pitoyo Subandrio

Chairman,
The Organizing Committe
July 17th, 2011

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Longterm Simulation of Phythoplankton Dynamics by Object Oriented Model to Control Eutrophication in the Jatiluhur Reservoir

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Abstract: *A reservoir can be catagorized as a multi-purpose water resources infrastructure. Unfortunately however, many of the reservoirs in Indonesia are facing the problem of eutrophication which recently has become a global concern. This problem can be solved by technical measures that include an object oriented conceptual model carried out by Powersim software. This paper focuses on the numerical simulation of reservoir water quality dynamics in controlling eutrophication. The water quality parameters simulated include the parameters as prime cause of eutrophication such as total Nitrogen dan total Phosphorus, whereas eutrophication is indicated by the phytoplankton concentration. The simulation result show that remedication of Jatiluhur Reservoir can be done by an integrated method, i.e. reduction of internal and external loading mainly on Total Nitrogen and Total Phosphorus loadings. Internal loading of nutrients compound should be reduce about 50%, while the nutrients come from external loading, must be lowered to 90%.*

Keywords: *Eutrophication, chlorophil-a, phytoplankton,Jatiluhur Reservoir, Conceptual Model*

INTRODUCTION

Eutrophication is a gradual process of excessive increase of fertility in a reservoir due to nutrients compounds, particularly Nitrogen and Phosphorus. This process causes an overly growth of primary vegetation and aquatic plants. Balcerzak (2006) sets forth that an euthrophication process takes place in several years and is mainly caused by anthropogenic activities. The eutrophication process in the reservoir eco-system shall decrease significantly with the increase of nutrient loading carried by the reservoir inflow started at the mesotrophic phase up to the eutrophic phase and finally reaching the hyper-eutrophic phase.

There are two types of nutrient pollution loading entering a reservoir, the point source and non-point source. Included in the non-point source is wastewater originated from agricultural land or run-off. *Lee,* and *Jones* (2007) denote that these two sources of nutrient pollution loading cause an excessive growth of algae population and It is significantly affecting to the dissolved oxygen concentration. *Kemp* (2009) on the other hand explains also that increase of nutrient loading shall increase not only the potential of harmful algae bloom but also anaerobic or hypoxia conditions at the bottom of reservoir. *Vandijk et al*., (1994) to Balcerzak (2006) indicate that low dissolved oxygen concentration and excessive phytoplankton growth may affect the decrease of reservoir ecosystem.

Melendez, et al. (2009) explains that the potential of algae growth because of the increase of nutrient loading shall cause difficulties in reservoir recovery process from hyper-eutrophic to mesotrophic. Reservoir remedy through reduction of nutrient loading and increase of dissolve ed oxygen at reservoir bottom is therefore to be implemented. *Melendez, et al.* (2009), has also denoted that pollution loading dynamics because of discharge fluctuation and concentration has a great effect on the condition of reservoir trophication.

Considering the obove conditions objective of the study is to indicate the effect of nutrient pollution load entering the reservoir water body cause the eutrophication dynamics. When the effects of decrease of pollution input loading have been identified, efforts of controlling reservoir eutrophication can be carried out.

METODOLOGY

This study is initiated with setting up an object oriented conceptual model to simulate the eutrophication dynamics in the Jatiluhur Reservoir. Analysis of input data included the water quality data causes eutrophication processes such as Total Nitrogen and Total Phosphorus in Jatiluhur Reservoir that has been polluted by reservoir inflow and waste of fish food. This model analysis is carried out by dynamic model and assisted with the "Powersim *Constructor* "software, mainly on external and internal loading..

So that, the results is the long-term estimation of phytoplankton dynamics affected by pollutant load reduction through an object oriented conceptual model.

LITERATURE REVIEW

Affect of Nutrient Loading to Eutrophication

Eutrophication is caused by an excessive input of nutrients loading and has been studied for the determination of control strategy since 1970 (*Paur, et al,* 2008). Major nutrients, such as total Nitrogen and to Phospor are limitation factors for phytoplankton, whereas silica is the limitation factor for diatoms in reservoir bottom deposit. Therefore, indications of excessive algae growth are shown by change of species composition, aesthetic disturbances, bad odour and taste and the drastically oxygen decrease or anaerobic conditions. Nutrient loading affecting the reservoir eutrophication process composes generally of nitrogen and phosphor particulates which further may dissolve into Available Nitrogen and Soluble Reactive Phosphor used to proliferate Phytoplankton (*Chapra,*1996). However, the dynamics of phytoplankton and diatom proliferation is also limited by zooplankton and the plankton death rate.

