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Research Article

Effect of Feed Types and Estimation of Nitrogen-Phosphorus Loading Caused by Common Carp (*Cyprinus carpio*) in Lake Maninjau, Indonesia

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Abstract

Background and Objective: In Indonesia, Lake Maninjau is one of the most important locations for fish aquaculture operations that use floating net cages. The objective of this research was to determine the effect of different feed type on Growth, Feed Conversion Efficiency (FCE), Nitrogen (N) and Phosphorus (P) load caused by *Cyprinus carpio*. **Methodology:** *Cyprinus carpio* L. fingerlings (initial weight 56.79±1.77 g) were collected from a private hatchery in Rao Pasaman Regency. The study was conducted at two locations in Lake Maninjau (i.e. Farm I and Farm II). The farms consisted of three floating net cage units with floating and drowned feed. Each floating net cage had a capacity of 32 m^3 (4×4×2 m) and individual stocking density of 60 m^{-3}. Approximately 1,500 kg of feed was used in each floating net cage during the experiment. The differences in growth, N and P loads from the different feed types (floating and drowned feed) were analyzed using one-way ANOVA. **Results:** The different feed types had significant ($p<0.05$) effects on the weight gain, FCE, N and P load of *Cyprinus carpio*. The N load of floating and drowned feed from Farm I and II were 42.95±5.49, 39.31±0.64 and 51.69±12.61 kg, 39.17±0.60 kg t^{-1} of fish production, respectively. While, the P load of floating and drowned feed from Farm I and II were 18.85±1.63, 19.07±0.20 and 18.52±2.21 kg, 17.44±2.76 kg t^{-1} of fish production, respectively. **Conclusion:** Drowned feed is preferred for aquaculture activity in floating net cages in Lake Maninjau because it minimizes the eutrophication process, while also maintain sustainable aquaculture activity.

Key words: Aquaculture, floating net-cages, feed types, mass balance, environmental factors

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The total organic matter and other nutrients released from aquaculture systems and aquaculture operations are categorized as waste loads[1,2]. The waste load causes the water quality within the culture system to deteriorate[3,4]. Furthermore, the excessive level of nutrients being loaded into water bodies can be harmful to the environment because they can stimulate the growth of phytoplankton, macro algae and vascular plants[5-6]. Meanwhile, the impacts associated with wastes near fish cages include eutrophication, toxic algal blooms, increased turbidity, decreased oxygen conditions and loss of biodiversity[7-9].

The waste load from aquaculture operations can be traced back to fish feed[10-11]. Boyd and Tucker[12] found that the waste load sourced from fish feed was 10 to 20% and was found in the form of feces and organic wastes. Furthermore, this waste load was excreted into the culture system as nitrogen (N) and phosphorus (P). The N and P load entering a water body depends on the diet composition[13], pelleted and extruded feed[14], feed quality, overstocking and stocking of premature fish[15], fish species[16], chewing feeding behavior[2], feed conversion ratio[17] and water quality, which includes variables such as nitrite and dissolved oxygen[18].

Floating net cage aquaculture was built in Lake Maninjau and this system pioneered commercial scale aquaculture in Indonesian lakes. However, the information related to the environmental impacts of aquaculture operations on Lake Maninjau are limited. Furthermore, other researchers state that cage aquaculture in Lake Wolsey in the North Channel of Lake Huron[19], Shallow Lake in the middle Yangtze River basin of China[20], Kesikköprü Dam Lake in Southeast Ankara[14] and in the South East Arm of Lake Malawi[15], where cage aquaculture has been practiced for a longer period, has been associated with numerous environmental impacts on host ecosystems.

Lake Maninjau is a tecto-volcanic zone spanning 99.5 km^2 with an average depth of 112 m. Additionally, Lake was located at an altitude of 461.50 m above sea level[21]. And being a tourist destination and hosting a hydroelectric power plant. Lake Maninjau has an important role as a host for floating net cage operations used to culture Common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) and as a fisheries capture area[3,21]. The total number of floating net cages has increased over time, there were 16 units in 1992, 2,856 units in 1997, 4,316 units in 2004 and 16,580 units in 2015[21-23].

