



## RESEARCH ARTICLE

**REVISED** Nutrient loading and farm characteristics of giant gourami fish aquaculture systems in Lake Maninjau, Indonesia: basic knowledge of production performance [version 2; peer review: 2 approved]

Hafrijal Syandri <sup>1</sup>, Azrita Azrita <sup>2</sup>, Eni Sumiarsih<sup>3</sup>, Elfiondri undefined <sup>4</sup>

<sup>1</sup>Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Padang, West Sumatera, 25133, Indonesia

<sup>2</sup>Department of Biology Education, Faculty of Education, Universitas Bung Hatta, Padang, West Sumatera, 25133, Indonesia

<sup>3</sup>Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Riau, Pekanbaru, 28293, Indonesia

<sup>4</sup>Faculty of Humanities, Universitas Bung Hatta, Padang, West Sumatera, 25133, Indonesia

**V2** First published: 12 May 2021, 10:378  
<https://doi.org/10.12688/f1000research.52613.1>

Latest published: 22 Sep 2021, 10:378  
<https://doi.org/10.12688/f1000research.52613.2>

## Abstract

### Background

Aquaculture systems for giant gourami, *Osphronemus goramy* Lacepède (1801), have significantly improved fish production yields and food security in Indonesia. However, these systems also cause serious problems in terms of eutrophication in waterbodies. This study analysed the nutrient loading and farm characteristics of giant gourami in floating cages in Lake Maninjau.

### Method

A total of 20 floating cages were used to record these nutrients in feed supply, female and male juvenile fish, dead fish and harvested fish to estimate nutrient loading. Data on the harvested fish, production cycle, stock number and cage capacity were used to estimate the stocking density, feeding rate, feed efficiency, and net fish yield, and the relationship between feed supply and nutrient loading and farm characteristics was analysed by least squares regression methods.

### Results

A total of 20 floating cages released nutrients into waterbodies at an average rate of 236.27±60.44 kg/cycle for C, 84.52±20.86 kg/cycle for N and 8.70±3.63 kg/cycle for P. On average, fish production for each floating cage (±SD) was 1226±282 kg wet weight/cycle, and the net fish yield was 12.63±2.82 kg/m<sup>3</sup>/cycle. Survival rates ranged from 86.33 to 95.27%/cycle. The production cycles varied from 160 to 175 days with feed conversion ratios between 1.60 and 1.75, feed conversion efficiencies were between 0.58 and 0.63. The production parameters that had strong relationships with the net fish yield were feed supply ( $r^2=0.960$ ), stocking rates ( $r^2=0.924$ ) and feeding rates ( $r^2$

## Open Peer Review

Approval Status

	1	2
<b>version 2</b>		
(revision)		
22 Sep 2021		
<b>version 1</b>		
12 May 2021		

1. **Zahidah Hasan** , Padjadjaran University, Jatinangor, Indonesia

2. **Christopher Mulanda Aura** , Kenya Marine and Fisheries Research Institute, Kisumu, Kenya

Any reports and responses or comments on the article can be found at the end of the article.

=0.961). In contrast, the length of the production cycle was not strongly related to the net fish yield ( $r^2=0.187$ ).

### Conclusion

Nutrient loading from the supplied feed was greater than that from the harvested fish, juvenile fish and dead fish. Increasing the net fish yield in floating cages was better predicted by the stocking densities and feeding levels than by the other factors.

### Keywords

Lake Maninjau, giant gourami culture, floating cage aquaculture, nutrient loading, farm characteristics.



This article is included in the **Agriculture, Food and Nutrition** gateway.

**Corresponding author:** Hafrijal Syandri ([syandri\\_1960@bunghatta.ac.id](mailto:syandri_1960@bunghatta.ac.id))

**Author roles:** **Syandri H:** Conceptualization, Data Curation, Formal Analysis, Methodology, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Azrita A:** Data Curation, Formal Analysis, Project Administration; **Sumiarsih E:** Data Curation, Methodology, Writing – Original Draft Preparation; **undefined E:** Resources, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** This study was funded by a competitive grant for productive and innovative research (Policy/Governance) from the Indonesia Education Fund Management Institution (LPDP), Ministry of Finance, Republic of Indonesia with contract number PRJ-99/LPDP/2019.

*The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.*

**Copyright:** © 2021 Syandri H *et al.* This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The author(s) is/are employees of the US Government and therefore domestic copyright protection in USA does not apply to this work. The work may be protected under the copyright laws of other jurisdictions when used in those jurisdictions.

**How to cite this article:** Syandri H, Azrita A, Sumiarsih E and undefined E. **Nutrient loading and farm characteristics of giant gourami fish aquaculture systems in Lake Maninjau, Indonesia: basic knowledge of production performance [version 2; peer review: 2 approved]** F1000Research 2021, 10:378 <https://doi.org/10.12688/f1000research.52613.2>

**First published:** 12 May 2021, 10:378 <https://doi.org/10.12688/f1000research.52613.1>

**REVISED Amendments from Version 1**

We have revised article No. 52613 as follows:

Reviewer 1: Prof. Zahidah Hasan, Padjadjaran University, Jatinangor, Indonesia

Part methods:

1. We have added the length of time for installing waste traps under floating net cages (highlight in Green)
2. We have added that aquaculture waste includes uneaten feed, metabolic waste, and feces (highlight in Green).

Reviewer 2: Prof. Christopher Mulanda Aura, Kenya Marine, and Fisheries Research Institute, Kisumu, Kenya

Part Discussion

1. We have added water quality parameters in part discussion and compare them to other lakes (highlight in Green).
2. We have added comments at the end of the conclusion, and conclusions drawn are adequately supported by the results (highlight in Green).

**Any further responses from the reviewers can be found at the end of the article**

## Introduction

Fish are a source of protein, lipids, carbohydrates, vitamins and essential minerals<sup>1-3</sup>. Therefore, fisheries production is very important to increasing food security<sup>3,4</sup> through capture fisheries and aquaculture sectors<sup>5</sup>. To increase the global production of aquaculture, freshwater can be provided in a variety of aquaculture systems, such as freshwater ponds, tanks and floating cages<sup>6-9</sup>.

Cage aquaculture is expanding in tropical lakes and has been ongoing for a long time<sup>9-11</sup>. Lake Maninjau in Indonesia has used cage aquaculture since 1992 (Nazarudin-Sepakat Aquaculture's farm manager, pers. comm.). Some authors have reported that the dominant species being cultured in tropical lakes is tilapia, and commercial feed pellets are used<sup>9,11-15</sup>. In the past five years, fish farmers in Lake Maninjau have also conducted giant gourami fish farming activities in floating cages with commercial feed pellets because it is an economically important species for food security in Indonesia, and most of the giant gourami that have been consumed for decades have been produced by aquaculture in freshwater ponds<sup>7,16,17</sup>.

Environmental impacts of tilapia aquaculture operations that have been recorded in tropical lakes have also been reported in Lake Malawi<sup>11</sup>, Lake Taihu<sup>18</sup>, Lake Victoria<sup>11,15,19</sup>, and Lake Kariba<sup>9</sup>. In contrast, Syandri *et al.*<sup>20</sup> reported that in a small lake, *i.e.*, Lake Maninjau in Indonesia, tilapia aquaculture is approximately 17 km long by 8 km wide and has mean and maximum depths of approximately 112 and 178 m, respectively. Many studies have been carried out to evaluate nutrient loading, such as C, N and P loadings, and the growth performance of tilapia farms in lakes and reservoirs<sup>11,12,18</sup>. However, no data are available for nutrient waste loads from feed, juvenile fish, dead fish and harvested fish, including data on the characteristics of farming giant gourami in floating cages,

such as stocking density, total stock weight, feed conversion ratio, production cycle, harvest size, feeding level and specific growth rate. To address these issues, the present study was conducted to evaluate the C, N and P nutrient loads of giant gourami fish in floating cages and the operational characteristics to determine the relationship between production and cultivation efficiency to provide basic knowledge about production performance for the future.

