# A study on phosphorus-based carrying capacity and trophic status index of floating net cages area in Ranu Grati, Indonesia

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**Abstract**. The utilization of Ranu Grati for aquaculture in the form of floating net cages loads more phosphorus to the water as the result of fish feed waste. The rising of phosphorus concentration in water may lead to eutrophication which indicates bad water quality. This study aim to estimate the amount of phosphorus that can be carried by Ranu Grati and to identify its water quality status based on Trophic State Index (TSI) measurement. The estimation of Lake carrying capacity was according to Indonesia Minister of Environment Act No. 28, 2009. The results show that Ranu Grati is capable to carry the phosphorus load due to floating net cages at 12.674,11 kg year$^{-1}$ which is lower than the current number of phosphorus waste that discharged from floating net cages that reaches 16.360,176 kg year$^{-1}$. Meanwhile, the TSI scores from all sampling sites indicate that Ranu Grati is light eutrophic until medium eutrophic.

**Key Words**: eutrophication, pollution, aquaculture waste, transparency, cholorphyll-*a*.

**Introduction**. Lake is one of the lentic freshwater ecosystems which has bigger size than a pond. A basin which contains waters on the earth surface is considered as a lake only if its size is greater than 2 Ha (Soeprobowati 2012). Lake has important role not only for environment but also for local communities. For environment, lake supports biodiversity since it becomes the natural habitat for various aquatic organisms. Meanwhile, it is also utilized as the source of water and aquaculture site for the local community (Bhagowati & Ahamad 2019).

In Javanese, lake is also referred as 'Ranu'. Ranu Grati is a natural lake which formed as a result of volcanic activity. It is located in Pasuruan Regency, East Java, Indonesia. The lake area covers about 1084 Ha. It is surrounded by villages such as Ranuklindungan and Gratitunon. Ranu Grati is used for floating net cages, capture fisheries (fishing area), agricultural irrigation, tourism attraction and as waste final disposal site (Suchaina 2014).

According to Nugroho (2015), aquaculture activity in Ranu Grati, in the form of floating net cages, is the biggest fisheries in Pasuruan Regency with tilapia fish (*Orechromis niloticus*) as the main commodity. Tilapia fish (*O. niloticus*) is one of the common aquaculture commodities in East Java because of its high demand in market and the ease of cultivation. Floating net cages in Ranu Grati takes around 36.6 Ha of the overall area. They contribute to the addition of organic matters to the lake. Therefore, they may affect the water quality of the lake.

Yuningsih et al (2014) stated that the main sources of organic matters from floating net cages activity are fish wastes and leftover feed. They accumulate on the bottom of the waters so that decrease the water quality status of the lake. The degradation of water quality will result to the mortality of fish and other aquatic organisms. Hence, the biodiversity will reduce and the aquaculture activity itself will not sustain. Therefore, the number of floating net cages does matter because the more cages are, the more organic matters collecting is (Gorlach-Lira et al 2013; Syandri et al 2016). Nevertheless, lake has capacity to carry the load of organic matters which mainly decomposed into phosphorus. Thus, it is urgent to analyse the ability of Ranu Grati in carrying the load of phosphorus resulted from the used of artificial feed for floating net cages activities in there.

Specifically, the high concentrate of organic matters raises nutrient (nitrate and phosphate) content in waters. Nutrients have important roles for phytoplankton growth. However, if the nutrients content rise excessively then it will lead to great phytoplankton abundance or algal blooming. The nutrient enrichment in waters is known as eutrophication. This phenomenon is causing mass mortality of aquatic organisms because it is toxic (Lv et al 2011). It also indicates that water quality of the lake is being deteriorated. Thus, eutrophication level or trophic status can be used as the indicator of water quality status (Bekteshi & Cupi 2014; El-Serehy et al 2018). For this reason, the assessment of trophic index status need to be carried out in order to identify the contribution of organic matters load to the water quality in Ranu Grati.

