Solid State Technology

by Zulkarnaini Zulkarnaini

Solid State Technology
Volume: 63 Issue: 6
Publication Year: 2020

Carrying Capacity of Total Phosphate from Aquaculture Cage in Maninjau Lake

Putri Sri Komala[1], Zulkarnaini[2], R I Kurniati[3] *
[1,2,3] *Department of Environmental Engineering, Andalas University, Padang*
*putisrikomala@eng.unand.ac.id

Abstract *The purpose of this study was to determine the total carrying capacity of total phosphate (TP) in Maninjau Lake using the Beveridge Model. Pollutant sources taken into account in this model are residents, hotels, agriculture, and livestock. Sampling was carried out in 10 locations around Maninjau Lake that refer to SNI 6989.57: 2008 guideline. It was located in the inlet, outlet, and middle of the lake, beside of hydropower plant and aquaculture cages. The trophic state of the Maninjau Lake was hypertrophic, with an index of 72.49. Two scenarios were proposed for controlling the TP of the lake. The first scenario, the mesotrophic state, the phosphorus limitations were needed to reduce the number of aquaculture cages by up to 69%. The TP capacity of this condition is 220,063,878 kg/yr, fish production 9,019 tons/yr, feed production 16,955.74 tons/yr with the number of aquaculture cages of 5398.92 units. The second scenario is the oligotrophic state. Under this condition, the TP capacity is 73,320.13 kg/yr, fish production 3,004.92 tons/yr, fish feed 5,649.25 tons/yr, and the number of aquaculture cage units is 1,799.64 units, which means an 89% reduction is required.*

Keywords: *aquaculture cages, Beveridge Model, Maninjau Lake, carrying capacity, total phosphate (TP)*

1. Introduction

In recent years, there has been an increase in aquaculture using the floating net cages in Maninjau Lake [1]. In 2018, the number of the cage had reached 17,426 units [1], while the maximum cage limit set by the Government of Agam Regency is 6,000 units [2]. The intensification of fish-farming leads to the release of high organic wastes and inorganic nutrients such as phosphorus as a result of the metabolism and fish feces [3]. Beveridge [4] said that each ton of fish production produces 23-29 kg of total phosphate (TP) that enters the waters and can cause eutrophication. This waste will accumulate at the bottom of the lake, causing sedimentation and anoxic conditions in the waters [5]. Although the Maninjau Lake has been designated by the Ministry of Environment as a priority lake that needs to be saved [6], however, the lake status in 2019 has reached the eutrophic-hypertrophic state [7]. For this reason, more reasonable efforts are required, such as limiting the pollutant load entering the lake by calculating the carrying capacity. The carrying capacity is very useful for making environmentally-related decisions.

The carrying capacity can also be an effort to control the pollutant load and also useful as a basis for the government in making policies to maintain water quality [8]. Many models that phosphorus budget in lakes such as Dillon-Rigler, Vollenweider, Chapra, Nunberg, and Walker. Among them, The Dillon-Rigler model has the best predictive ability for pollutant load calculation in shallow lakes, deep lakes, and reservoirs in temperate and tropical regions [9]. This model was then developed by Beveridge for the lakes with intensive aquaculture by considering the capacity of fish production and fish feed.

Some studies of the carrying capacity of phosphorus have been carried out, such as Macbub on Maninjau Lake [10] and Oakley on Toba Lake [11]. It was reported that fish cage is the primary source of phosphorus pollutants, followed by domestic wastewater, agriculture, and livestock. The TP restrictions at Maninjau Lake were carried out by limiting pollutants from the cage based on eutrophic and mesotrophic states, while in Lake Toba, control of all sources of contaminants on the TP load was evaluated. The comparison of the Dillon-Rigler and OECD models for calculation of the phosphorus load from the cage in Lake Volta showed that the amount of phosphorus load using the Dillon-Rigler Model is higher than the OECD due to considering the phosphorus deposition from the cage [12]. However, the TP control of aquaculture from several studies is still concentrated to reduce the number of the fish cage. Besides limiting the number, the size of fish production and the fish feed could also be considered to control TP [13]. This study aims to calculate the TP capacity using the Beveridge Model and control scenarios referring to the Ministry of Environment Regulation No. 28/2009 to reduce the TP load by considering the fish production, the fish feed use, and the number of the cage.

2. Methodology

2.1 Study Area

Maninjau Lake is located in Tanjung Raya District, Agam Regency, West Sumatra. It has a surface area of 99.5 km^2 with a catchment area 24,800 ha, and a maximum depth is 165 m. Geographically, the lake is located between 00˚17'- 07.04'LS and between 100˚ - 09'58"BT with an altitude of 461.5 m above sea level. The lake was used as a hydroelectric power plant (PLTA), tourism and aquaculture. The location of water sampling refers to SNI 6989.57: 2008 [14]. The sampling site was in the middle of the lake, PLTA, aquaculture, Antokan's River, Kurambit's River, Kularian's River, Baluran's River, Maransi's River, BandarLigin's River, and Tanjung Sani's River (**Figure 1**). For TN, chlorophyll-a and brightness measurement were conducted in the middle of the lake, PLTA, and aquaculture.