## Methods

### Ethical considerations

In the present study, no permits from the Government of the Republic of Indonesia were needed to record data on feed supply, initial weight, stocking density, fish production, fish mortality and production cycle of giant gourami in 20 floating cages in Lake Maninjau from 2019 to 2020. The study included collecting sediment and fish and killing as many as three giant gourami in each floating cage to analyse the chemical composition of carbon, nitrogen and phosphorus from the carcasses. This research was recommended by the Research and Community Service Universitas Bung Hatta with sponsorship from the Indonesian Education Management Institution, Ministry of Finance Republic of Indonesia, through a competitive grant called Productive Innovative Research 2019 with contract number PRJ-99/LPDP/2019. Ethical approval was granted by the Ethics Commission for Research and Community service at Universitas Bung Hatta (098/LPPM/Hatta/X-2019).

### Study area

The research was conducted in Lake Maninjau, located in the Agam District, West Sumatera Province, Indonesia, at an altitude of 463 m above sea level with a surface area of 97.37 km<sup>2</sup>, a water volume of 10.4 km<sup>3</sup>, a water retention time of 24.5 years, and a catchment area of 13.26 km<sup>2</sup>. Since 1973, lake water has been used for electric power generation with a capacity of 64 MW, and starting in 1992, the lake has also been used floating-cage fish farming activities.

### Study design

A total of 200 floating cages using for giant gourami aquaculture by fish farmers in Lake Maninjau (Nazaruddin-Sepakat Aquaculture farm manager, personal communication). A total of 20 floating cages for giant gourami culture were used as samples. The sample was determined by simple random sampling using an ordinal method<sup>21</sup>. The data recorded were stock size (g), stock number (fish), total stock weight (kg), mortality (fish), feed supply (kg), total harvest weight (kg) and production cycle (days). Death fish are noted every day, which fish farmers report. Each floating cage had a capacity of 75 m<sup>3</sup> (5×5×3 m) and was constructed using a 10 mm mesh sieve. Each floating cage was combined with other resources, such as a buoy, a feeding lodge and cage pathways.

### Nutrient analysis

The chemical compositions carbon (C), nitrogen (N) and phosphorus (P) of the feed, fish and faeces were analysed. For the feed nutrient analysis, the feed samples were floating commercial feed (pelleted). The approximate composition of the feed was 12% moisture, 29% crude protein, 6% crude lipid, 12%

crude fibre and 6% crude ash. The fish were sampled from 10 floating cages (3 fish/cage) that were cultured for 150 days, and the fish weighed between 235 and 250 g/fish. Carbon (C) and nitrogen (N) concentrations (as % of dry weight) of the feed and fish were determined by the standard methods of the Association of Official Analytical Chemists<sup>22</sup>. The phosphorus (P) concentrations were determined using a spectrophotometer (Shimadzu UV-160 UV160 UV-Vis-NIR Spectrophotometer in Hayward, CA, USA) and the molybdate–ascorbic acid method indicated by the Association of Official Analytical Chemists<sup>22</sup> at the Chemistry Laboratory of Universitas Bung Hatta Padang. To complement the data, we also analysed the waste material of cultured giant gourami fish collected with traps under the floating cages. This study placed waste traps under floating net cages for four months of fish rearing or one production cycle. We analyze that aquaculture waste includes uneaten feed, metabolic waste, and feces. To collect the faeces, ten giant gourami were kept for 3 days in an aquarium with a capacity of 0.48 m<sup>3</sup> (2×0.6×0.4 m), and then, the faeces were deposited on the bottom of the aquarium. Furthermore, the deposited faeces were sucked into a clean bowl and dried. Waste material and faeces were analysed by the AOAC method<sup>22</sup>.

### Estimation of nutrient loading and farm characteristics

The C, N and P loadings from feed, juvenile fish, dead fish and harvested fish were estimated according to the method described by 23. The following parameters with their corresponding equations were analysed:

$$C \text{ (loss, kg)} = (F \times C_{DF} + J \times C_{DJ}) - (H \times C_{DH} + M \times C_{DM})$$

$$N \text{ (loss, kg)} = (F \times N_{DF} + J \times N_{DJ}) - (H \times N_{DH} + M \times N_{DM})$$

$$P \text{ (loss, kg)} = (F \times P_{DF} + J \times P_{DJ}) - (H \times P_{DH} + M \times P_{DM})$$

where *F*, *J*, *H* and *M* are the dry weight (kg) of the supplied feed, stocked juvenile fish, harvested fish and total dead fish in floating cages, respectively. The data were recorded at the end of each production cycle from the 20 floating cages. *C<sub>DF</sub>*, *C<sub>DJ</sub>*, *C<sub>DH</sub>* and *C<sub>DM</sub>* are the carbon contents in dry feed (DF), dry juvenile (DJ), dry harvest (DH) and dry mortality (DM), respectively.

The farm characteristic parameters were analysed using the following formulas:

$$\text{Specific growth rate (\%/day)} = \frac{(\text{Log harvests weight} - \text{Log stock weight})}{\text{Culture days}} \times 100$$

$$\text{Gross fish yield (kg/m}^3\text{)} = \frac{(\text{Total harvest number in individual} \times \text{average final fish weight in kg})}{\text{Cage capacity}} \times 100$$

$$\text{Net fish yield (kg/m}^3\text{)} = \frac{(\text{Total number of fish harvest in kg} - \text{total stock weight in kg})}{\text{Cage capacity}}$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed supply in kg}}{\text{Total harvest weight in kg}}$$

$$\text{Feed conversion efficiency (FCE)} = \frac{1}{\text{Feed conversion ratio}}$$

$$\text{Feeding rate (\%)} = \frac{\text{Average weight gain per day in kg}}{\text{Mean harvests size in g}} \times 100$$

$$\text{Survival rate (\%)} = \frac{\text{Total number of fish harvested}}{\text{Total number of fish stocked}} \times 100$$

The relationships between feed supply and nutrient load, harvested fish, production cycle and net fish yield, feeding level, feed conversion efficiency, stocking density and net fish yield were estimated by the least square's regression method<sup>24</sup>, and the figures were plotted using Microsoft Office Professional plus 2019.

## Results

### C, N and P loadings from giant gourami fish in floating cages

The C, N and P contents of the feed, fish and faeces of the giant gourami in this study are presented in Table 1. Furthermore, the estimated mass balances of C, N and P of the feed, juvenile fish, dead fish and harvested fish from the 20 floating cages are summarized in Table 2.

Fish feed was the main factor accounting for the C, N and P nutrient loadings of the giant gourami reared in floating cages, while stocked juvenile fish and dead fish accounted for a minor amount (Table 2). The average C, N and P loadings estimated from the floating cages were 236.27 kg/cycle, 84.52 kg/cycle and 8.70 kg/cycle, respectively, while the C, N and P loadings from each floating cage of giant gourami fish are displayed in Figure 1. Feed supply and carbon, nitrogen, and phosphorus loadings had linear relationships for the giant gourami reared in floating cages as shown by  $C = 0.1339 \times \text{FS} - 37.238$  (with  $r^2 = 0.988$ , Figure 2),  $N = 0.0455 \times \text{FS} - 8.1604$  (with  $r^2 = 0.996$ , Figure 3), and  $P = 0.0048 \times \text{FS} - 1.117$  (with  $r^2 = 0.991$ , Figure 4). The feed supply and net fish yield (kg/m<sup>3</sup>/cycle) relationship for the giant gourami reared in floating cages was shown by a net fish yield =  $0.0059 \times \text{FS} + 0.7396$  (with  $r^2 = 0.9609$ , Figure 5).