## Material and Method

***Description of the study sites***. The research was conducted in Ranu Grati, Pasuruan Regency, East Java Province from December 2018 until February 2019. The location can be seen in Figure 1 below. There are six sampling sites which determined purposively. They represent (1) outlet, (2) inlet, (3) – (5) floating net cages area, and (6) center of the lake. The study employs two kinds of approaches. Firstly, phosphorus-based carrying capacity of Ranu Grati due to floating net cages activities was calculated according to the Indonesia Minister of Environment Act No. 28, 2009 on water pollution load capacity in lake or reservoir. Secondly, analysis on current water quality status of Ranu Grati by utilizing Trophic State Index (TSI).

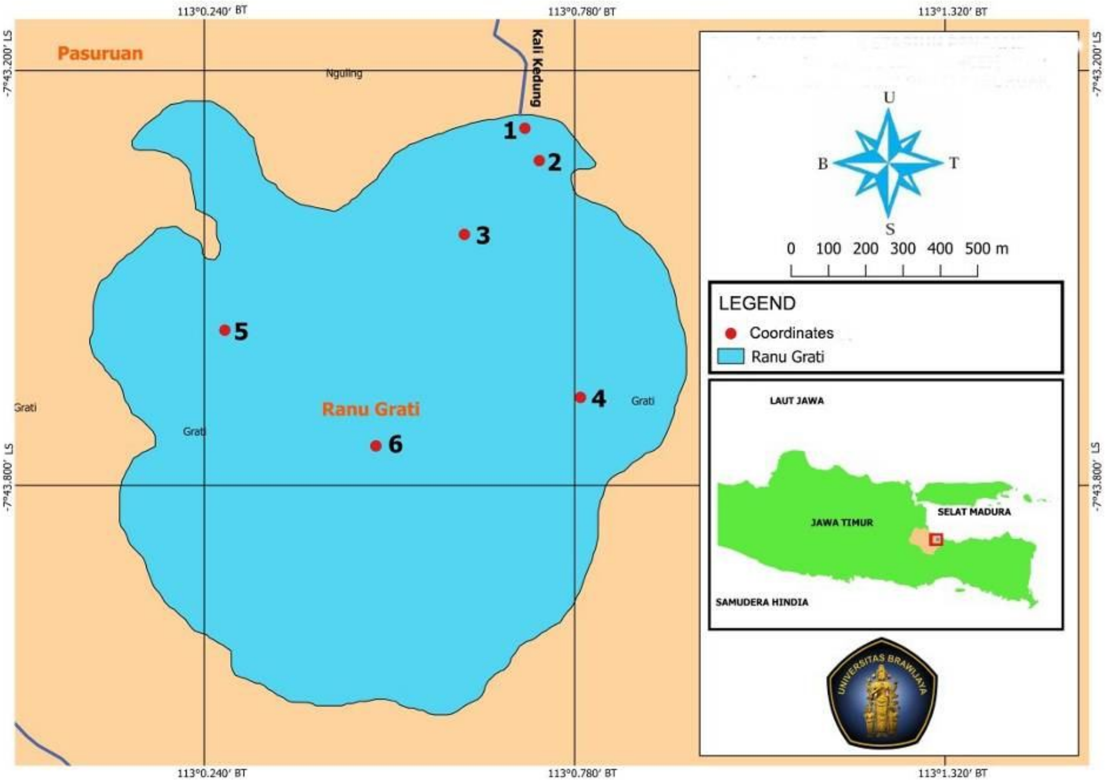


Figure 1. Sampling sites location in Ranu Grati, Pasuruan, Indonesia.

***Phosphorus-based carrying capacity estimation approach***. The calculation of phosphorus-based carrying capacity uses several variables that are presented in Table 1.

The characteristics of Ranu Grati such as volume and depth were estimated by the utilization of *Echosounder Single Beam* device. Kautsar et al (2013) said that acoustic wave from echosounder transducer can be used to obtain the depth, bottom form of the waters, volume, and hydrography. Meanwhile, total-P measurement of the lake ($[P]_i$) was conducted in chemical laboratory in Faculty of Mathematics and Natural Science of Brawijaya University, by using a spectrophotometer.