Nutrient loading into reservoir indicated from various sources that is natural and cultural activities mainly from human activities. Whereas, because of the reservoir retention time, nutrient loading shall show the bio-chemical exchange, deposition and evaporation processes also used by aquatic biota. *Carpenter,S* (2005) explains that phosphor loading tends to deposit and accumulate in sediment and biota. However, according to a study conducted in Lake Michigan, 60 % of deposited phosphor shall re-enter to the water column (*Pauer, et al*, 2008). The entering and release of nutrient loading particularly phosphor shall cause eutrophication dynamics, which initiates microcystic toxin in the reservoir produced by Cyanobacteria (*Brahmana, et al,* 2002).

Thus, in order to prevent toxic substances in water bodies, especially reservoirs, *Kiirikki,et al.* (2001) suggested to reduce nutrient loading particularly phosphorous subtance flowing from catchment areas. *Kiirikki,et al.* (2001) also denoted that the reduction of phosphor loading, mainly come from catchment areas, could be done with improving the domestic waste treatment system, which can significantly decrease the intensity of algae growth including Cyanobacteria in the water bodies in Finland. However, the recovery time of an eutrophic reservoir by decreasing the nutrient loading in a reservoir is still difficult to be estimated.

Dynamic Simulation of Eutrophication

Tangirala, et al. (2003) indicate that the dynamic simulation system is the concept based on the idea where dynamic interaction between elements of a system can be studied and their behavior showing the overall system. *Forester* (1961) to *Tangirala*, et al. (2003) explained that the main idea of a dynamic system model is to understand the behavior of a system by use of a simple mathematical structure. *Huang* and *Chang* (2003) indicated that the dynamic system can be applied in environmental issues by an object oriented simulation (Figure 1). *Nirmalakhandan* (2002) explained that the dynamic system model can be applied in both environmental and water resources issues particularly the water quality on a reservoir as illustrated in Figure 2.

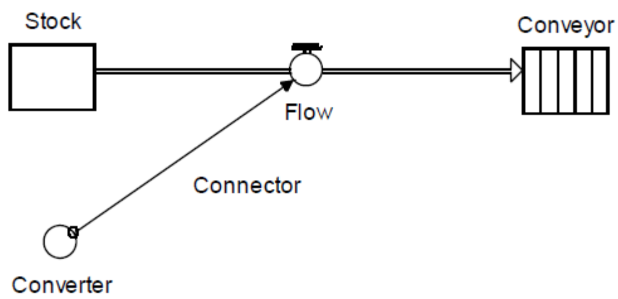

Figure 1 Components of the object oriented simulation model (*Tangirala et al.*,2003)

Figure 1 illustrates an object oriented dynamic model formed by model blocks comprising (1) Stocks ; (2) Flow; (3) Converter; and (4) Connector. Stocks are functioning as storage for tangible or intangible variables. Flow to model the flow of specific amount by time series. Whereas connectors are modeling the information flow of a certain variable, and the converter is the model of functional relationship of variables, for instance mathematics, logic or others. Table 1 shows a list of water quality components and the model used, and Figure 3 depicts a Phytoplankton object oriented dynamic model

Table 1 Water quality components and object oriented modeling

Water quality component	Category of object oriented modeling
Lake and reservoir, retention pond, deposition, pollution load	Stock
River flow, pollution load	Flow
Mathematical relationship (discharge and pollution load), decay process	Converter
Catchment system, outlet Functional relationship and correlation	Sources dan Sinks Connector

Source: *High Performance System* (2000)