2.2 Water Quality Measurement

Water quality measurement was carried out in July 2019 to September 2019 refers to SNI 6989.57: 2008. Water sampling at various locations of the lakes was conducted composite with depth, as shown in **Table 1**. Meanwhile, in the river with less than 5 m^3/s discharge, the sampling was performed in the middle of the river. The water sample of the lake was collected using a vertical water sampler meanwhile for the river using 1 L bottle samples. The water temperature, pH, and DO were analyzed immediately on the spot. pH and temperature were measured using pH-meter HI-9813-5 and DO with Lutron DO-5510. The samples for analysis TN and TP were preserved with H_2SO_4. TP and TN were analyzed using a UV-Vis spectrophotometer [15]. In order to find the temporal variation of DO, pH, temperature, and TP parameter data were subjected to one way ANOVA with a significant level $p < 0,05$.

Table 1: Composite water sampling depth

Sampling location	Coordinate	Composite depth
Middle of lake	S 0º22'17''E 100º11'22.3"	0, 22, 40, 100, 130 (m)
PLTA	S 0º17'24.1''E 100º08'58.8''	0, 2.5 (m)
Aquaculture	S 0º13'13.3'' E 100º10'08.8"	0, 9, 19 (m)
Kurambit's River	S 0º15'36.6" E 100º10'02.6"	9 cm
Kularian's River	S 0˚14'52" E 100˚11'28"	32 cm
Baluran's River	S 0˚15'19" E 100˚12'30"	15 cm
Maransi's River	S 0˚17'03" E 100˚13'27"	6.5 cm
Bandarligin's River	S 0˚20'50" E 100˚13'20"	16 cm
Tanjung Sani's River	S 0˚21'43" E 100˚12'57,3"	27 cm
Antokan's River	S 0º17'36.1" E 100º08'49.5"	123 cm

The water samples for chlorophyll-a analysis were taken by a phytoplankton net at a depth of 10 m to the surface. The sample was put into the 25 mL bottle sample then wrapped with aluminum foil. Before being analyzed, the samples were filtered using Whatman paper measuring 47 µm. The filter paper was crushed using a mortar and then added 13.5 mL of acetone. Next, the chlorophyll-a analysis was carried out using a UV-Vis spectrophotometer [16].

2.3 Fish and Fish Feed Samples

Fish and feed sampling was conducted at the Koto Malintang's cage, where the most cages number located. The *O.Niloticus tilapia* as a fish sample was taken three times in line with water sampling frequency. Fish samples were collected by 20 cm fish traps and wrapped with aluminum foil for analysis. 1 g sample mixed in 100 ml of distilled water and shake at 100 rpm for 30 min and filtered with 47 µm Whatman [17]. The fish feed brand Bintang was pellet the most fish feed used at cage 100 gr feed samples put into plastic containers. The method of fish feed analysis is similar to fish samples.

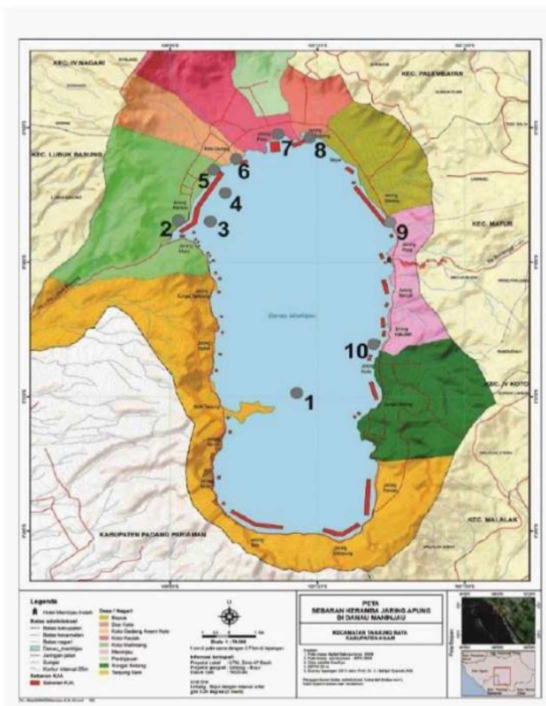

Figure 1: Sampling location in Maninjau Lake, Sumatera Barat. Middle of the lake S 0º22'17" E 100º11'22,3" (a) Antokan;s River S 0º17'36,1" E 100º08'49,5" (b) PLTA S 0º17'24,1''E 100º08'58,8" (c) Cage S 0º13'13,3" E 100º10'08,8" (d) Kurambit'River S 0º15'36,6" E 100º10'02,6" (e) Kularian's River S 0˚14'52" E 100˚11'28" (f) Baluran's River S 0˚15'19" E 100˚12'30" (g) Maransi's River S 0˚17'03" E 100˚13'27" (h) Bandar Ligin's River S 0˚20'50" E 100˚13'20" (i) Tanjung Sani's River S 0˚21'43" E 100˚12'57,3" (j)

