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Water Quality and Planktological Approach to Monitor Eutrophication by Cage-Culture of Red Tilapia (*Oreochromis* sp.) at the Sermo Reservoir, Yogyakarta, Indonesia

RUSTADI[1], R. KUWABARA[2] and H.N. KAMISO[1]

[1] *Department of Fisheries*
Faculty of Agriculture
Gadjah Mada University
Indonesia

[2] *Department of Bio-production*
Faculty of Bio-Industry
Tokyo University of Agriculture
Japan

Abstract

Water quality and plankton monitoring were conducted at the Sermo reservoir in Yogyakarta, Indonesia to characterize water quality, mostly on the relationships among phosphorus and nitrogen nutrients and plankton species, as a proposal to monitor the eutrophication of the reservoirs used for fish cage-culture. Monthly water samples were taken from six stations (September 1996 to February 1997). During monitoring, chemical and planktological analyses were applied and fish culture of red tilapia (*Oreochromis* sp.) was carried out for three months. Two units of floating net cages, 6 x 6 m^2 and 3 x 3 m^2 respectively, with a water depth of 2 m, were stocked with 40 to 50 gram size fish at the rate of 200 and 100 kg each. Commercial feed was given daily at the rate of 3% of the total fish weight. Phosphate in water was 0.033 to 1.050 mg·l that means within the categories of eutrophic, it has a positive relationship with the plankton density. *Chlorophyta*, *Cyanophyta* and *Chrysophyta* were identified as dominant species. Fish culture produced 1,082 and 486 kg on the average in each cage, a survival rate of 93 to 97% and feed conversion of 1.41 to 1.46.

Introduction

The Sermo reservoir is located in the Kulonprogo subdistrict, which is about 46 km to the west of Yogyakarta City. The reservoir was first inundated in early 1996. At the optimum water level of 136.6 m, the reservoir has an area of 157 ha and a water volume of 25 million cubic meters. The construction of Sermo reservoir is multi-purpose, the primary being to irrigate 2.925 ha

of rice fields and to provide public water supply, while the secondary function is for fishery, aquaculture and recreation (Directorate General of Irrigation 1996).

Eutrophication may first happen in a new inundation due to the enrichment of nutrients originating from soil mineralization and decomposition of organic matter. This problem may occur intensively due to the water inflow of the river that is full of sewage and agricultural waste discharges. Therefore, monitoring of water quality of the newly inundated Sermo reservoir is necessary to improve understanding of eutrophication mechanism as the key to provide tools for the management of reservoir multi-uses.

Fish culture system in a reservoir is practically easier and simpler than in ponds and is even more productive. Fish culture in reservoir change the water flow, produce wastes primarily from uneaten feed and excretion from fish and enhance eutrophication.

In this paper, the authors intend to characterize the water quality of Sermo reservoir, particularly with regard to the relationships among phosphorus and nitrogen nutrients, and also to analyze related plankton species to the nutrients as a preliminary step to propose the indicator species for monitoring of water quality and waste control in cage culture of fish in the reservoir.

Material and Methods

The study was conducted from September 1996 to January 1997. Water samples were collected monthly from six stations (Fig.1), in two or three different depths. Water samples were taken directly from the surface using a bucket (10 l volume), while at the middle and bottom, a water sampler was used.

Water quality includes physical, chemical and biological parameters. Water temperature, total dissolved solid (TDS), transparency, dissolved oxygen, free carbon dioxide, pH and alkalinity were measured directly in the field, while ammonium, nitrate, phosphate and plankton were measured in the laboratory. All procedures for water quality measurements followed the Standard Methods (APHA, AWWA, WPCF, 1985). Before determination of ammonia, nitrite, nitrate and phosphate, water samples were filtered using Whattman paper No 42. Plankton samples were collected using plankton net No. 25 and preserved with 5% neutralized formalin. For identification of plankton species, the authors referred to Schmith (1950) and Shirota (1966, 1975).