### General characteristics of farms

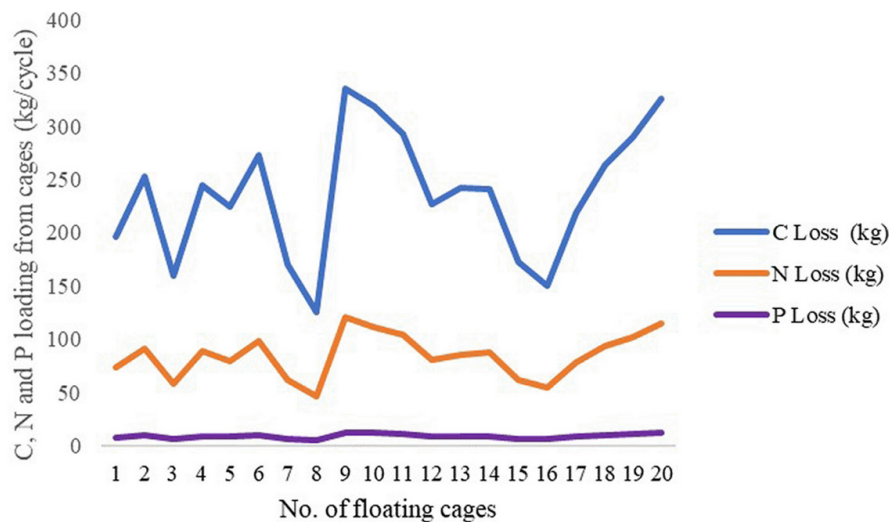
In this study, a 75 m<sup>3</sup> floating-cage capacity was used by fish farmers (5 × 5 × 3 m). The giant gourami fish stock number was between 40 individuals/m<sup>3</sup> (3000 individuals/cage) and 106 individuals/m<sup>3</sup> (8000 individuals/cage), with an average fish stock number of 75 individuals/m<sup>3</sup>. A mean weight of approximately 50 g for juveniles was stocked at the beginning of culture and reared from 160 to 175 days. To maximize the growth of giant gourami, all fish farmers used commercial, floating feed pellets (30% crude protein and 5% crude lipid). Based on recorded data by the fish farmers, the fish were fed daily at 09:00–10:00 h and 16:00–17.00 h. The amount of feed provided was adjusted according to temporal changes in biomass and the growth of the fish in the floating cages during the production cycle. The results of our analysis were that their feeding

**Table 1. Carbon (C), nitrogen (N) and phosphorus (P) composition (%) of the dry weight of the feed, harvested fish and faeces (±SD).**

	C	N	P	H <sub>2</sub> O
Feed	20.23±0.10	6.02±0.29	0.71±0.03	8.75±0.01
Fish	16.56±0.13	3.01±0.07	0.40±0.03	68.90±0.77
Faeces	14.21±1.65	1.20±0.05	0.95±0.02	72.29±0.40

**Table 2. Carbon (C), nitrogen (N) and phosphorus (P) mass balances estimated from the 20 floating cages (mean ± SD in kg/cage/cycle), and the numbers in parentheses are the range of the nutrient mass balances of C, N and P from the feed, juvenile fish, dead fish and harvested fish (kg/cage/cycle).**

Nutrient	Fish feed	Juvenile fish	Mortality	Fish harvest	C, N, P loss (kg)
C	412.19±95.72 (245.27–592.23)	44.49±11.67 (23.94–63.84)	17.40±3.68 (11.84–26.23)	203.01±46.74 (11.84–26.23)	236.27±60.44 (125.65–335.95)
N	121.93±28.31 (72.55–175.19)	8.39±2.20 (4.51–12.04)	4.73±0.94 (3.28–7.27)	41.06±9.45 (25.55–60.93)	84.52±20.86 (46.74–121.06)
P	14.38±3.33 (8.55–20.66)	1.11±0.29 (0.6–1.6)	0.53±0.11 (0.36–0.80)	6.25±1.43 (3.89–9.27)	8.70±3.63 (4.73–12.40)



**Figure 1. C, N and P loadings of giant gourami reared in floating cages.**

levels ranged from 1.24 to 3.47% of their body mass. Harvested fish weight ranged from 225 to 290 g/fish, and the gross yield of fish was 10.4 and 24.25 kg/m<sup>3</sup>/cycle, while the net fish yield was 8.17–18.92 kg/m<sup>3</sup>/cycle. The giant gourami were reared in the floating cages for each production cycle of 160 to 175 days, and the specific growth rate ranged from 0.87 to 1.04%/day. The net fish yield (kg/m<sup>3</sup>/cycle) in the floating cages was better predicted by the stocking rates (fish/m<sup>3</sup>) ( $r^2 = 0.9246$ , Figure 6) than by the length of the production cycles ( $r^2 = 0.1875$ , Figure 7). In addition, the supplied feed was not strongly

related to the survival of the giant gourami ( $r^2 = 0.6123$ ). On the other hand, there was a strong linear correlation between feeding levels and the net fish yield (kg/m<sup>3</sup>/cycle) ( $r^2 = 0.9611$ , Figure 8).

**Discussion**

**Nutrient loads from floating cages**

Many studies have reported that aquaculture has a negative impact on the aquatic environment<sup>12,25–28</sup>, that is generally caused by waste loads of C, N and P from supplied feed, faeces and

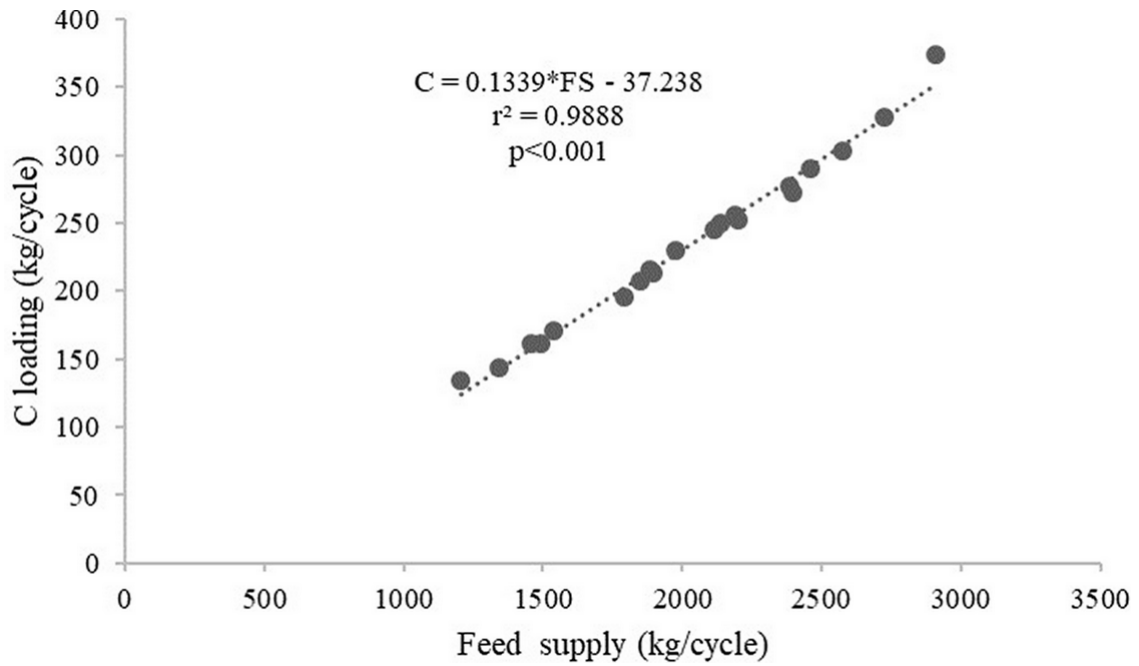


Figure 2. Feed supply and carbon loading relationship for giant gourami reared in floating cages.