2.4 Trophic State

The trophic state index (TSI) of each lake was calculated based on chlorophyll-a, total nitrogen (TN), TP, and Secchi depth. The average of TSI scores is used to Carlson [18].

$$TSI\ (TP) = 14{,}42 \ln(TP) + 4{,}15 \quad (1)$$

$$TSI\ (TN) = 54{,}45 \ln(TN) + 4{,}15 \quad (2)$$

$$TSI\ (Chla) = 9{,}81\ \ln(Chla) + 30{,}6 \quad (3)$$
$$TSI\ (SD) = 60 - 14{,}41\ln(SD) \quad (4)$$
$$\sum TSI = TSI\ (TP + TN + chla + SD)/4 \quad (5)$$

where:

TSI : trophic state index
TP : total phosphate
TN : total nitrogen
Chl-a : chlorophyll-a
SD : sechi depth

Table 2: TSI Classification

State	Value
Oligotrophic	<40
Mesotrophic	>40-50
Eutrophic	>50-70
Hypertrophic	>70

2.4 Questionnaire

The method used in distributing the questionnaires is cluster sampling. Cluster sampling is a probability sampling technique where researchers divide the population into multiple groups for research. The cluster is considered as the district in Maninjau Lake, where the activity takes place. The questionnaires were distributed to those that were supposed to be the sources of pollutants, namely residents, hotels, agriculture, and livestock. Questionnaires were intended to get a description of the existence of the wastewater treatment, solid waste disposal as well as sewerage in the residential and hotels. For agricultural activities, the type of fertilizer used, the frequency of fertilizer application, and the irrigation for wastewater runoff were asked. The kind of fish feed, the frequency of fish feeding, the fish production, and the length of harvest were enquired to the aquaculture owner. While the number of livestock, the feed use, and the waste treatment from livestock. The questionnaires for residential, agriculture, and livestock were distributed throughout the district in 9 clusters surrounding the lake. In contrast, aquaculture cages and hotels are spread in 8 and two communities, respectively. The hotels are located only in Bayur and Maninjau district. The number of questionnaires was calculated using equation 6, and the result is shown in Table 3.

$$F = m/M \quad (6)$$

Where :

F : questionnaire number
m : population number
M : cluster number

Table 3: TSI Classification

Activities	Number (m)	Cluster (district, M)	Questionnaire number (F)
Residental (household)	3,399	9	378
Agriculture owner (person)	121	9	13
Aquaculture owner (person)	1,636	8	204
Hotels/lodging owner (unit)	14	2	7
Livestock owner (person)	180	9	20

2.6 Pollutant Load Analysis

The watershed TP inputs come from domestic and hotel wastewater, as well as livestock and agriculture runoff. The pollutant of each activity is the multiplying the amount of pollutant unit (a) and the TP loading factor (f) in **Table 4** by using equation 7. Data on population, paddy fields, number of animals, and hotel visitors were obtained from the Central Statistics Agency of Tanjung Raya Subdistricts in Figures [1]. In contrast, emission factors for domestic wastewater, agriculture, hotels, and livestock referring to the Ministry of Environment No. 1 of 2010 [19]. The settlement wastewater emission factors were divided into two categories, namely, houses with a septic tank and without a septic tank. This data was obtained from the previously distributed questionnaires in Tanjung Raya District. Each animal has different emission factors. The pollutant load from the cage is derived from is the result of multiplying the Food Conversion Rate (FCR) and the TP content in fish (TP_{fish}) minus TP in the feed (TP_{feed}), which is shown in equations 8.

$$BP = a\ x\ f \tag{7}$$
$$P_{lp} = FCR\ x\ TP_{feed} - TP_{fish} \tag{8}$$

Table 4: Emission Factor

Source of pollutant	Emission factor (g/day)
Residential	
With Septic tank	0,9
Without septic tank	3,8
Agriculture	
Rice fields	10
Hotel	5,4
Livestock	
Cow	0,153
Buffalo	0,39
Goat	0,116
Duck	0,03
Chicken	0,005

2.7 Beveridge Method

The calculation of carrying capacity using the Beveridge Model consists of total phosphate capacity and cage capacity. TP carrying capacity (L_a) was calculated from the multiplying the loading from fish (L) and the surface area (A). L is obtained from the TP load allocation (P_d) obtained from the reduction in the maximum TP limit (P_{std}) and TP levels from the middle of the lake (P_i). The maximum TP limit refers to the government regulation, for mesotrophic is 30 mg/m^3 and oligotrophic 10 mg/m^3. ẑ = the average lake depth (m); ρ = the flushing rate (year^{-1}), R = the fraction of total-P retained by the sediments, X = total-P wastes from the cage is likely to be permanently lost to the sediment as a result of solids (feces and food) deposition (0.45-0.55), and P = proportion of dissolved total-P lost to the sediment. The formulas L_a, L, P_d, R, can be seen in equations 9,10,11,12, and 13.