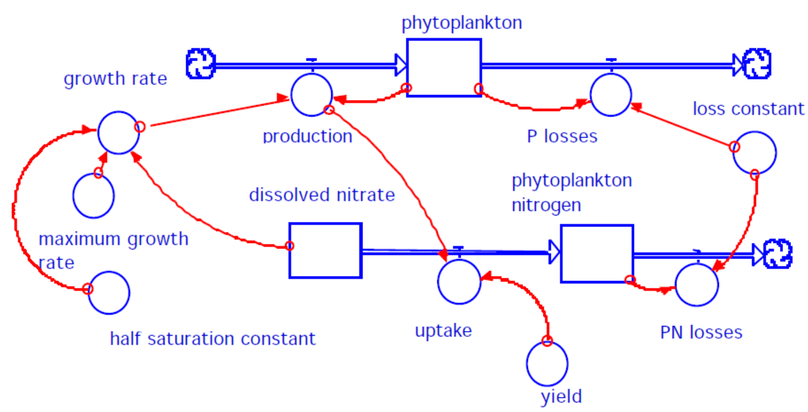

Figure 2 Phytoplankton growth dynamic process desribed by object oriented model (Gurung,P.2007)

RESULTS AND DISCUSSION

The eutrophication conceptual model that is suitable to be applied in Indonesia has to consider a water quality model that can be measured, monitored and calibrated according to the Indonesian standard of water quality laboratory measurements. Water quality parameter standards that can be measured on site include Dissolved Oxygen, pH, temperature and transparency. Parameters measured in the laboratory taken from water samples may comprise suspended particles, Nitrogen compounds like ammonium, nitrite and nitrate; phosphorus compounds, dissolved phosphate or ortho-phosphate and the organic parameter, as BOD, as shown in Figure 3. While Figure 4 illustrates a conceptual model of water quality parameters initiating eutrophication processes that can be described as a causal-loop diagram of eutrophication dynamic process affected by nutrients and organics in reservoir.