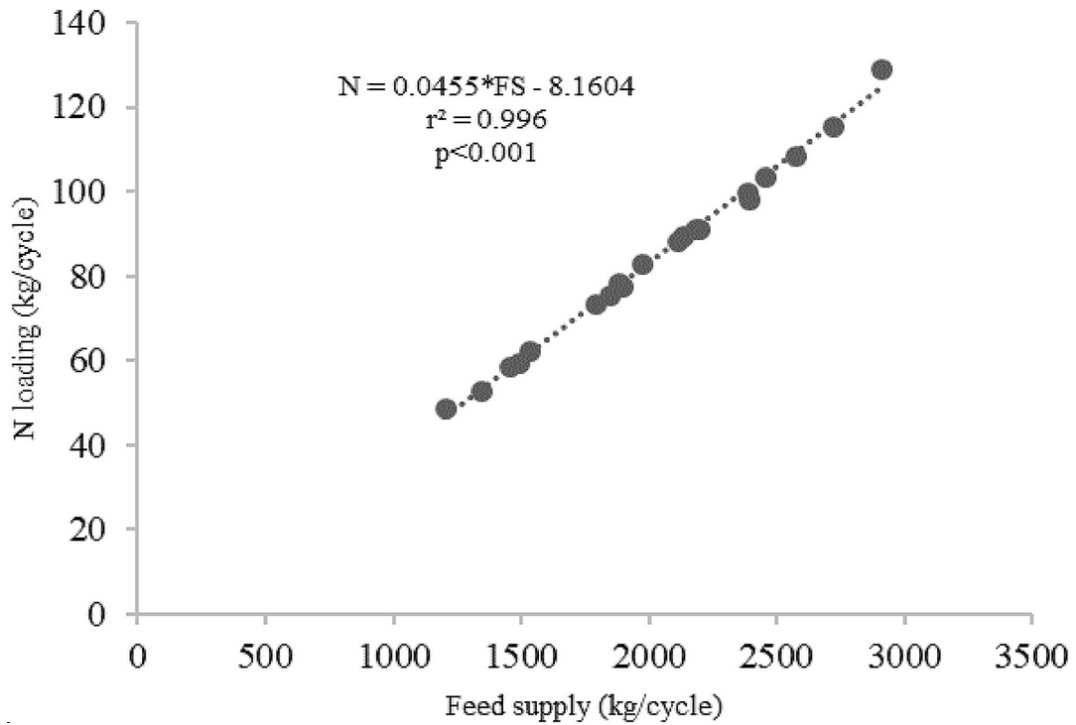
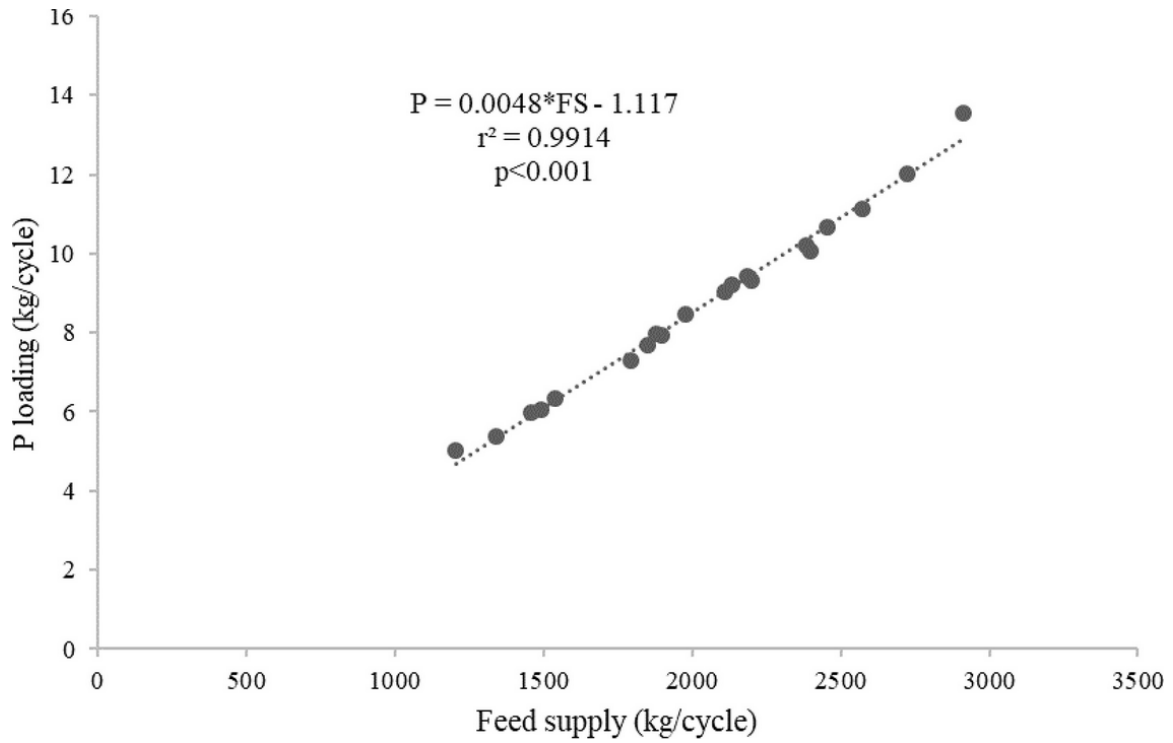
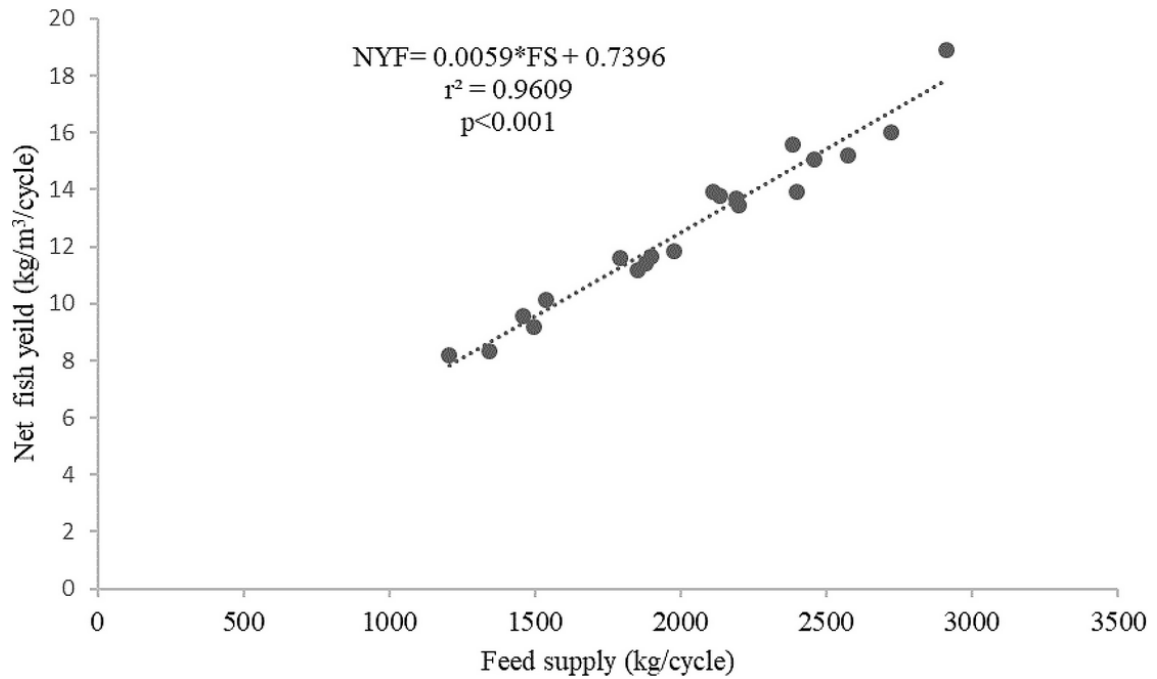


Figure 3. Feed supply and nitrogen loading relationship for giant gourami reared in floating cages.