$$L_a = L\ x\ A \tag{9}$$
$$L = P_d \times \rho \times \hat{z}/(1 - R) \tag{10}$$
$$P_d = P_{std} - P_i \tag{11}$$
$$R = x + ((1 - x)P) \tag{12}$$
$$P = 1/1 + 0{,}747\ \rho^{0{,}507} \tag{13}$$

The TP capacity (L_a) for the cage is calculated by the amount of fish production (L_i, tons/yr), fish feed (L_p, tons /yr), and the number of the cage (L_r, units). L_i, L_p, and L_r calculations can be seen in equations 14.15 and 16.

$$L_i = L_a / P_{lp} \quad (14)$$

$$L_p = FCR \times L_i \quad (15)$$

$$L_r = L_i / L_u \quad (16)$$

3. Results and Discussion

3.1 Water Quality

In-situ water quality parameters, namely temperature, pH, and dissolved oxygen (DO), are shown in Table 3. The value of water temperature, pH, DO, and total phosphate (TP) in Maninjau Lake compared government regulations No 82/2001. The water temperature was in the range of 27.30±31.67˚C **(Table 5).** The maximum temperature was recorded in aquaculture and the minimum in TanjungSani's River. Generally, water temperature relevant to the tolerance limit, i.e., 25±32 ˚C.

Table 5: Water Quality

Location	pH	Temperature (˚C)	DO (mg/L)	TP (mg/L)
Middle of the lake	7.92	31.47	5.3	0.66
PLTA	7.71	30.7	6.93	0.61
Aquaculture	8.5	31.67	4.3	0.76
Antokan;s River	7.08	29.83	6.33	0.69
Kurambit's River	7.19	29.06	6.26	0.57
Kularian;s River	7.46	30.36	6.63	0.5
Baluran's River	7.3	27.70	6.66	0.60
Maransi's River	7.26	28.68	6.03	0.59
BandarLigin's River	7.10	28.35	7.2	0.61
TanjungSani's River	7.4	27.3	7.3	0.65

The pH value recorded ranges between 7.08±8.5 **(Table 5).** The maximum pH was recorded in aquaculture and minimum in Antokan's River. High pH is due to the high photosynthetic activity of blue, green algae, and relative rates of respiration [20]. The amount of dissolved oxygen (DO) recorded in Maninjau Lake ranges between 4.3-7.3 mg/L **(Table 5).** The minimum DO was recorded in aquaculture, whereas the maximum in TanjungSani's River. DO is often attributed to activities [21]. The DO depletion in the lake is due to high temperatures and increased microbial activity.

The TP concentration is significant to primary production [22]. The maximum TP value was 0.76, and it varied between 0.5±0.76 mg/L in general. The standard TP concentration is 0.2 mg/L, so it has exceeded. The measurements in aquaculture were found higher than the other locations. The high concentration of TP indicated hypertrophic conditions. According to the results of statistical analysis, spatial variability of pH, DO, and temperature significantly varying and TP not varying.

3.2 Trophic State

The trophic state is an essential part of assessing and managing lake ecosystems. The main parameter in deciding the trophic state of aquatic is phosphorus concentration. Phosphorus is a limiting nutrient in algal growth and algal growth estimated by chlorophyll-a. Transparency depends upon the density of the algal population. The nutrient such as phosphorus can enter into lakes as agriculture, agriculture runoff, and domestic wastewater. Eutrophication that occurs in lakes can be known by using the Carlson trophic state index with four-parameter indicators, namely TP, TN, chlorophyll-a, and brightness. Effects of eutrophication on lakes

such as increased biomass of lakes, reduced water clarity, possible health risks in water supplies, increased fish production and the increased chance of fish kills [23].
Based on TN, chlorophyll-a, and brightness, the trophic state is eutrophic, and TP is hypertrophic. Overall, the trophic state in Maninjau Lake, based on the location of the middle lake, cage, and hydropower calculated by equation 5, is hypertrophic with an index of 72.49 (Table 6**).** The hypertrophic state is characterized by low brightness and high levels of TP and TN in Maninjau Lake [7]. Cage is the main activity that produces high levels of TP and TN in Maninjau Lake from fish feces and feed [24]. This condition can result in high primary productivity activity, which an increase in aquatic plants such as *Eichhornia Crassipes* and reduced phytoplankton diversity [25].

Table 6: Trophic State of Maninjau Lake

Parameter	Score	Trophic status
TP	97.28	Hypertrophic
TN	65.47	Eutrophic
Chlorophyll-a	62.09	Eutrophic
Brightness	65,13	Eutrophic
Ave TSI	72.49	Hypertrophic

The trophic state of Maninjau Lake has increased in recent years. In 2005-2007, it was in a mesotrophic, in 2008-2013, was eutrophic, and in 2016 it had risen to hypertrophic [26]. It means the trophic state in Maninjau Lake is varying.