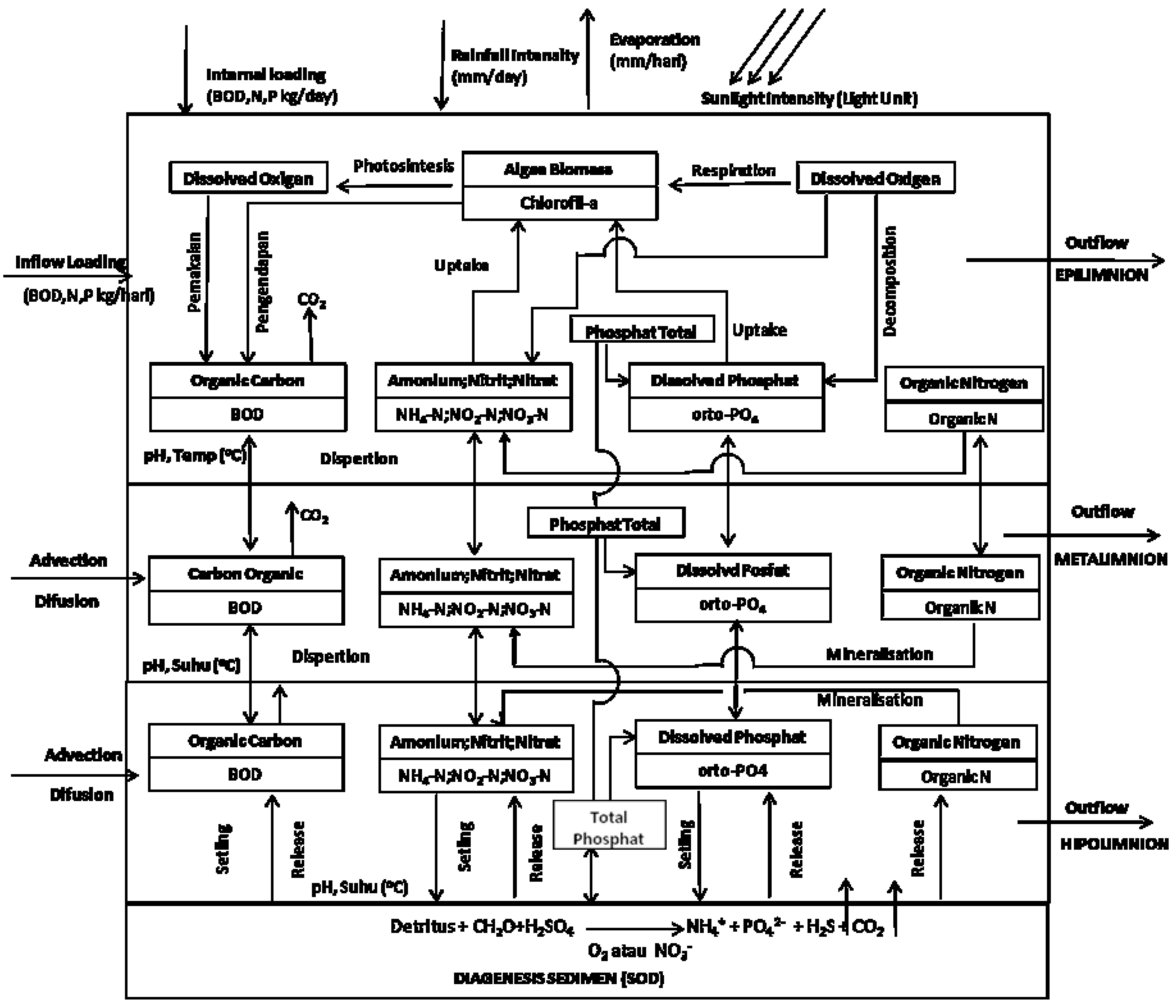

Figure 3 Conceptual model of parameters interaction initiating eutrophication process in a reservoir

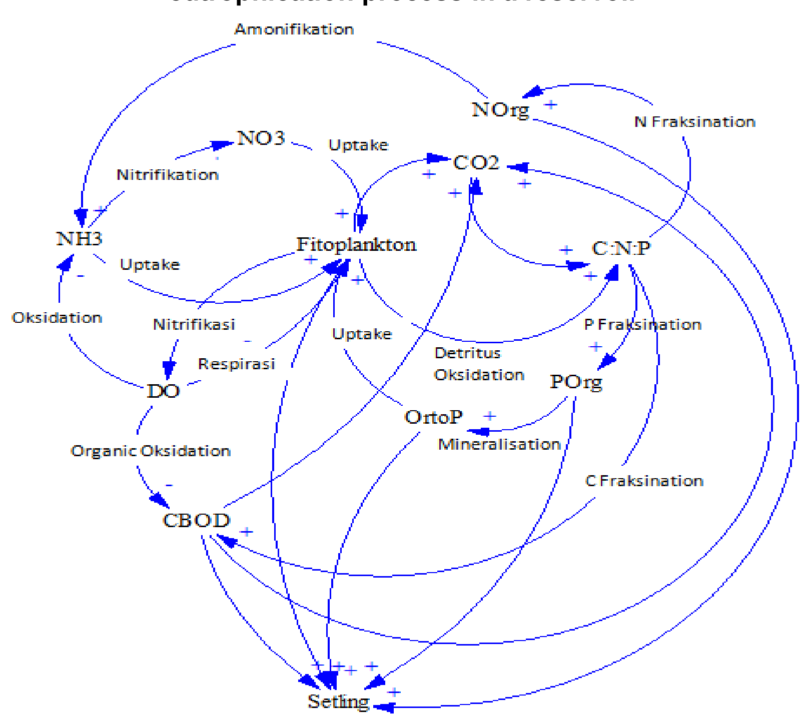

Figure 4 Causal-loop diagram of water quality parameter affect to Phytoplankton growth

Figure 4 indicates two positive loops that have a snow ball effect to the excessive phytoplankton growth process or eutrophication. First loop starts at the NH_3 uptake by phytoplankton. Phytoplankton is decomposed into Detritus (C:N:P), N fractionized into N Organic, N-organic ammonified into NH_3, then NH_3 is uptaken to Phytoplankton. Second loop denotes the ortho-phosphate uptake by phytoplankton. Phytoplankton is decomposed into Detritus (C:N:P) , Detritus-P fractionized into P Organic, then there is mineralization process of P-Organic into Ortho-phosphate and then Ortho-phosphate is uptaken to Phytoplankton. Thus, these two nutrients loops are main instigate the eutrophication reservoir problem.While, Figure 5 and 6 show slider control and detailed program for eutrophication dynamic simulation assisted with Powersim software. Constants used in the model are depicted in Table 3, and calibration is done by comparison of observed and simulation data (Figure 7). Observed data are taken from the 2009 phytoplankton data of the Jatiluhur Reservoir (*Gunadi*, 2010)

Table 3 Constants used in the eutrophication dynamic model (Gurung, 2007)