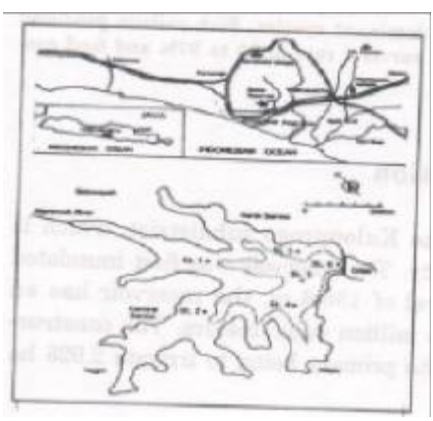

Fig. 1. Locations of Sermo reservoir and sampling stations

Fish culture experiment was conducted from December 1996 to February 1997. Two units of floating net cages at St.3 were located at the center of the reservoir. Each unit comprises two plots of 3×3 m^2 and 6×6 m^2 with a water depth of 2 m. The nets were fixed at a frame made of bamboo and drums as floats. Red tilapia (*Oreochromis* sp.) having an individual size of 40 to 54 g was stocked at a weight of 100 kg in a cage of 3×3 m^2 and 200 kg in 6×6 m^2. Commercial pellet with 25% protein content was given daily at the rate of 3% of the total weight of fish. Individual weight and length were measured by fish sample of 5% of the total number of fish every two weeks for fish growth. The total weight, total number of fish, and feed conversion ratio were evaluated at the end of the experiment and for its calculation, the authors referred to Weatherley (1972) and Schmittou (1991).

Results

Water temperature during the term ranged from 28.0 to 33.0°C at the surface except on December 6 when it fell to 25°C, and showed no considerable change in the depth of water, i.e. approximately 30 m. The monitoring item of water qualities to begin the fish culture was restricted to dissolved oxygen, pH, total solids and transparency for convenience and reasons based on experience. The result is illustrated in figure 2, showing the increase of dissolved oxygen, pH and transparency, and decrease of total solids.

Results of the red tilapia culture as one source of eutrophication from December 1996 to February 1997 are shown in table 1. Difference in cage size influential to fish growth was recognizable in many items on the harvest, namely, the result of 6×6 m^2 cage (72 m^3) showed a high total harvest (1,282 kg) but a low gross productivity (35.61 kg·m^2), while 3×3 m^2 cage (18 m^3) had a low total harvest but a high gross productivity (65.77 kg·m^2), showing successful harvests for both. As shown in table 1 and figure 3, initial fingerlings

Table 1. Data of fish culture experiment from December 10, 1996 to February 21, 1997.

Items	Cage size (m^2)	
	6x6	3x3
Fish stocking		
total weight (kg)	200	100
total number (ind.)	4,625	2,211
individual size (g)	43.25	45.22
Fish harvesting		
total weight (kg)	1,282	592
total number (ind.)	4,312	2,080
individual size (g)	297.31	284.61
Individual growth rate (g/day)*	2.82	2.65
Net production (kg)*	1,082	492
Gross productivity (kg/m^2)	35.61	65.77
Survival rate (%)	93.23	94.07
Food conversion ratio*	1.41	1.46

*calculated from Weatherley (1972) and Schmittou (1991)

of 43.25 g in a 6×6 m^2 cage and 45.22 g in a 3×3 m^2 cage grew linearly up to 297.31 and 284.61 g for three months on the average. The individual growth rate was 2.82 g·day in a 6×6 m^2 cage and 2.65 g·day in a 3×3 m^2 cage. Food conversion ratios of the experiment were 1.41 and 1.46 respectively.