3.3 Pollutant Load

The pollutant load comes from aquaculture, domestic, agriculture, livestock, and hotels. The total pollutant load from total phosphate can be seen in **Table 7**. TP pollutant load calculation results from equations 6 and 7 obtained the largest source of pollutants came from the cage that is 625,213,360 kg/yr. Then, a domestic wastewater load of 13,505.18 kg/yr divided into wastewater treatment using septic tanks 10,895.51 kg/yr (95%) without septic tank 2609.66 kg/yr (5%), agriculture 11,671.5 kg/yr, livestock 280.54 kg/yr, and lodging 37.44 kg/yr.
The existence of cages in Maninjau Lake is a significant anthropogenic activity that affects water quality. For aquaculture, the phosphorus content of fish and feed obtained 17.77 kg/ton and 9 kg/ton so that the TP pollutant load originating from the cage is 24.40 kg/tons meaning that into the category of waste produced by a cage in the range of 23-29 kg/tons [4]. So, the total of TP pollutants from aquaculture is 625,213,360 kg/yr, with fish production is 25615.52 tons. Lukman [27] gets value the loss of TP because fish production (Nile Tilapia) into Maninjau Lake was 220.2 tons/yr, so the TP pollutant has increased. Syandri [28] analyzed nitrogen and phosphorus levels in carp, tilapia, goldfish, and catfish from a fish culture cage area, obtained that the most considerable nitrogen and phosphorus content sequentially from tilapia, carp, goldfish, and catfish due to the different FCR values and eating habits in fish. Each fish has a different effect on the mass balance of nitrogen and phosphorus on fish metabolism. The FCR value in this study is 1.88 higher than Nile Tilapia's FCR is 1.55. It means the amount of feeding is not efficient [29].
The amount population in Tanjung Raya district is 35.049, and the largest population in Nagari Tanjung Sani. From the questionnaire, the amount of using a septic tank is 95% and without a septic tank 5%. Settlement activities are the second-largest source of pollutant load on Maninjau Lake. It has been utilized to bathe, wash, and closet. According to Macbub [10], the pollutant load obtained are 2.308,22 kg/yr. The pollution load from the settlements increases significantly. The phosphate content in detergents can increase the burden of TP pollutants that enter the lake; it can stimulate algal growth and eutrophication [30].

Table 7: Trophic State of Maninjau Lake

No	Activity	TP load
1	Aquaculture	625,213,360 kg/yr
2	Domestic	13,505.19 kg/yr
3	Septic tank	10,895.51 kg/yr
4	Without Septic tank	2,609.66 kg/yr
5	Agriculture	11,671.5 kg/yr
6	Livestock	280.54 kg/yr
7	Lodging	37.44 kg/yr
8	Total	625,238,855 kg/yr

Agricultural activities were also a high TP source in Maninjau Lake due to the excessive use of fertilizers and pesticides. From the questionnaire, almost 90% of farmers use urea fertilizer. Annika [31] suggested control efforts to reduce agricultural waste by regulating the use of fertilizers and pesticides. Pollutant load from hotels and livestock was not very significant because the amount still low. There is 5 type of animals that is the cow, buffalo, goat, duck, and chicken.

4.4 Total Phosphate Control Scenarios

Carrying capacity is defined as the standing stock of particular species at which production is maximized without negatively affecting growth rates [32]. Carrying capacity for cage aquaculture can be used to help match cage aquaculture development with societal objectives and to reduce risks to fish farmers [4]. Maninjau Lake, with a flushing rate of 0.043/yr, was very small and may increase the organics or phosphorus content result in the pollutant load entering the lake. Carrying capacity in Maninjau Lake can be seen in Table 8.

The carrying capacity of TP was carried out with four scenarios, such as TP budget, fish production, fish feed, and amount of cage. The estimated carrying capacity based on the Beveridge method TP budget for mesotrophic conditions is 220,063.887 kg/yr, its lower than the TP pollutant load. The amount of fish production allowed is only 9,019.011 tons/yr, if compared the fish production in 2018, must be reduced up to 64%. Not only the TP budget and fish production have exceeded the carrying capacity, but also the fish feed. Based on equation 13, the feed fish estimated is 16,955.74 tons/yr; this amount is very much lower when compared with the feed fish data in 2018. Therefore, it is necessary to reduce fish feed up to 58% to reach the mesotrophic state. The number of cage units in 2018 is 17,426 units, while the number of cage units allowed was calculated by equation 14 was 5,398.92 units. So, the number of cages must be reduced to 69%. Serap [33] estimated TP capacity in Lake Kesikkopru Ankara and TP budgets ten times higher than current TP production due to the small surface area and short residence time of the lake. The maximum allowable TP limits, the average depth of the lake, and the sedimentation fraction also influence the carrying capacity [34].