Table 1

Variables remarks on carrying capacity equation

| *Variable* | *Symbol* | *Formula* | *Unit* |
|---|---|---|---|
| Volume | $V$ | - | $m^3$ |
| Surface area | $A$ | - | $m^2$ |
| Depth average | $\check{Z}$ | $\hat{Z} = \frac{V}{A}$ | M |
| Water debit average | $Q$ | - | $m^3\ year^{-1}$ |
| Flushing coefficient | $P$ | $\rho = \frac{Q}{V}$ | $year^{-1}$ |
| Feed conversion rate | $FCR$ | $\frac{\text{Total feed given}}{\text{Total fish production}}$ | - |
| Total P allocation load | $\Delta[P]$ | $\Delta[P] = [P]_r - [P]_i$ | $mg\ m^{-3}$ |
| Standard total-P for any fish aquaculture | $[P]_r$ | - | $mg\ m^{-3}$ |
| The total-P measurement of the lake | $[P]_i$ | - | $mg\ m^{-3}$ |
| Proportion of total-P left in sediment | $R$ | $R = \left(1 + 0.747\rho^{0.507}\right)^{-1}$ | $g\ m^{-3}$ |
| Proportion of total-P left in sediment due to floating net cage | $R_{fish}$ | $R_{fish} = x + (1-x)R$ | $g\ m^{-3}$ |
| Proportion of total-P dispersed permanently in sediment | $x$ | - | - |
| Lake carrying capacity on total-P from floating net cage | $L_{fish}$ | $L_{fish} = \Delta[P]\hat{Z}\rho \big/ (1 - R_{fish})$ | $g\ m^{-2}\ year^{-1}$ |

Source: Indonesia Minister of Environment Act No. 28, 2009.

In addition, the formula to calculate the amount of total-P released by fish aquaculture waste (relatively to fish production) is denoted by equation (1) as follows:

$$P_{LP} = FCR \text{ x } \left(P_{feed} - P_{fish}\right) \quad (1)$$

where: $P_{LP}$ = total-P released by aquaculture wastes (kg $ton^{-1}$);
FCR = feed conversion rate;
$P_{feed}$ = total-P in feed (kg $ton^{-1}$);
$P_{fish}$ = total-P eaten by fish (kg $ton^{-1}$).

***Trophic state index (TSI)***. It is an index which indicates the water quality status of any aquatic ecosystem by measuring its fertility according to the biomass of algae. The abundance of first producers in waters estimated based on the amount of chlorophyll-*a*, secchi disc depth or transparency, and total-P. Trophic status classification using TSI is presented in Table 2 (Carlson 1977).

Table 2

TSI levels of waters eutrophication

| *Index* | *Classification* |
|---|---|
| < 30 | Ultraoligotrophic |
| 30-40 | Oligotrophic |
| 40-50 | Meso-trophic |
| 50-60 | Light eutrophic |
| 60-70 | Medium Eutrophic |
| 70-80 | Heavy Eutrophic |
| > 80 | Hyper-eutrophic |

TSI score can be calculated using formula in equation (2):

$$TSI(SD) = 60 - 14.41\ln(SD)$$
$$TSI(CHL) = 30.6 + 9.81\ln(CHL)$$
$$TSI(TP) = 4.15 + 14.42\ln(TP)$$
$$TSI = \frac{TSI(SD) + TSI(CHL) + TSI(TP)}{3} \qquad (2)$$

where: SD = secchi disc depth (m);
CHL = chlorophyll-*a* (μg $L^{-1}$)
TP = total-P (μg $L^{-1}$)

## Results and Discussion

***Ranu-Grati carrying-capacity for phosphorus.*** The existence of floating net cages for aquaculture purposing in Ranu Grati rises the phosphorus content in the water. According to Table 1, there are some factors determining the ability of the lake to carry the phosphorus. First of all, volume (V) and surface area (A) of Ranu Grati are 124,491,952.55 $m^3$ and 1,734,223.07 $m^2$ respectively while water debit (Q) according to water irrigation service of Pasuruan Regency, is 31,104,000 $m^3$ $year^{-1}$. Therefore, the flushing coefficient comprised to 0.25 $year^{-1}$.