Among the results of water quality determination, phosphate = Phos-P and items of inorganic N (ammonium-N = Am-N, nitrate-N = Nit-N and total inorganic-N = Tot-N) at St. 3 were arranged to the monthly fluctuation in different depths (Figs. 4a, 4b, 4c and 4d). It showed a drastic increase of phosphate in October, December and February. Meanwhile, inorganic-N increased only in October. Monthly changes of inorganic P and N in relation to the plankton growth at surface water was illustrated in figure 4e. Numerical plankton decreased since the beginning up to the end of the experiment and inorganic nutrients stabilized after their increase in October.

Plankton species and quantitative composition of species during the term of the research are presented in table 2. It shows that differences of species showing high composition rate mostly in *Cyanophyta* and *Chlorophyta*, and in separated St. 3 in *Cyanophyta*. Then, prominent species in the composition rate should be abstracted as *Synechocystis aquatilis*, *Arthrospira jenneri*, *A.* sp., *Lyngbya birgei*, *Anabaena* sp., and *Nostoc* sp. of Cyanophyta, *Nitzschia philippinarum* and N. sp. of Bacillariophyta, *Palmella miniata*, *Chlorococcum humicola*, *Closteriopsis longissima*, *Schizomeris lebleinii*, and *Polycystis incerta* of Chlorophyta, *Peridinium* sp. of Protozoa: Dinoflagellida, and *Brachionus* sp. of Rotatoria. These species are often situated at the best dominance in a sample. The relationship between phosphate and numerical density of plankton showed an approximate correlative trend (Fig. 5).

Discussion

Monthly monitoring of water qualities

The monthly change in water quality at the Sermo reservoir since its inundation showed a tendency towards stability (Fig. 3). This alteration is related to

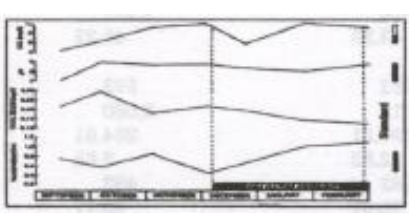

Fig. 2. Monthly changes of major water qualities and the standard values for fish culture (Sources: Schmittou 1991, Boyd 1979)

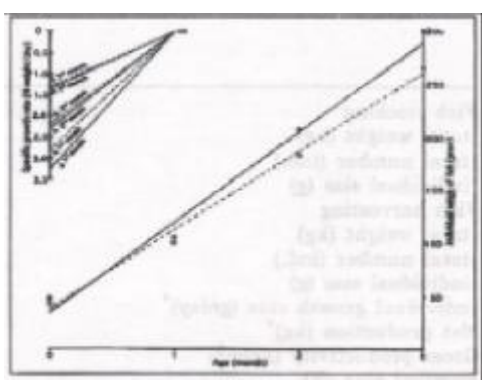

Fig. 3. Individual growth of red tilapia in different size of floating net cage from December 10, 1996 to February 26, 1997

the level of decomposition and time. The decomposition of organic material was slower because water stayed longer in the reservoir and consequently the dissolved materials settled in. In turn, production of acidic substances decreased and pH increased, light was able to penetrate the water more deeply and solubility of oxygen increased. Fluctuation of water qualities consist of temperature, dissolved

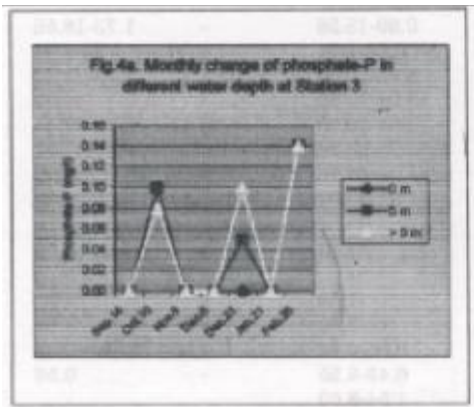

Fig. 4a. Monthly change of phosphate-P in different water depth at Station 3.