**Figure 4.** Feed supply and phosphorus loading relationship for giant gourami reared in floating cages.



**Figure 5.** Feed supply and net fish yield (kg/m³/cycle) relationship for giant gourami reared in floating cages.

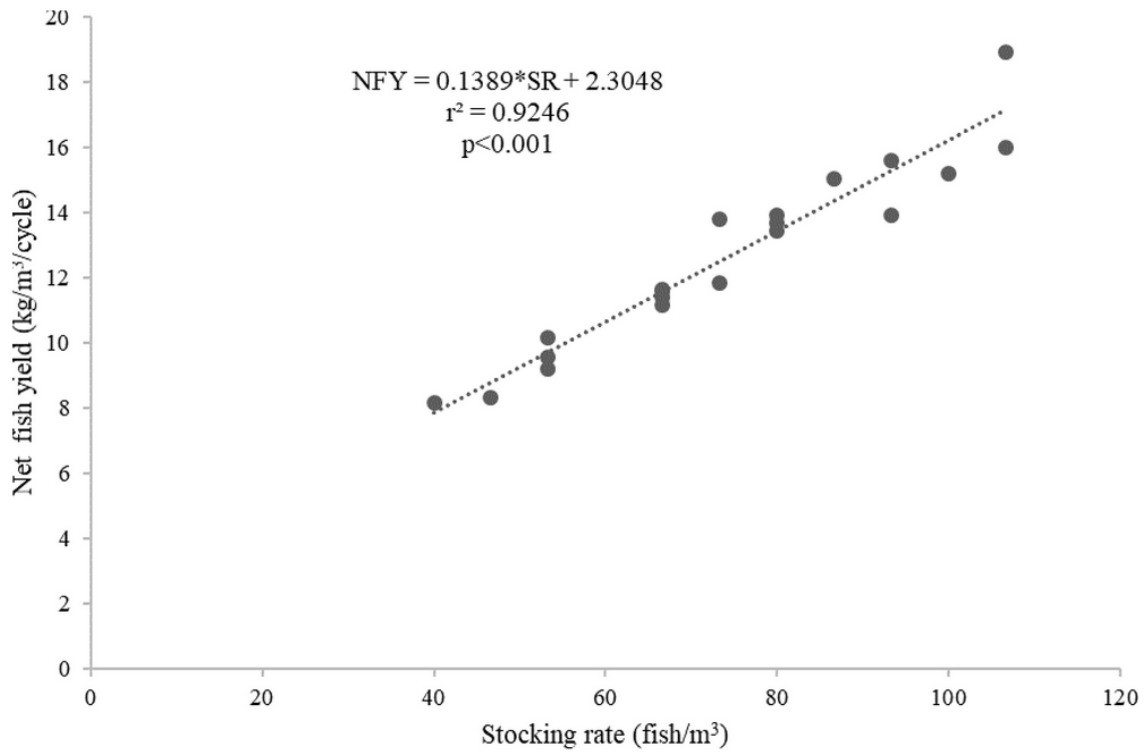


Figure 6. Stocking rates and net fish yield (kg/m<sup>3</sup>/cycle) relationship for giant gourami reared in floating cages.

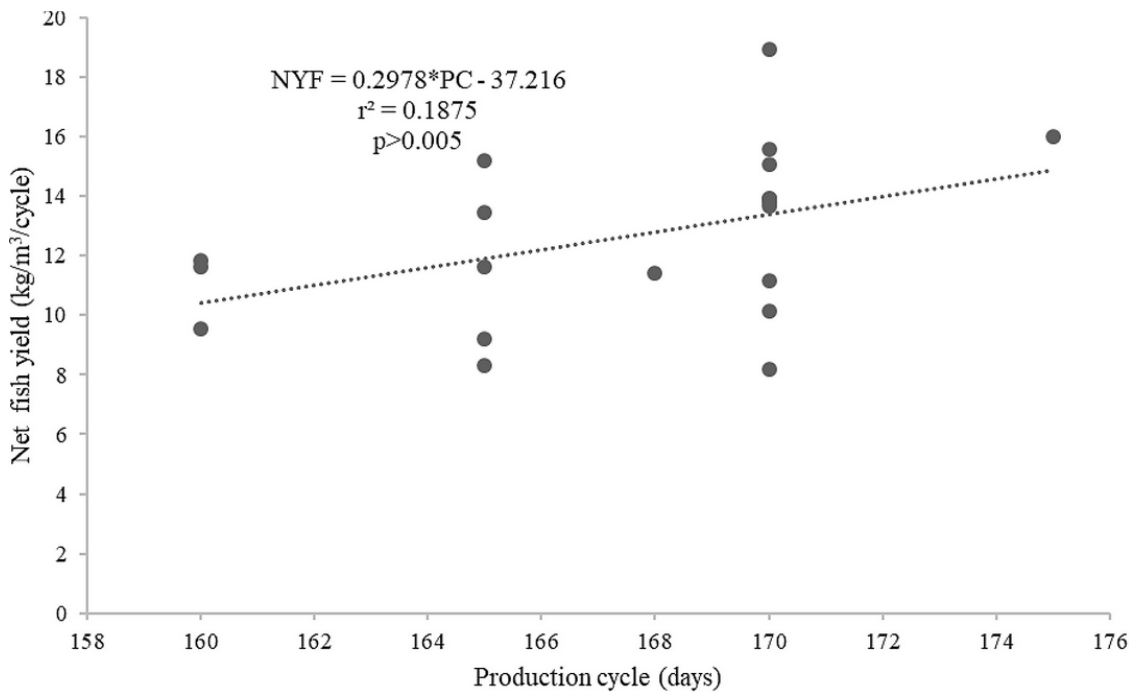
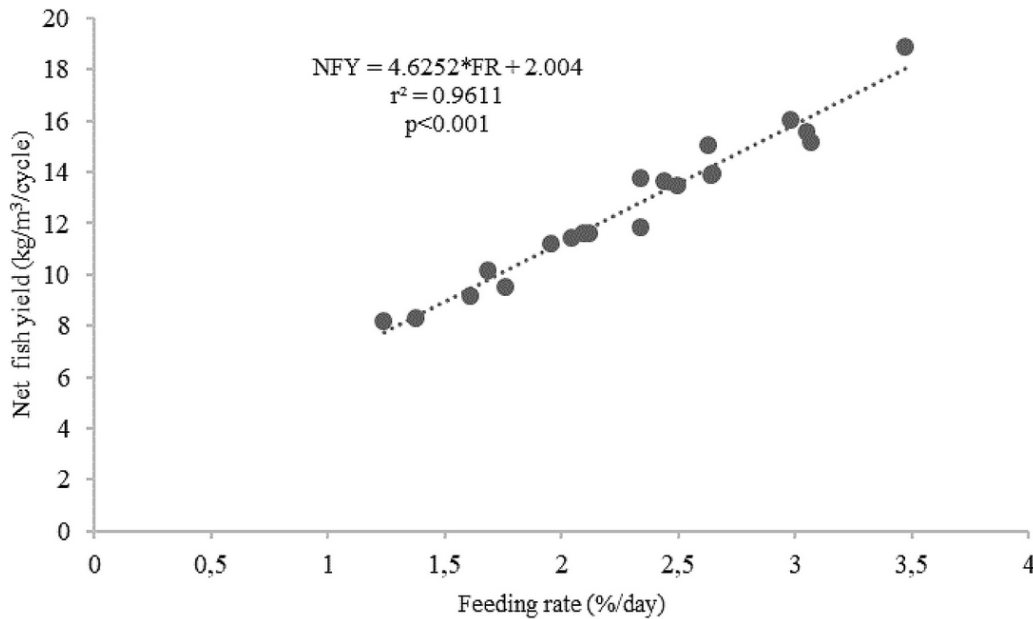


Figure 7. Production cycle and net fish yield (kg/m<sup>3</sup>/cycle) relationship for giant gourami reared in floating cages.