The total-P measurement for the lake ($[P]_i$) was 145 mg $m^{-3}$. Meanwhile, the standard of total-P for aquaculture purposes ($[P]_r$) based on the government regulation is 200 mg $m^{-3}$. Thus, the allocation for total-P load ($\Delta[P]$) equals to 55 mg $m^{-3}$. Besides, the total-P left in sediment ($R$) result is 0.73. It leads to the proportion total-P left in sediment due to floating net cages ($R_{fish}$) as much as 0.87 in which proportion of total-P dispersed permanently in sediment or $x$ decided according to Pulatsu (2003), is 0.50. Consequently, the amount of total-P which able to be carried by the lake as the result of floating net cages equals to 7.31 g $m^2$ $year^{-1}$ or equivalents to 12.674,11 kg $year^{-1}$ compared to the overall surface area of the lake.

On the other hand, the content of total-P of the feed that used by the aquaculture activities ($P_{feed}$) was observed at 21.75 kg $ton^{-1}$. Furthermore, the FCR was accounted for 1.7. Meanwhile, the total-P in the fish determined to 3.4 kg $ton^{-1}$ (Beveridge 1984). As the result, the amount of total-P released by fish aquaculture waste ($P_{LP}$) reaches 33.58 kg $ton^{-1}$. It was known from the observation that the number of fish yield from floating net cages aquaculture in Ranu Grati was 487.200 kg $year^{-1}$. Hence, the amount of waste resulted from that production equivalents to 16.360,176 kg $year^{-1}$ which outnumbers the carrying capability of the lake (12.674,11 kg $year^{-1}$).

***TSI of Ranu Grati.*** Trophic state index (TSI) was calculated by using the amount of chlorophyll-*a*, total phosphate, and transparency indicated by secchi disc measurement. Carlson (1977) believes that these three variables have high correlation to each other, for instance, each doubling of algal biomass related in halving of the transparency. Chlorophyll-*a* is the key variable in depicting trophic status in tropical lakes. Moreover, total P has reciprocal relationship to transparency when phosphorus considered as the limiting growth of algal. The advantage of TSI is the scale prenseted in numerical rather than nomenclatural, which allowing a large number of lakes to be classified.

The measurement of chlorophyll-*a*, transparency, and total-P in Ranu Grati are presented in Table 3.

It can be seen from Table 3 that sites 2 and 6 have higher chlorophyll-*a* concentration than other sites. Thus, it reveals that the two sites have the biggest primary productivity. An almost similar pattern can be seen in total-P concentration in which the higher value found in sites 5 and 6. Specifically, site 6 is the center of the lake. Samudra et al (2013) stated that phosphorus concentration in the lake's center is relatively high because of the domestic wastes carried by the water flows so that the organic matters accumulated in the middle of the water. As a consequence, the nutrient be enriched and resulted to the algal abundance. Meanwhile, the water transparency in Ranu Grati is still optimum for phytoplankton growth since it is greater than 45 cm (Suryanto 2011).

Table 3

Variables measurement results used in TSI for assessing Ranu Grati trophic state

| *Site* | *Chlorophyll-a (μg $L^{-1}$)* | *Total-P (μg $L^{-1}$)* | *Transparency (cm)* |
|---|---|---|---|
| 1 | 4.47±0.48 | 109.67±6.66 | 141.00±21.00 |
| 2 | 8.12±0.63 | 141.33±22.37 | 158.67±34.85 |
| 3 | 4.78±1.32 | 141.33±34.15 | 115.33±2.31 |
| 4 | 3.67±1.02 | 140.33±1.53 | 139.67±5.86 |
| 5 | 6.98±0.82 | 175.67±17.56 | 102.67±15.14 |
| 6 | 8.11±2.41 | 147.33±11.15 | 121.67±16.50 |