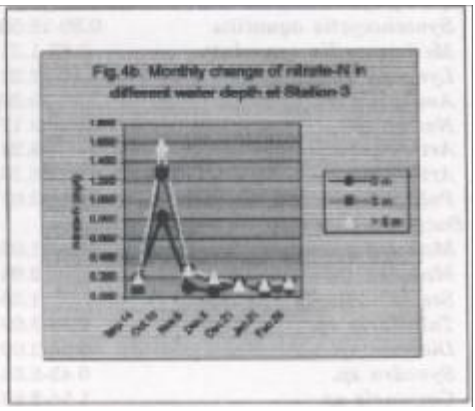

Fig. 4b. Monthly change of nitrate -N in different water depth at Station 3.

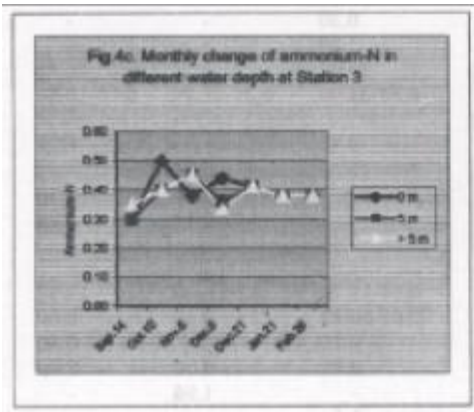

Fig. 4c. Monthly change of ammonium-N in different water depth at Station 3.

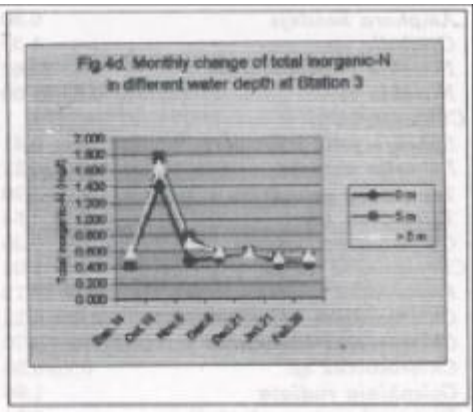

Fig. 4d. Monthly change of total inorganic-N in different water depth at Station 3.

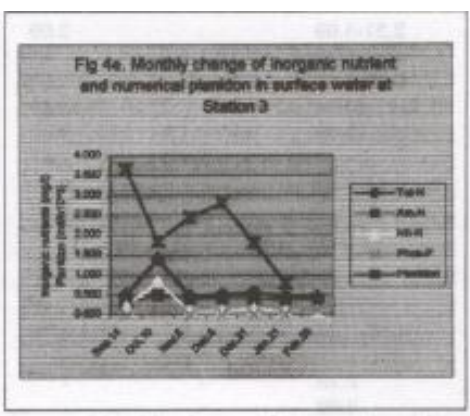

Fig. 4e. Monthly change of inorganic nutrient and numerical plankton in surface water at Station 3.

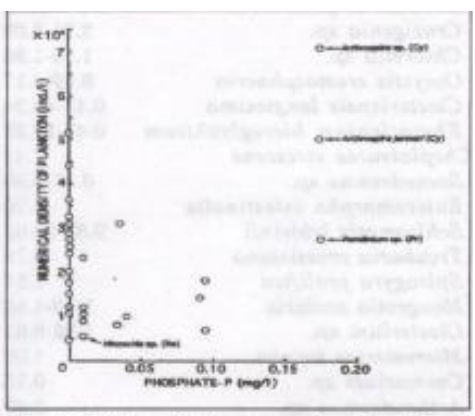

Fig. 5. Relationship between phosphate-P and plankton density at surface water (italic with arrow: the species dominant).

Table 2. Plankton species and the quantitative species composition in Sermo reservoir during 1996 and 1997.