No	Constant	Value	Unit
1	Monod nitrate nitrogen constant	0.001	mg/L N
2	Monod ammonia nitrogen constant	0.001	mg/L N
3	Monod phosphor constant	0.001	mg/L P
4	Ammonia preference factor	1.46	mg/L N
5	Optimum light intensity	250	W/m^2
6	Optimum temperature	23	^0C
7	Shaping factor as temperature limit	0.6	-
8	Temperature lowest limit	5	^0C
9	Maximum growth rate	0.9	1/day
10	Grazing rate	0.265	1/day
11	Death rate	0.3	1/day
12	Respiration rate	0.1	1/day
13	Temperature coefficient for respiration	1	-

Source:*Gurung,*2007

Simulation results of phitoplankton dynamic, affected by nutrients reduction, is illustrated in Figure 7 and 8. This simulation can be done by several scenarios, among others: without policy, reducing internal factors, reducing phosphor loading by 20% and reducing Total Nutrients by 60%, 80% and 90%. Results indicate that remedy of the Jatiluhur Reservoir should be done by integrated method i.e: (1) internal management of the reservoir environment and (2) reduction of external nutrien loading. Expectantly, internal management of reservoir environment can reduce the potential phytoplankton growth into 50%. This initiative has to be combined with the reduction of external nutrient loading at least 90%, in order to restore the Jatiluhur Reservoir to be an oligotrophic-mesotrophic category.

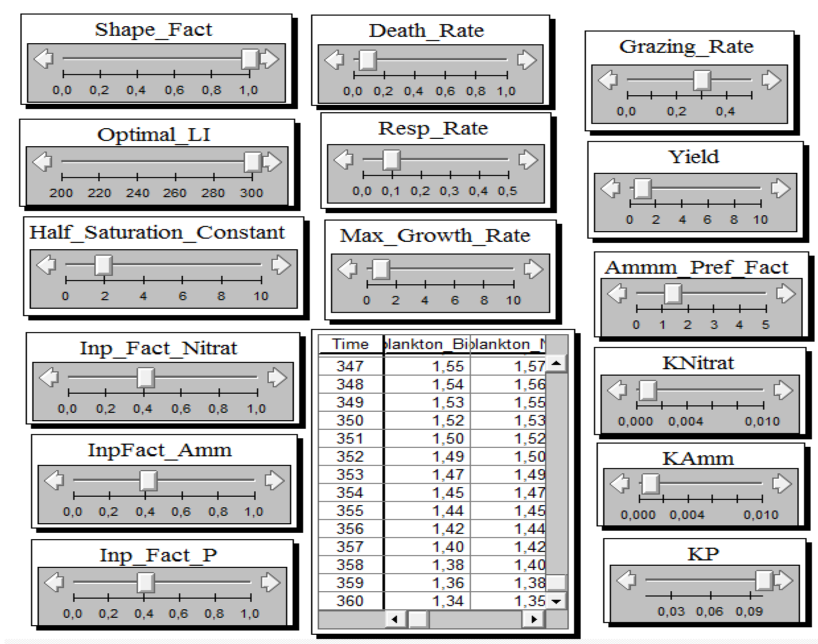

Figure 5 Slider control for dynamic simulation of hytoplankon growth in Jatiluhur Reservoir