TP capacity based on oligotrophic is 73,320.13 kg/yr, and fish production capacity calculated using equation 12 is only 3,004.92 tons/yr. This amount is smaller than that obtained in the mesotrophic state, so it needs to reduce 88%. The carrying capacity of fish feed is 5,649.25 tons/yr, and the number of the cage is 1,799.64 units. It should be reduced up to 86% and 89% if compared in data 2018. The high level of TP is due to fish feed containing high protein such as phosphorus, commercial fish diets, and the lack of feeding regulations in fish culture. Commercial fish diets can be classified into floating and sinking food. The Bintang's fish feed contained 20-22% protein and included the sinking food. Sinking food has several disadvantages, such as being easily destroyed in water and having a high FCR value, which reduces feed efficiency and increases sedimentation [35]. In addition to deposition, acceptable TP and fish production also plays a significant role in determining the carrying capacity [36]. This calculated value can be taken as a baseline that can be used as an indicator of a possible ecologically sustainable aquaculture production level for Maninjau Lake.

Table 8: Carrying Capacity of Aquaculture for Mesotrophic and Oligotrophic State

	Unit	Mesotrophic	Oligotrophic
Surface Area (A)	Ha	9,763	9,763
Flushing rate (ρ)	/yr.	0.043	0.043
Average lake depth (ẑ)	M	104.84	104.84
P_{std}	mg/m^3	30	10
P_i	mg/m^3	684.4	684.4
P_d	mg/m^3	- 1246.5	-1266.5
R		0.06	0.06
L	g/m^2.yr	2.254	0.751
L_a	kg/yr	220,063,878	73,320,13
FCR		1,88	1,88
P_{lp}	kg/ton	24,40	24,40
L_i	ton/yr	9,019.011	3,004.92
L_p	ton/yr	16,955.74	5,649.25
L_r	Unit	5,398.92	1,799.64
Reduction	%	69	89

4. Conclusion

The primary source of the TP burden on Maninjau Lake comes from fish cages, which results in the lake's hypertrophic status with an index of 72.49. Control of TP load was carried out by limiting pollutant sources based on oligotrophic and mesotrophic state. In the mesotrophic state, the TP capacity is 220,063.887 kg/yr, with the number of the cage is 5398.92 units so that the cage should be reduced to 69%. Meanwhile, in an oligotrophic state, the number of cages in the lake must be reduced to 89% from 17,426 units to 1,799.64 units. For further research, it is necessary to consider other TP load sources such as settlements and agriculture for the determination of lake carrying capacity. The variety of the feed fish used and the other fish species and its effect on the TP load also need to be considered for further research.

Cage aquaculture offers a potential source of food fish production in many areas of the world, mainly where there are plenty of natural water resources and also provides a source of income for resource-poor farmers. However, cage aquaculture offers a potential source of eutrophication and nutrient loadings in the ecosystem. Feeding of caged fish has been identified as the most important source of nutrients. The nutrient impact of fish farming on surrounding coastal and sea areas is mainly a function of the feed wastage and feed coefficient, the feed composition, and metabolic processes in the fish, and, therefore, should be considered for sustainable management. So far, there is perhaps no regulation around the world as to the allowable limit P discharge from aquaculture to the environment.

Acknowledgment

This work was supported by the Directorate General of Research and Development Strengthening of the Ministry of Research and Higher Education of the Republic of Indonesia through the scheme of Magister Thesis, the fiscal year 2020. Thanks also addressed to the Faculty of Engineering Universitas Andalas for financial support of this publication (Grant number 045/UN.16.09.D/PL.2020).