Species	Percentage of total number in sample			
	Whole term	Sept.-Nov.	Dec.-Jan.	Station 3
Cyanophyta				
Synechocyctis aquatilis	0.89-18.56	0.89-18.56	-	1.73-18.56
Merismopedia convoluta	0.83-1.31	0.83-1.31	1.00	0.83-1.31
Lyngbya birgei	2.19-22.22	5.45-10.00	2.19-22.22	2.19-22.22
Anabaena sp.	13.24-33.20	13.24-33.20	-	30.06
Nostoc sp.	0.84-82.17	0.84-50.00	2.44-82.17	3.09-47.44
Arthrospira jenneri	38.24	38.24	-	-
Arthrospira sp.	66.76	66.76	-	-
Polycystis incerta	2.44-43.07	3.33-43.07	2.44-2.94	3.33
Bacillariophyta				
Melosira granulata	1.03	1.03	-	1.03
Melosira sp.	2.94	-	2.94	-
Stephanodiscus hantzshii	1.39	1.39	-	-
Tabellaria sp.	2.38-3.09	3.09	2.38	3.09
Diatoma sp.	0.66-2.00	0.66-0.83	2.00	0.83
Synedra sp.	0.43-5.55	0.43-5.55	-	0.58
Cocconeis sp.	1.54-8.63	1.54-8.63	-	-
Stauroneis onceps	0.73	0.73	-	-
Navicula sp.	0.43-12.19	0.43-1.82	12.19	-
Amphora hendeyi	0.30	0.30	-	-
Cymbella sp.	1.39	1.39	-	-
Nitzchia philippinarum	20.62	20.62	-	20.62
Nitzchia sp.	0.83-32.00	0.83-32.00	2.32-21.94	0.83-10.98
Chlorophyta				
Sphaerocystis schroeteri	0.41	0.41	-	-
Palmella miniata	3.56-15.32	3.56-15.32	-	-
Tetraspora cylindrica	1.16-3.70	-	1.16-3.70	3.70
Tetraspora sp.	0.73-6.54	-	0.73-6.54	0.73
Chrysamoeba radians	0.30	0.30	-	-
Chrysamoeba minor	1.03	1.03	-	-
Protococcus viridis	0.77-12.72	0.77-12.72	3.92-4.00	12.72
Chlorococcum humicola	2.61-16.22	2.61-16.22	2.61-5.88	2.89
Chlorococcus limneticus	0.70	0.70	-	0.70
Chlorococcus sp.	0.73-8.50	3.09	0.73-8.50	3.09
Golenkinia radiata	1.96	-	1.96	-
Dictyosphaerium pluchellum	1.54	1.54	-	-
Coelastrum cambricum	0.42	0.42	-	-
Chodatella quadriseta	3.70	-	3.70	-
Crucigenia sp.	2.21-3.09	2.21-3.09	-	3.09
Chlorella sp.	1.16-1.96	1.23	1.16-1.96	-
Oocystis eremosphaeria	0.59-4.17	0.59-4.17	-	-
Closteriopsis longissima	0.41-43.24	0.41-43.24	-	5.78-43.24
Rhyzoclonium hieroglyphicum	0.42-13.89	0.42-13.89	4.00-9.76	1.15-3.33
Cheplaleuros virescens	7.41	-	7.41	7.41
Scenedesmus sp.	0.41-0.90	0.41-0.90	-	0.83
Enteromorpha intestinalis	3.70	-	3.70	3.70
Schizomeris lebleinii	9.80-29.03	18.52	9.80-29.03	18.52
Treubaria crossispina	0.78	-	0.78	-
Spirogyra prolifica	1.54	1.54	-	-
Mougeotia scalaris	1.00-4.88	-	1.00-4.88	-
Closterium sp.	1.03-8.82	1.03-2.35	1.31-8.82	1.03-3.70
Microsterias torreyi	1.00	-	1.00	-
Cosmarium sp.	0.73	0.73	-	-
Arthrodesmus sp.	0.90	0.90	-	-
Staurastrum sp.	0.43-0.90	0.43-0.90	-	-