**Figure 8.** Feeding rates and net fish yield (kg/m<sup>3</sup>/cycle) relationship for giant gourami reared in floating cages.

dead fish<sup>29–31</sup>. In this study, the C, N and P loadings from the supplied feed were more predominant than those from the harvested fish, juvenile fish and dead fish because the content of C, N and P in the feed was higher than that in the harvested fish, juvenile fish and dead fish (Table 1). In addition, the average feed conversion ratio (FCR) of the cultured giant gourami cultured was 1.65, and the feed conversion efficiency (FCE) was 0.60 (1 kg of feed fish results in 0.60 kg of fish). This result suggests that the waste load was 0.40 kg (1 kg feed–0.60 kg of fish). These FCE values were lower than those of Nile tilapia and common carp cultured in floating cages in Lake Maninjau<sup>13</sup>. Increasing amounts of C, N and P released into waterbodies from intensive aquaculture activities can cause or accelerate eutrophication in natural water systems<sup>32–34</sup>. We recorded the value of water quality parameters near floating net cages, namely dissolved oxygen ranging from 5.42 and 5.59 mg/L, biochemical oxygen demand (BOD) ranged between 3.24 and 5.30 mg/L. Total phosphorous (TP) ranged from 490 to 540 µg/L; orthophosphate ranged from 500 to 900 µg/L, total nitrogen ranging from 710 and 1,050 µg/L. At the same time, conductivity was between 0.21 to 0.30 ms/cm, alkalinity went between 80.51 and 82.66 mg/L as CaCO<sub>3</sub>, hardness ranged between 61.64 and 64.59 mg/L as CaCO<sub>3</sub>, and pH ranges were between 7.62 and 7.69. Water quality (i.e., DO, BOD, TN, and TP) is higher in Lake Maninjau than in Lake Victoria<sup>11</sup>. The differences may be due to cages number, the depth of the lake, and the distance of cages from the shoreline. According to Aura *et al.*<sup>11</sup>, water quality is an element essential for developing cage culture towards “The Blue Economy” concept. Furthermore, in Lake Maninjau, no regulation regulates the location of floating net cages for aquaculture operation of giant gourami and Nile tilapia. However, most of them are within 300 m of the shoreline with a lake depth of 50 – 75 m and water transparency ranging between 1.6 and 2.1 m. Conversely, in Lake Victoria,

most cages were located within ≥ 200 m from the shoreline with a lake depth of less than < 10 m; some such regions (≤200 m) are breeding areas for natural fish populations and demarcated for fishing<sup>11</sup>. Nevertheless, accelerated eutrophication also depends on diet composition, feed characteristics, feed intake and feed quality<sup>13,35–37</sup>. On the other hand, accelerated eutrophication in freshwater is largely determined by phosphorus. Therefore, efforts to control eutrophication in waterbodies focus mostly on phosphorus reduction. In the present study, the P load from giant gourami was 4.29 kg/tonne of feed and lower than the P load from common carp (11.45 kg/tonne of feed) and Nile tilapia (9.11 kg/tonne of feed)<sup>13</sup>. Therefore, giant gourami fish farming can be considered for long-term development based on the aquaculture carrying capacity in Lake Maninjau and other regions.

Trophic food habits of fish might also affect the C, N and P was retained in the fish body because these habits are correlated with digestibility coefficients. Under natural conditions, giant gourami is an herbivorous fish<sup>38</sup>. In comparison to other fish, herbivorous fishes have more efficient digestion of feed because their extralong intestines contain special enzymes and microbes, such as cellulose enzymes and Bacteroides and Cetobacterium<sup>39,40</sup>. In the present study, the types of enzymes and microbial communities that were dominant in the giant gourami intestines are poorly understood. Regardless, herbivorous fish such as giant gourami release less N and P nutrients into waterbodies than omnivorous fish and carnivorous fish such as Nile tilapia, *Oreochromis niloticus*<sup>38</sup> and Crimson snapper, *Lutjanus erythropterus*<sup>41</sup>.

In the present study, in comparison with the harvested and juvenile fish, the dead fish released only a small amount of nutrients into the waterbodies during the production cycle.

Conversely, the availability of N and P in the waterbodies was significantly high after the extensive tilapia deaths due to upwelling (local namely: *tubo belerang*) and had a negative effect on the water quality of Lake Maninjau<sup>33</sup>. In contrast, giant gourami did not experience extensive fish death because this species has a labyrinth organ. Many scientists have reported that the release of significant amounts of C, N and P waste loads into waterbodies from feed and extensive fish deaths has a negative environmental impact<sup>14,42–45</sup>. In fact, feed supply and C, N and P loadings had a strong relationship with giant gourami cultured in floating cages, except in terms of fish mortality.

### General characteristics of farms

The 20,608 units of floating cages used for rearing Nile tilapia and common carp have exceeded the estimated aquaculture carrying capacity in Lake Maninjau over the past several years<sup>33</sup>. This factor has had a negative impact on the water quality of Lake Maninjau, and the net yields of Nile tilapia and common carp were 14.42 and 14.11 kg/m<sup>3</sup>/cycle, respectively<sup>13,46</sup>. In contrast, poor water quality does not have a negative impact on the growth and mortality of giant gourami because this species is resistant to poor water quality. Hence, the survival of giant gourami in floating cages ranged from 86.33 to 95.27%/cycle, and the net fish yield was as high as 18.92 kg/m<sup>3</sup>/cycle. In addition, the survival of giant gourami also depended on feeding level during the rearing period. Our analysis of the feeding level of giant gourami by fish farmers varied between 1.24 and 3.47%/body weight/day, and the majority of the fish farmers (80%) provided pellet feed at less than 3%/body weight/day. For giant gourami, a feeding level of 4–6%/body weight/day has been recommended<sup>47</sup>. Similarly, Skov *et al.*<sup>48</sup> concluded that biomass weight gain and the specific growth rate of Nile tilapia depend on feeding rate and the feed conversion ratio. In this study, the feeding rate and feed conversion ratio had a strong linear correlation with the net fish yield. Therefore, feeding levels played a significant role in increasing the net giant gourami yield. Many studies have reported that a lower feeding level might result in slow growth and inefficient aquaculture, whereas overfeeding may lead to feed waste, inefficiency and negative environmental impacts<sup>37,49–51</sup>.

On the other hand, the length of the production cycle did not have a strong linear correlation with the net giant gourami yield (kg/m<sup>3</sup>/cycle). In contrast, the stocking rate had a strong correlation with the net fish yield. In this study, the stocking rate ranged from 40 to 107 fish/m<sup>3</sup>, and the majority (70%) ranged between 40 and 80 fish/m<sup>3</sup>. Therefore, we recommended achieving a market size of 300 g/fish and a net fish yield (18.92 kg/m<sup>3</sup>/cycle) using a stocking density of 107 fish/m<sup>3</sup> for 170 days of culture. Conversely, if the equation by Schmittou<sup>23</sup> was applied to meet the target mean weight of 300 g/fish and net fish yield at harvest of 30.93 kg/m<sup>3</sup>/cycle, then we recommend using a stocking density of 106 fish/m<sup>3</sup>, with a length production cycle of 170 days. Therefore, to increase production performance of giant gourami in floating cages the management strategy must be to control the optimal seed stock, fish health, feed quality,

feeding level, feeding time and husbandry factors. Based on current scientific knowledge, scientists strongly advocate a combination of optimal stocking density, feeding practices, rearing techniques and eco-dam system to increase fish production performance and reduce the aquaculture waste released into waterbodies<sup>41,52,53</sup>.

### Conclusion

This research analysed the carbon, nitrogen and phosphorus loadings and the farm characteristics of giant gourami reared in floating cages in Lake Maninjau. There was a strong linear relationship between feed supply and nutrient loading for the reared giant gourami. Nutrient loading from feed supply was greater than that from juvenile fish, dead fish and harvested fish. Keys to increasing the net fish yield were stocking density and feeding level. The maximum target for the net fish yield and market size was achieved for 160 days. Therefore, giant gourami cultivation is an important practice to consider continuing in Lake Maninjau in accordance with the aquaculture carrying capacity because the phosphorus released into the waterbodies was very low, and this species also has a high survival rate in floating cages, thereby increasing production volumes and bringing more significant financial benefits.

### Data availability

#### Underlying data

Fig share: Underlying data for 'Nutrient loading and farm characteristics of giant gourami fish aquaculture systems in Lake Maninjau, Indonesia: basic knowledge of production performance'. <https://doi.org/10.6084/m9.figshare.14369999>

The project contains the following underlying data:

Table 1. Carbon (C), nitrogen (N) and phosphorus (P) composition (%) of the dry weight of the feed, harvested fish and faeces

Table 2. Raw data carbon loss from 20 floating cages

Table 3. Raw data nitrogen loss from 20 floating cages

Table 4. Raw data phosphorus loss from 20 floating cages

Table 5. Raw data production performance of giant gourami fish from floating cages in Lake Maninjau

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/) (CC-BY 4.0).