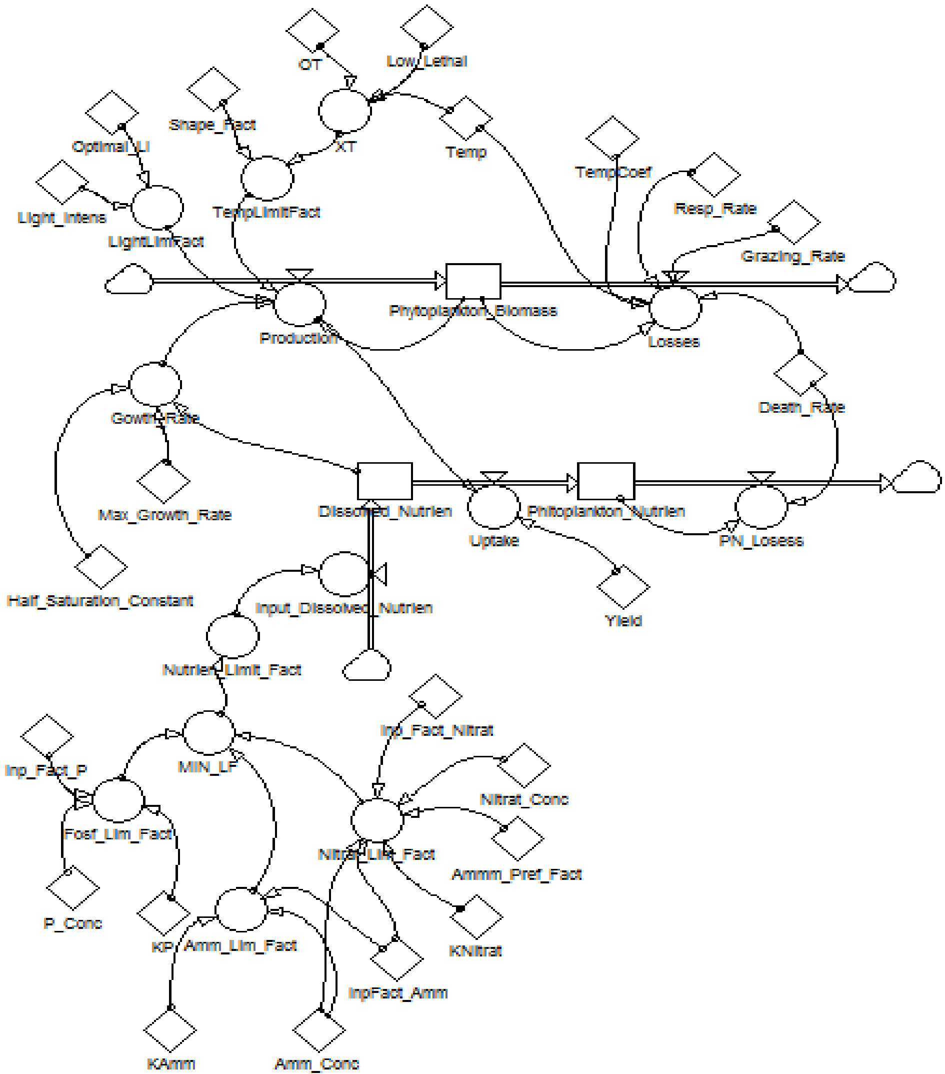

Figure 6 Diagram of the object oriented dynamic simulation program of phytoplankton growth affected by water quality parameters