continued

Table 2. continued

Pachycladon umbrinus	0.59-2.31	0.59-2.31	1.00-2.44	-
Planktosphaeria gelatino	6.72	6.72	-	-
Chrysophyta				
Leuvenia natans	1.16-17.52	3.29-15.38	1.16-17.52	17.52
Epichrysis paludosa	5.88	-	5.88	-
Phaeosphaera perforata	8.82	-	8.82	-
Protozoa				
Hemidinium nosutum	0.65	-	0.65	-
Peridinium sp.	0.58-56.89	0.58-56.89	0.78-23.53	0.58-29.17
Arcella megastone	1.39	1.39	-	-
Arcella sp.	1.61-2.94	-	1.61-2.94	-
Euglena sp.	0.66-1.55	0.66	1.55	-
Phacus sp.	2.94	-	2.94	-
Euglypha tuberculata	0.77	0.77	-	-
Dileptus anser	0.77	0.77	-	-
Frontoniella complanata	1.46-11.29	1.47-5.84	1.46-11.29	1.46-5.84
Loxodes magnus	0.41-14.43	0.41-14.43	1.96-4.88	14.43
Glenodinium sp.	0.66-3.45	0.66-3.45	-	-
Tintinnidium fluviatile	1.54	1.54	-	-
Companella umbellaria	0.43	0.43	-	-
Rotaria				
Brachionus sp.	0.42-19.44	0.42-19.44	0.78-17.00	3.47-16.79
Ascormorphella volvocicola	0.73-0.83	0.73-0.83	-	0.83
Polyarthra sp.	0.83-2.94	0.83-1.54	1.96-2.94	0.83
Euchlanis dilatzia	1.82	1.82	-	-
Resticula melanodocus	1.03	1.03	-	1.03
Gastropus satylifer	0.83-1.82	0.83-1.82	-	0.83
Trichocera similis	1.67	1.67	-	1.67
Crustacea				
Moina sp.	1.39	1.39	-	-
Cyclops sp.	0.83-4.88	0.83	1.96-4.88	0.83-3.70
Diaptomus sp.	2.94	-	2.94	-

oxygen, pH, transparency and total solids were in satisfactory ranges for standard of fish culture (Boyd 1979 and Schmittou 1991).

The fish culture experiment

Good water condition supported the result of fish culture experiment. The similar and high survival rates in both cages suggest that mortality would mostly have occurred in the initial culture time due to stress by transportation. The lower gross productivity in the larger cage means that the density of fish did not attain the available maximum density, in comparison to the result of the smaller cage, which is probably due to less efficiency in the feeding method.

The high growth rates of the present study could be sustained through the use of complete pellets. Based on experience, the red tilapia could survive in the net cages for two months without artificial feeding, because the fish were fed on the periphyton attached to the net of the cage and other planktonic organisms (Rustadi 1994). Although these are shown in the top left diagram by straight lines, specific growth rate indicates that curves of later months are decreasing in slope.

Food conversion ratios (FCR) that showed considerably low values at 1.41 and 1.46 in both cages indicate that the experiment was more efficient than

the other red tilapia culture in Indonesian reservoirs which had FCR = 1.83 in Lido reservoir (Jangkaru 1986) and 1.67 to 1.94 in Kedungombo reservoir (Kamiso et al. 1992).

The low FCR could be partially attributed to availability of natural foods such as phytoplankton and others in addition to given artificial pellets. Result of stomach content analysis of *Oreochromis* spp. in other investigations at the Sermo reservoir showed that 24 families of phytoplankton were consumed in which Chroococcaceae (Cyanophyta, including *Synechocystis*, *Chroococcus*), Nitzschaceae (Bacillariophyta, including *Nitzschia*), and Tabellariaceae (Bacillariophyta, including *Tabellaria*) had a considerable amount (Kamiso et al. 1997). Phytoplanktivorous fishes doing filter feeding are essentially pump filter feeders (Delince 1992). Digestion rate of blue-green algae by *Oreochromis niloticus* has attained 70% (Yada 1990), and this was applied for the improvement of the water quality (Yada et al. 1990). The feeding and food habit of red tilapia may be attributed to the decrease in plankton density during fish experiment.