### Acknowledgements

The authors thank for Rionald Silaban the Director of Indonesian Education Fund Management Institution, Ministry of Finance Republic of Indonesia, for supporting this study through the competitive grant for productive and innovative research (policy/governance) 2019. We appreciate all of the students (Puji Kurniawan and Muhammad Vajri Djauhari), fish farmers (Satria Aferi and Nazarudin) and partners (Ermanto) who helped the authors during data collection in the field.

## References

- Mohanty BP, Mahanty A, Ganguly S, et al.: **Nutritional composition of food fishes and their importance in providing food and nutritional security.** *Food Chem.* 2019; **293**: 561–570.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Hasselberg AE, Aakre I, Scholtens J, et al.: **Fish for food and nutrition security in Ghana: Challenges and opportunities.** *Glob Food Secur.* 2020; **26**: 100380.  
[Publisher Full Text](#)
- Chan CY, Tran N, Pethiyagoda S, et al.: **Prospect and challenges of fish for food security in Africa.** *Glob Food Secur.* 2019; **20**: 17–25.  
[Publisher Full Text](#)
- Ma NL, Peng W, Soon CF, et al.: **Covid-19 Pandemic in the lens of food safety and security.** *Environ Res.* 2020; **193**: 110405.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Pauly D, Zeller D: **Comments on FAOs State of World Fisheries and Aquaculture (SOFIA 2016).** *Mar Pol.* 2017; **77**: 176–181.  
[Publisher Full Text](#)
- Henriksson PJG, Tran N, Mohan CV, et al.: **Indonesian aquaculture futures- Evaluating environmental and socioeconomic potentials and limitations.** *J Clear Prod.* 2017; **162**: 1482–1490.  
[Publisher Full Text](#)
- Pouil R, Samsudin R, Slembrouck J, et al.: **Nutrient budgets in a small-scale freshwater fish pond system in Indonesia.** *Aquaculture.* 2019; **54**: 267–274.  
[Publisher Full Text](#)
- Pedrosa RU, de Mattos BO, Costa SDP, et al.: **Effect of feeding strategies on growth, biochemical parameters waste excretion of juvenile arapaima (*Arapaima gigas*) raised in recirculating aquaculture systems.** *Aquaculture.* 2018; **500**: 562–568.  
[Publisher Full Text](#)
- Hasimuna OJ, Maulu S, Monde C, et al.: **Cage aquaculture production in Zambia: Assessment of opportunities and challenges on lake Kariba Siavonga district.** *Egypt J Aqua Res.* 2019; **45**(3): 281–285.  
[Publisher Full Text](#)
- Berg H, Michélsen P, Troell M, et al.: **Managing aquaculture for sustainability in tropical lake Kariba, Zimbabwe.** *Ecol Econ.* 1996; **18**(2): 141–149.  
[Publisher Full Text](#)
- Aura CM, Musa S, Yongo E, et al.: **Integration of mapping and socio-economic status of cage culture: Toward balancing lake-use and culture fisheries in Lake Victoria Kenya.** *Aqua Res.* 2017; **49**(1): 532–545.  
[Publisher Full Text](#)
- Gondwe MJS, Guildford SJ, Hecky RE, et al.: **Carbon, nitrogen and phosphorus loadings from tilapia cages in Lake Malawi and factors influencing their magnitude.** *J Great Lakes Res.* 2011; **37**(Supplement 1): 93–101.  
[Publisher Full Text](#)
- Syandri H, Azrita MA: **Nitrogen and phosphorus waste production from different fish species cultured in the floating net cages in Lake Maninjau Indonesia.** *Asian J Sci Res.* 2018; **11**(2): 287–294.  
[Publisher Full Text](#)
- Brigolin D, Pranovi F, Kholeif S, et al.: **Interaction cage of aquaculture in Nile Delta Lakes: Insights from field data and models.** *Reg Stud Mar Sci.* 2016; **7**: 129–135.  
[Publisher Full Text](#)
- Musinguzi L, Lugya C, Rwezewula P, et al.: **The extent of cage aquaculture, adherence to best practices and reflections for sustainable aquaculture on African inland water.** *J Great Lakes Res.* 2019; **45**(6): 1340–1347.  
[Publisher Full Text](#)
- Slembrouck J, Arifin OZ, Pouil S, et al.: **Gender identification in farmed giant gourami (*Osphronemus goramy*): A methodology for better broodstock management.** *Aquaculture.* 2019; **498**: 388–395.  
[Publisher Full Text](#)
- Azrita A, Aryani N, Mardiah A, et al.: **Growth, production and feed conversion performance of the gurami sago (*Osphronemus goramy* Lecepede, 1801) strain in different aquaculture systems.** *F1000Res.* 2021; **9**: 161.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Jia Y, Dan J, Zhang M, et al.: **Growth characteristics of algae during early stages of phytoplankton bloom in Lake Taihu China.** *J Env Sci (China).* 2013; **25**(2): 254–261.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Opiyo MA, Marijani E, Muendo P, et al.: **A review of aquaculture production and health management practices of farmed fish in Kenya.** *Int J Vet Sci Med.* 2018; **6**(2): 141–148.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Syandri H, Azrita N: **Tropic status and load capacity of water pollution waste fish culture with floating net cages in Lake Maninjau.** *Eco Env & Cons.* 2016; **22**(1): 469–476.  
[Reference Source](#)
- Antal E, Tillé Y: **Simple random sampling with over replacement.** *J Stat Plan Inference.* 2011; **141**(1): 597–601.  
[Publisher Full Text](#)
- AOAC: **Official Methods of Analysis.** 15th Edn. Association of Official Analytical Chemists (AOAC); Washington, DC., USA; 1990.  
[Reference Source](#)
- Schmittou HR: **Cage culture.** In: Lim C, Webster CD (Eds.) *Tilapia: Biology Culture and Nutrition.* Binghamton New York: Haworth Press; 2006; 313–342.  
[Reference Source](#)
- Zar HR: **Biostatistical analysis.** Prentice Hall, New Jersey. 1984; 817.  
[Reference Source](#)
- Avadi A, Pelletir N, Aubin J, et al.: **Comparative environmental performance of artisanal and commercial feed uses in Peruvian freshwater aquaculture.** *Aquaculture.* 2015; **435**: 52–66.  
[Publisher Full Text](#)
- David GS, Carvalho ED, Lemos D, et al.: **Ecological carrying capacity for intensive tilapia (*Oreochromis niloticus*) cage aquaculture in a large hydroelectrical reservoir in Southeastern Brazil.** *Aquac Eng.* 2015; **66**: 30–40.  
[Publisher Full Text](#)
- Farmaki EG, Thomaidis NS, Pasiadis IN, et al.: **Environmental impact of intensive aquaculture: Investigation on the accumulation of metals and nutrients marine sediment of Greece.** *Sci Total Environ.* 2014; **485-486**: 554–562.  
[Publisher Full Text](#)
- Dauda AB, Ajadi A, Tola-Fabunmi AS, et al.: **Waste production in aquaculture: Sources, components and management in different culture systems.** *Aquac Fish.* 2019; **4**(3): 81–88.  
[Publisher Full Text](#)
- Horppila J: **Sediment nutrients, ecological status and restoration of lakes.** *Water Res.* 2019; **160**: 206–208.  
[Publisher Full Text](#)
- Du HZ, Chen Z, Mao G, et al.: **Evaluation of eutrophication in freshwater lakes: A new non equilibrium statistical approach.** *Ecol Indic.* 2019; **102**: 866–692.  
[Publisher Full Text](#)
- Dupas R, Delmas M, Dorioz JM, et al.: **Assessing the impact of agricultural pressures on N and P loads and eutrophication risk.** *Ecol Indic.* 2015; **48**: 396–407.  
[Publisher Full Text](#)
- Yu C, Li Z, Xu Z, et al.: **Lake recovery from eutrophication: Quantitative response of trophic states to anthropogenic influences.** *Ecol Eng.* 2020; **143**: 105697.  
[Publisher Full Text](#)
- Syandri H, Azrita, Junaidi, et al.: **Levels of available nitrogen-phosphorus before and after fish mass mortality in Maninjau lake of Indonesia.** *J Fish Aquatic Sci.* 2017; **12**(4): 191–196.  
[Publisher Full Text](#)
- Silvenius F, Grönroos J, Kankainen M, et al.: **Impact of feed raw material to climate and eutrophication impacts of Finnish Rainbow trout farming and comparisons on climate impact and eutrophication between farmed and wild fish.** *J Clean Prod.* 2017; **164**: 1467–1473.  
[Publisher Full Text](#)
- Larico AJM, Dávila VOR, Tapia ÁMS, et al.: **Bioenergetic and water quality modeling for eutrophication assessment of El Pañe Reservoir, Peru.** *Ecohydrol & Hydrobiol.* 2021; **21**(1): 114–128.  
[Publisher Full Text](#)
- Hlordzi V, Kuebotornye FKA, Afriyie G, et al.: **The use of *Bacillus* species in maintenance of water quality in aquaculture.** *Aqua Rep.* 2020; **18**: 100503.  
[Publisher Full Text](#)
- Sun M, Hassan SG, Li D: **Models for estimating feed intake in aquaculture: A review.** *Comput Electron Agri.* 2016; **127**: 425–438.  
[Publisher Full Text](#)
- Caruso D, Arifin ZO, Subagja J, et al.: **Osphronemus goramy. Cultured Aquatic Species Information Programmed.** In: *FAO Fisheries and Aquaculture Department Rome.* 2019.  
[Reference Source](#)
- Gominho-Rosa MC, Rodrigues APO, Mattioni B, et al.: **Comparison between the omnivorous jundiá catfish (*Rhamdia quelen*) and Nile tilapia (*Oreochromis niloticus*) on the utilization of dietary starch sources: Digestibility, enzyme activity and starch microstructure.** *Aquaculture.* 2015; **435**: 92–99.  
[Publisher Full Text](#)
- Yang G, Jian SQ, Cao H, et al.: **Changes in microbiota along the intestine of grass carp (*Ctenopharyngodon idella*): Community, interspecific interactions, and functions.** *Aquaculture.* 2019; **498**: 151–161.  
[Publisher Full Text](#)
- Qi Z, Shi R, Yu Z, et al.: **Nutrient release from fish cage aquaculture and mitigation strategies in Daya Bay, Southern China.** *Mar Pollut Bull.* 2019; **146**: 399–407.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Chatvijitkul S, Boyd CE, Davis DA, et al.: **Pollution potential indicators for feed-based fish and shrimp culture.** *Aquaculture.* 2017; **477**: 43–49.  
[Publisher Full Text](#)