References

1. L.H. Pelizer, J.C.M. de Carvalho and I. de Oliveira Moraes, "Protein production by Arthrospira (Spirulina) platensis in solid state cultivation using sugarcane bagasse as support", Biotechnology Reports, vol. 5, (2015), pp. 70-76.
2. Peraturan Daerah Kabupaten Agam 2018 Kecamatan Tanjung Raya dalam angka 2018 p 176.
3. Peraturan Daerah Kabupaten Agam 2014 Pengelolaan kelestarian kawasan Danau Maninjau p 27.
4. Y. Abou, A. Saidou, D. Mama, E. D. Fiogbé, and J. Micha 2012 Evaluation of nitrogen and phosphorus wastes produced by nile tilapia (oreochromis niloticus l) fed azolla -diets in earthen ponds. African Journal of Aquatic Science. vol. 2012. pp. 502–507.
5. B. Malcom 2004 Cage Aquaculture. (USA :Blackwell Publishing)
6. G. W. Ngupula and R. Kayanda 2010 Benthic macrofauna community composition, abundance and distribution in the Tanzanian and Ugandan inshore and offshore waters of Lake Victoria. African Journal of Aquatic Science. vol. 35, no. 2. pp. 185–192.
7. Kementerian Lingkungan Hidup 2011 Profil 15 danau prioritas nasional. p 154.
8. S. N. Sulastri, C. Henny 2019 Phytoplankton diversity and trophic status of Lake Maninjau, West Sumatra, Indonesia. pros sem nas masy biodiv indon. vol. 5. Chalar 2009. pp. 242–250.
9. Y. Bangyou, X. Jiusheng, T. Huiru, and D. Shaoping 2011 Analysis on water environment capacity of the Poyang Lake. Procedia Environmental Sciences. vol. 10, no. Esiat. pp. 2754–2759.
10. D. K. Mueller 1983 Mass balance model estimation of phosphorus concentrations. vol. 18, no. 3.
11. B. Machbub 2010 Model perhitungan daya tampung beban pencemaran air pp. 129–144.
12. J. Oakley 2014 Modeling the aquaculture carrying capacity of Lake Toba, North Sumatra, Indonesia. pp. 1–35.
13. A. Ekpeki 2016 Development of carrying capacity estimates for zonation of cage aquaculture in Lake Volta, Ghana.
14. Kementerian Lingkungan Hidup 2009 Daya tampung beban pencemaran air danau dan/atau waduk. p. 15.
15. Standar Nasional Indonesia 2008 Metoda pengambilan contoh air permukaan. p. 23.
16. APHA 2017 Standard methods for the examination of water and wastewater. p. 1546.
17. F. B. Johan, M. Zubir, B. Mat, and L. H. San 2018 Chlorophyll a concentration of fresh water phytoplankton analysed by algorithmic based spectroscopy. J. Phys.: Conf. Ser. 1083 012015
18. D. Copetti et al. 2019 Science of the Total Environment Phosphorus content in a deep river sediment core as a tracer of long-term (1962 – 2011) anthropogenic impacts : A lesson from the Milan metropolitan area. Sci. Total Environ.. vol. 646, pp. 37–48.
19. R. E. Carlson 1977 A trophic state index for lakes 1. vol. 22. March.
20. Kementrian Lingkungan Hidup 2010 Tata laksana pengendalian pencemaran air.
21. V. P. A. Weerasinghe and K. Handapangoda 2019 Monitoring & management surface water quality analysis of an urban lake;East Beira,Colombo, Sri Lanka. Environ. Nanotechnology, Monit. Manag. vol. 12. p. 100249.
22. V. Pradeep, C. Deepika, G. Urvi, and S. Hitesh 2012 Water Quality Analysis of an Organically Polluted Lake by Investigating Different Physical and Chemical Parameters. International Journal of Research in Chemistry and Environment. vol 2. pp 105-111.
23. K. Gunes 2008 Point and nonpoint sources of nutrients to lakes – ecotechnological measures and mitigation methodologies – case study. vol. 4, pp. 116–126.

24. S. S. Rathore, P. Chandravanshi, A. Chandravanshi, and K. Jaiswal 2016 Eutrophication : Impacts of Excess Nutrient Inputs on Aquatic Ecosystem. Iosr-Javs. vol. 9, no. 10. pp. 89–96.
25. L. Serrano et al. 2017 A new tool for the assessment of severe anthropogenic eutrophication in small shallow water bodies. Ecol. Indic. vol. 76 pp. 324–334.
26. Q. I. N. Boqiang et al. 2013 Lake eutrophication and its ecosystem response vol. 58, no. 9, pp. 961–970.
27. C. H. and S. Nomosatryo 2016 Changes in water quality and trophic status associated with cage aquaculture in Lake Maninjau, Indonesia. Earth and Environmental Science vol. 31.
28. I. Setyobudiandi, I. Muchsin, and S. Hariyadi 2015 Impact of cage aquaculture on water quality condition in Lake Maninjau, West Sumatera Indonesia. vol. 4531, pp. 120–137.
29. H. Syandri and A. Mardiah 2018 Nitrogen and phosphorus waste production from different fish species cultured at floating net cages in Lake Maninjau, Indonesia Asian Journal of Scientific Research. pp. 1992-1454.
30. S. R. Samudra et al 2013 Daya tampung beban pencemaran fosfor untuk budidaya perikanan danau rawapening. Prosiding Workshop Penyelamatan Ekosistem Danau Rawapening.
31. S. Kundu, M. V. Coumar, S. Rajendiran, and A. S. Rao 2015 Phosphates from detergents and eutrophication of surface water ecosystem in India. vol 108.
32. A. Svanbäck et al 2019 Science of the total environment reducing agricultural nutrient surpluses in a large catchment – links to livestock density. Sci. Total Environ.. vol. 648, pp. 1549–1559.
33. L. Mhlanga, W. Mhlanga, and P. Mwera 2013 The application of a phosphorus mass balance model for estimating the carrying capacity of Lake Kariba. Turkish Journal of Veterinary and Animal Sciencespp. vol 37 p. 316–319.
34. S. Pulatsü 2003 The application of a phosphorus budget model estimating the carrying capacity of Kesikköprü Dam Lake. vol. 27. pp. 1127–1130.
35. R. M. Neto, H. R. Nocko, and A. Ostrensky 2016 Carrying capacity and potential environmental impact of fish farming in the cascade reservoirs of the Paranapanema River, Brazil. Aquaculture Research. pp. 1–17.
36. S. M. Limbu 2015 The effect of floating and sinking diets on growth performance , feed conversion efficiency, yield and cost- effectiveness of African sharptooth catfish, Clarias gariepinus reared in earthen ponds. vol. 2, no. 5. pp. 253–259.
37. G. S. David, E. D. Carvalho, D. Lemos, A. N. Silveira, and M. D. Aglio-sobrinho 2015 Aquacultural Engineering ecological carrying capacity for intensive tilapia (Oreochromis Niloticus) cage aquaculture in a large hydroelectrical reservoir in Southeastern Brazil. Aquac. Eng. vol. 66, pp. 30–40.