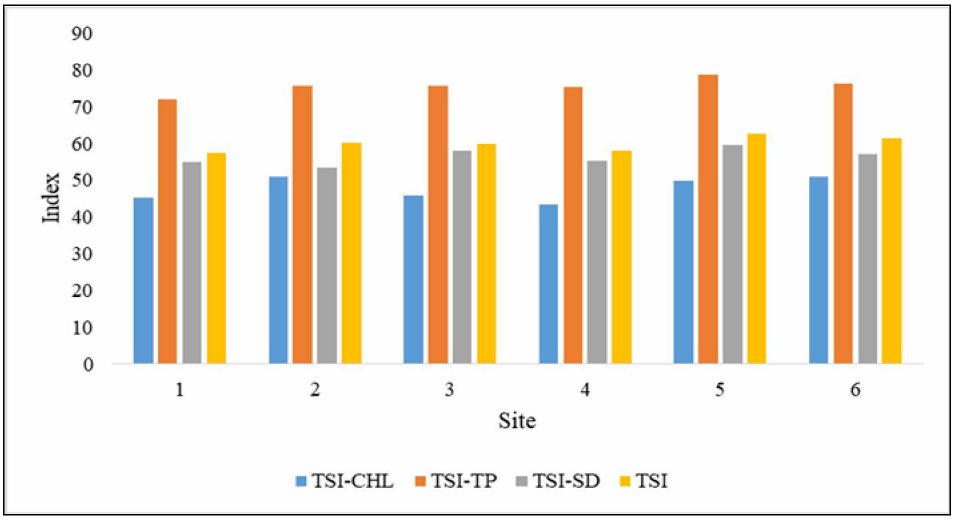


Figure 2. TSI scores for site sampling in Ranu Grati.

The overall TSI of the six sampling sites ranges from 57 to 61. It means that the trophic state in Ranu Grati is categorized as light eutrophic until medium eutrophic. However, it can be seen in Figure 2 that the highest index of the three indicators of all sites comes from Total Phosphate (TSI-TP). This finding is in line with the result from carrying capacity analysis in which the concentration of phosphorus in Ranu Grati has been outnumbered that of the lake capability. Fortunately, the other two indicators have low scores that reflect the phosphorus content in the water has not much affected the light availability and chlorophyll-*a* yet. Therefore, water quality status in Ranu Grati has not been too deteriorated.

Nevertheless, this condition does not mean that the finding suggestion of carrying capability can be ignored even though the water quality status in Ranu Grati still supports the aquatic animals' growth. Schindler et al (2008) show the results of a long-term experiment in order to prevent eutrophication. For 5 years, a lake was eutrophied by adding excess N and P. Then, N inputs were decreased for more than fifteen years. N fixation by cyanobacteria resulted to N deficiency. For final period of experiment, N was absent for addition and P fertilization kept going. If N can rule eutrophication, this research should have prevented algae blooms. However, the lake persisted to be highly eutrophic, with rich cyanobacteria. Cyanobacteria blooms are among the most severe consequences of eutrophication causing taste and odor problems in drinking water. It is now commonly considered that P discharging must be lessen to prevent eutrophication of lakes and reservoirs (Vrede et al 2009). Hence, keeping phosphorus input in safe limit is a must to prevent the eutrophication in Ranu Grati.

**Conclusions**. The phosphorus-based carrying capacity of Ranu Grati was estimated at 12.674,11 kg year$^{-1}$ which has been outnumbered by the current phosphorus waste resulted from floating net cages (16.360,176 kg year$^{-1}$). As the consequence, the TSI for total phosphate is relatively high compared to TSI for chlorophyll-*a* and transparency. However, the overall TSIs of all sampling sites show that the trophic state in Ranu Grati are light eutrophic until medium eutrophic which means that eutrophication is not a major problem for Ranu Grati yet. However, P input need to be well monitored to keep Ranu Grati safe from eutrophication.

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