43. Horppila J, Holmroos H, Niemistö J, *et al.*: **Variations of internal phosphorus loading and water quality in a hypertrophic lake during 40 years of different management efforts.** *Ecol Eng.* 2017; **103**(A): 264–274.  
[Publisher Full Text](#)
44. Glibert PM, Landsberg JH, Evans JJ, *et al.*: **A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: the roles of bacterial disease, harmful algae, and eutrophication.** *Harmful Algae.* 2002; **1**(2): 215–231.  
[Publisher Full Text](#)
45. Azanza RV, Fukuyo Y, Yap LG, *et al.*: **Prorocentrum minimum bloom and its possible link to a massive fish kill in Bolinao, Pangasinan, Northern Philippines.** *Harmful Algae.* 2005; **4**(3): 519–524.  
[Publisher Full Text](#)
46. Syandri H, Azrita A, Mardiah A: **Water quality status and pollution waste load from floating net cages at Maninjau Lake, West Sumatera Indonesia.** *IOP Conf Series: Earth and Environmental Science.* 2020; **430**: 012031.  
[Publisher Full Text](#)
47. Aryani N, Azrita, Mardiah A, *et al.*: **Influence of feeding rate on the growth, feed efficiency and carcass composition of the giant gourami (Osphronemus goramy).** *Pak J Zool.* 2017; **49**(5): 1775–1781.  
[Publisher Full Text](#)
48. Skov PV, Duodu CP, Adjei-Boateng D: **The influence of ration size on energetics and nitrogen retention in tilapia (Oreochromis niloticus).** *Aquaculture.* 2017; **473**: 121–127.  
[Publisher Full Text](#)
49. Rahman MT, Nielsen R, Khan MA, *et al.*: **Efficiency and production environmental heterogeneity in aquaculture: A Meta-frontier DEA approach.** *Aquaculture.* 2019; **509**: 140–148.  
[Publisher Full Text](#)
50. Ul Hassan H, Ali QM, Ahmad N, *et al.*: **Assessment of growth characteristics, the survival rate and body composition of Asian sea bass Lates calcarifer (Bloch, 1790) under different feeding rates in closed aquaculture system.** *Saudi J Biol Sci.* 2021; **28**(2): 1324–1330.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
51. Luna M, Llorente I, Cobo Á: **Integration of environmental sustainability and product quality criteria in the decision-making process for feeding strategies in seabream aquaculture companies.** *J Clean Prod.* 2019; **217**: 691–701.  
[Publisher Full Text](#)
52. Mungkung R, Aubin J, Prihadi TH, *et al.*: **Life Cycle Assessment for environmentally sustainable aquaculture management: a case study of combined aquaculture systems for carp and tilapia.** *J Clean Prod.* 2013; **57**: 249–256.  
[Publisher Full Text](#)
53. Ni Z, Wu X, Li L, *et al.*: **Pollution control and in situ bioremediation for lake aquaculture using an ecological dam.** *J Clean Prod.* 2018; **172**: 2256–2265.  
[Publisher Full Text](#)

# Open Peer Review

Current Peer Review Status:  

---

## Version 2

Reviewer Report 27 September 2021

<https://doi.org/10.5256/f1000research.77752.r95097>

© 2021 Hasan Z. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Zahidah Hasan** 

Department of Fisheries. Faculty of Fisheries and Marine Science, Padjadjaran University, Jatinangor, Indonesia

The authors have revised article as suggestion. I have no further comments, this article eligible to be indexed.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** I am aquaculturist majoring in water quality

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

Reviewer Report 22 September 2021

<https://doi.org/10.5256/f1000research.77752.r95096>

© 2021 Aura C. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Christopher Mulanda Aura** 

Department of Freshwater Department, Kenya Marine and Fisheries Research Institute, Kisumu, Kenya

The authors have incorporated my suggestions fully and I believe the paper is ready for indexing. This is a good paper for future guidance on cage culture.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Aquatic sciences

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

---

Version 1

Reviewer Report 14 September 2021

<https://doi.org/10.5256/f1000research.55914.r92790>

© 2021 Aura C. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Christopher Mulanda Aura** 

<sup>1</sup> Department of Freshwater Department, Kenya Marine and Fisheries Research Institute, Kisumu, Kenya

<sup>2</sup> Department of Freshwater Department, Kenya Marine and Fisheries Research Institute, Kisumu, Kenya

I have read through the paper and it is well written and at the same time, it will add value to cage culture knowledge on Ecosystem Approach to Aquaculture.

Although the article is well written, there is a need to provide some data on selected physio-chemical parameters such as Oxygen, Conductivity, depth etc. that may have a role in the discussion of the results (i.e. are factors affecting nutrient loading and farm characteristics covered in terms of data to help in the discussion).

Furthermore, it would be important if the methodology adopts a comparing scenario to offer justifiable results.

If the above major comments are incorporated, the paper will be in good shape.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

Partly

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Aquatic sciences

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Reviewer Report 23 July 2021

<https://doi.org/10.5256/f1000research.55914.r88018>

© 2021 Hasan Z. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Zahidah Hasan** 

<sup>1</sup> Department of Fisheries. Faculty of Fisheries and Marine Science, Padjadjaran University, Jatinangor, Indonesia

<sup>2</sup> Department of Fisheries. Faculty of Fisheries and Marine Science, Padjadjaran University, Jatinangor, Indonesia

This article is clearly written. The literature cited are mostly up to date. The methods are mostly clearly written except for those related to the collection of dead fish and waste material.

Waste material collection needs to be explained further. How long is the trap installed; is the trap removed periodically or left throughout the cultivation period? Is there also faeces in the waste material component?

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** I am aquaculturist majoring in water quality

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

---

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact [research@f1000.com](mailto:research@f1000.com)

**F1000Research**