Solid State Technology

ORIGINALITY REPORT

20%	17%	13%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	solidstatetechnology.us Internet Source	5%
2	teaching.ust.hk Internet Source	3%
3	www.researchgate.net Internet Source	2%
4	journals.tubitak.gov.tr Internet Source	2%
5	arpnjournals.org Internet Source	1%
6	cyberleninka.org Internet Source	1%
7	P S Komala, A Nur, N L Badriah, M Harefa, S Silvia, Ridwan, Zulkarnaini. "An Assessment of Heavy Metals Pollution in the Waters and Sediments of Lake Maninjau, Indonesia", IOP Conference Series: Materials Science and Engineering, 2021 Publication	<1%

8	Yi-Che Shih, Chiu L. Chou, Wen-Yan Chiau. "Geographic information system applied to measuring benthic environmental impact with chemical measures on mariculture at Penghu Islet in Taiwan", Science of The Total Environment, 2009 Publication	<1 %
9	www.questionpro.com Internet Source	<1 %
10	Lukman, M S Syawal, M Maghfiroh. "Sumatran major lakes: limnological overviews", IOP Conference Series: Earth and Environmental Science, 2020 Publication	<1 %
11	coek.info Internet Source	<1 %
12	P S Komala, B Primasari, Q Ayunin. "The Influence of the Physicochemical Parameters on the Ortho Phosphate and Total Phosphate Concentrations of Maninjau Lake", Journal of Physics: Conference Series, 2020 Publication	<1 %
13	V.P.A. Weerasinghe, Kosala Handapangoda. "Surface water quality analysis of an urban lake; East Beira, Colombo, Sri Lanka", Environmental Nanotechnology, Monitoring & Management, 2019 Publication	<1 %

14	file.scirp.org Internet Source	<1 %
15	www.ilec.or.jp Internet Source	<1 %
16	www.lummi-nsn.gov Internet Source	<1 %
17	Piotr Sugier. "The influence of Ceratophyllum demersum L. and Stratiotes aloides L. on richness and diversity of aquatic vegetation in the lakes of mid-eastern Poland", Hydrobiologia, 11/2010 Publication	<1 %
18	Yinka Titilawo, Aderonke Akintokun, Olufunke Shittu, Mobolaji Adeniyi, Janet Olaitan, Anthony Okoh. "Physicochemical Properties and Total Coliform Distribution of Selected Rivers in Osun State, Southwestern Nigeria", Polish Journal of Environmental Studies, 2019 Publication	<1 %
19	dergipark.org.tr Internet Source	<1 %
20	Arina Khofiyanida, Margaretha Widyastuti. "Water quality index and pollution loading capacity of Setu Babakan, Jakarta-Indonesia", E3S Web of Conferences, 2020 Publication	<1 %

21	Lecture Notes in Electrical Engineering, 2015. Publication	<1%
22	Muzzalifah Abd Hamid, Amir Shah Ruddin Md Sah, Izwandy Idris, Siti Azizah Mohd Nor, Mashhor Mansor. " Trophic state index ( ) and carrying capacity estimation of aquaculture development; the application of total phosphorus budget ", Aquaculture Research, 2022 Publication	<1%
23	docplayer.net Internet Source	<1%
24	iwaponline.com Internet Source	<1%
25	Fernanda Garcia Sampaio, Carlos A.S. Araújo, Bruno Stéfano Lima Dallago, José Luiz Stech et al. "Unveiling low-to-high-frequency data sampling caveats for aquaculture environmental monitoring and management", Aquaculture Reports, 2021 Publication	<1%
26	Hafrijal Syandri, Elfiondri ., Ainul Mardiah, Azrita .. "Social Status of Nile Tilapia Hatchery Fish-farmers at Maninjau Lake Areas, Indonesia", Journal of Fisheries and Aquatic Science, 2016 Publication	<1%

27 L Lukman, R Dina, A Ibrahim, A Waluyo. "Phosphorus load base carrying capacity estimation for fish culture in Lake Ranau in Indonesia", IOP Conference Series: Earth and Environmental Science, 2021 <1 %
Publication

28 www.ijsk.org <1 %
Internet Source

29 Hafrijal Syandri, Azrita ., Ainul Mardiah. "Effect of Feed Types and Estimation of Nitrogen-Phosphorus Loading Caused by Common Carp (Cyprinus carpio) in Lake Maninjau, Indonesia", Pakistan Journal of Nutrition, 2018 <1 %
Publication

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		