The monthly change of phosphate showed more fluctuation concentrations among the nutrient items and has stratification (Fig. 4a). Total-N was also identical because the component nitrate-N was fluctuated and stratified, meanwhile, ammonia-N was relatively stable.

Considering the constant numerical density of plankton (Fig. 4e), the first increase of phosphorus in October could have been derived from the contaminants, but the second increase in February was probably due to wastes from the fish culture experiment. Although FCR of fish culture was low, the loss of P could be due to the addition of one phosphate-P concentration in water as calculated by Beveridge et al. 1982. Meanwhile the inorganic-N in water was not affected by feed application during the fish culture experiment. The effect of fish culture has to be justified by the continuous monitoring of the water quality.

The temporal increase of phosphorus should be remarkable because of the speedy decrease to one order lower concentration. The trend would be supported by the facts that the turnover time of phosphate in freshwater epilimnion is 10 to 280 minutes in summer in European countries and about ten minutes even in high latitude regions in North America (Wetzel 1983).

Since phosphorus is well known as a limiting factor for phytoplankton growth, the obtained data is marked in relation to the other nutrients and occurrence of plankton species. The values of phosphate-P obtained from the research ranged from 0.011 to 0.343 mg·l and with undetectable values which belong to the category of eutrophic (most lakes) and hypertrophic (polluted lakes) waters (Bronmark and Hansson 1998) and Lampert and Sommer (1997) even as total phosphorus. Higher content of phosphate ranging from 0.02 to 2.10 mg·l occurred at the Saguling reservoir after inundation (Krismono et al. 1987) because of high phosphate content in water inflow.

Planktonic community

From all the plankton samples, 80 species were identified and counted for each (Table1). The major taxa were the following: *Cyanophyta* yielded 8 spp.,

Bacillariophyta 13 spp., *Chlorophyta* 33 spp., *Protozoa* 13 spp., *Rotatoria* 7 spp. Additional minor groups were *Chrysophyta* and *Crustacea/Cladocera*, 3 spp. each. The occurrence of *Chrysophyta* in high abundance is remarkable, because Ruttner's report (1952) on plankton of Indonesian lakes has found only a few *chrysophyte* species at a small percentage of quantitative composition from only Central Java (Telaga Pasir) (Serruya and Pollingher 1983).

As phosphorus in lake water is often present in low concentrations, it tends to act as a limiting factor for phytoplankton growth. There was a trend relationship between phosphate and the numerical density of plankton (Fig. 5). As it has been said, since phytoplankton can use only soluble phosphate (PO_4) among all of the phosphorus compounds (Horne and Goldman 1994), the fact that the increase in phosphate led correlatively the high numerical density of plankton (mostly phytoplankton) is reasonable. Total phosphorus concentrations have been correlative to the total phytoplankton biomass for 20 years in the lakes of Austria and Hungary within the range 0.05 to 0.3 mg·l (Dokulil and Padisak 1994). Dominant species were seen in the high phosphates and numerical densities were mostly species of *Cyanophyta*, i.e. *Arthrospira* spp. It is general knowledge that many species of *Cyanophyta* are known to occur in blooming and bluish water under eutrophicated condition rich in nutrients

Conclusion

Monitoring of water quality is necessary to find a good start for fish culture and to watch the eutrophication process in used reservoir. Selected items of water quality should be at least three, including DO, suspended solid and phosphate.

Phosphate as a limiting factor of phytoplankton blooming was proven from the appearance of the known indicator species that have been studied through laboratory work, as a result of field investigation and arrangement of data in a reservoir.

A variety of dominant phytoplankton species would be proposed as indicator species of eutrophication in relation to phosphate increase.

The experimental culture of *Oreochromis* sp. (red tilapia) contribute to the increase in phosphate concentration, but the species regulate plankton density.

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