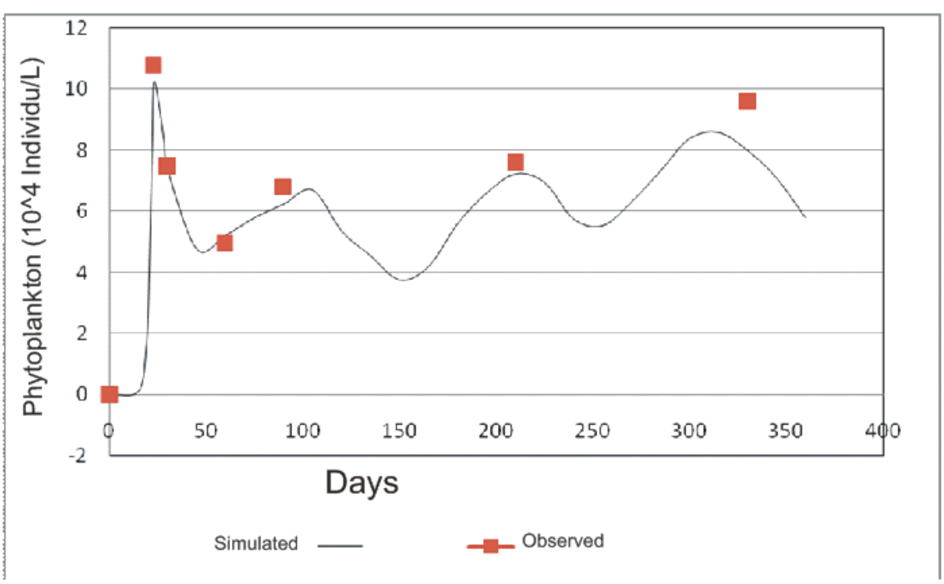

Figure 7 Comparison of simulation results and observed data

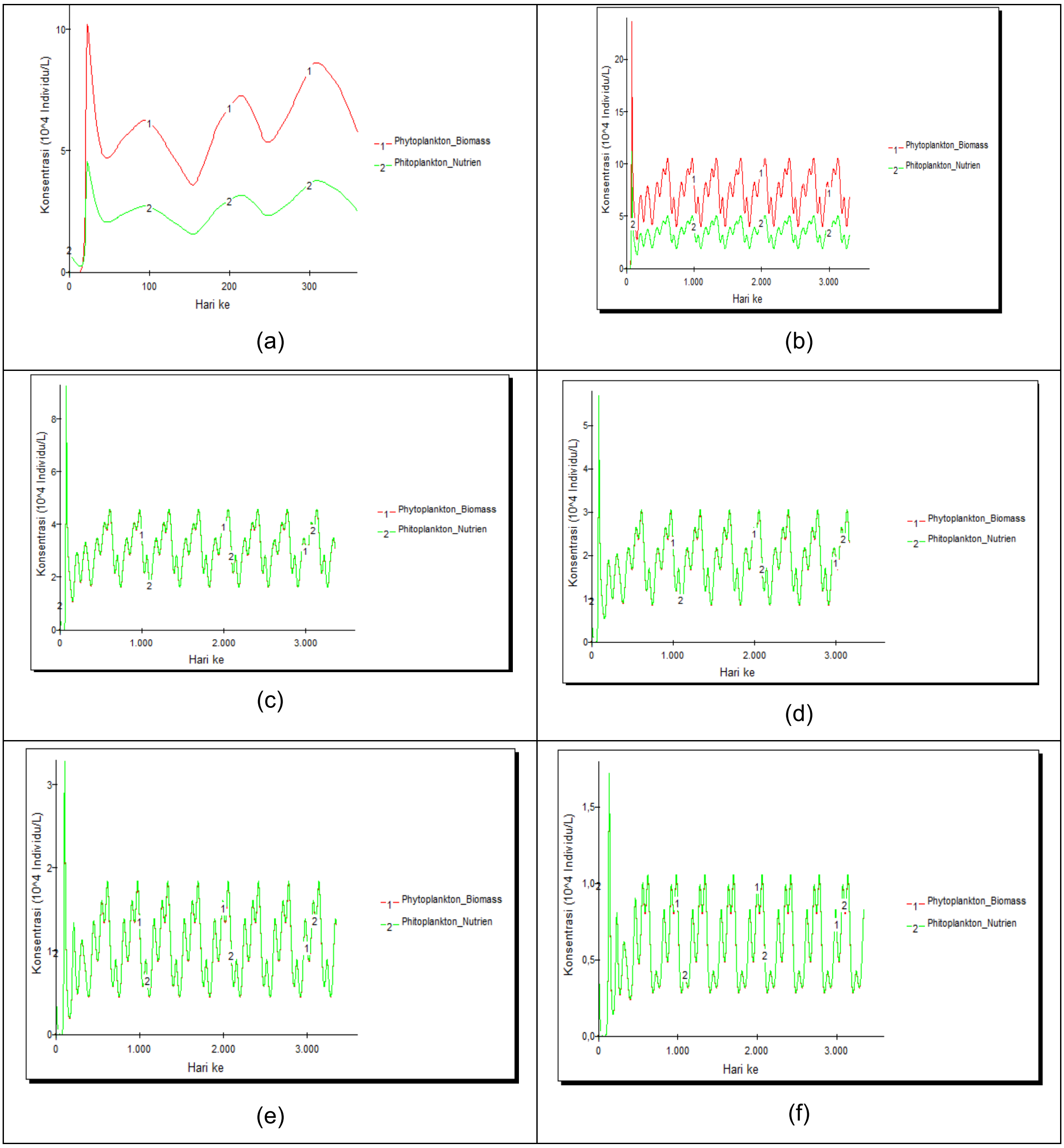

Figure 8 Dynamic simulation of Phytoplankton in Jatiluhur reservoir (a) without eutrophication control in short-term; (b) without eutrophication control in long-term; (c) internal control 50% and external reduction of P loading 20%; (d) internal control 50% and external reduction both TN and TP loading 60%; (e) internal control 50% and external reduction both TN and TP loading 80%;(e) internal control 50% and external reduction both of TN and TP loading 90%.

CONCLUSION

Results of the literature review and tests on the use of an object oriented dynamic conceptual model show that eutrophication in a reservoir can be controlled by reducing 90% of external nutrient loading of 90% in combination with reservoir internal environmental conditions.

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