Commercial feed types, such as floating and drowned feed, have been used for *C. carpio* aquaculture operations in Lake Maninjau recently. Intensive aquaculture operations can increase the loading of N and P into water bodies. As a result, a rigorous assessment of the potential impacts of cage wastes on the receiving ecosystem is required for cage aquaculture to be accepted socially, environmentally and economically. The aims of this study were to quantify the N and P loads released from the two types of feed (i.e. floating and drowned) used in the cultured *C. carpio* floating net cages in Lake Maninjau, Indonesia.

MATERIALS AND METHODS

Study area: The study was conducted in Lake Maninjau West-Sumatera Province, Indonesia. The lake has a geographical position of 00 12'26.63"-00 25'02.80" S and 100 07'43.74"-100 16'22.48" E. Based on the Schmidt-Ferguson climate classification, Lake Maninjau has climate type A and an annual rainfall of 3,490 mm[21].

The research was conducted between September 2017 and November 2017 (i.e., 90 days) at two randomly selected farms (farm I, was located in the Koto Malintang area and farm II was located in the Sungai Batang area). During the experiment, *C. carpio* were fed two types of commercial feed (pelleted) floating feed and drowned feed. The stocking density was 60 fish m^{-3}. For each farm, the floating net cage had a capacity of approximately $4\times4\times2$ m (32 m^3) and was constructed using a 10 mm mesh size.

Cyprinus carpio fingerlings had a mean initial weight of 56.79$\pm$1.77 g and were collected from a private hatchery in Rao Pasaman Regency. Each floating net cage received 1,920 individual fish that were placed into two farms (one with floating feed and one with drowned feed). The experiment was conducted with three replicates for each farm. During the experiment, 1,500 kg of floating and drowned feed was used. The floating feed and drowned feed contained 29 and 27% of crude protein, 5 and 4% of crude fat, 6 and 8% of crude ash, 12 and 13% of crude fiber, then 12 and 12% of moisture content, respectively. The fish were fed daily at a rate of 4% of their biomass at 9:00, 14:00 and 18:00. Dead fish were removed and their bodies were weighed daily. The amount of feed provided was adjusted based on the temporal changes in biomass and the growth of fish in the floating net cages.

Parameter measurements: To determine the growth performance of fish, the following parameters were calculated:

final mean weight, weight gain (WG %), feed conversion ratio (FCR), feed conversion efficiency (FCE %) and survival rate (SR %). The parameters were analyzed according to Aryani *et al.*[24], Sun *et al.*[18], Desai and Singh[25] and Chatvijitkul *et al.*[26] with the following Eq.:

$$\text{WG (\%)} = \frac{\text{Final body weight (g) - Initial body weight (g)}}{\text{Initial body weight (g)}} \times 100$$

$$\text{FCR} = \frac{\text{Total feed fed (g)}}{\text{Total wet weight gain (g)}}$$

$$\text{FCE (\%)} = \frac{\text{Fish weight gain}}{\text{Total feed ingested (g)}} \times 100$$

$$\text{SR (\%)} = \frac{\text{Number of fish that survived}}{\text{Number of fish that were stocked}} \times 100$$

Water quality: Water transparency was measured using a Secchi disk. Surface water samples (depth 0.10 m) were collected in September and November, 2017 at each farm and determine of dissolved oxygen (DO) concentrations. An oxygen meter (YSI model 52, Yellow Spring Instrument Co., Yellow Springs, OH, USA) was used *in situ* and pH values were determined with a pH meter (Digital Mini-pH Meter, 0-14 PH, IQ Scientific, Chemo-science Thailand) Co., Ltd, Thailand). Water temperature was measured with a thermometer (Celsius scale). The values of ammonia, alkalinity, hardness and N and P levels of the water were measured in each replicate according to standard procedures[27]. The water quality parameters were measured once per month.

Analytical methods: The N concentrations (as % of dry weight) of feed and fish were determined using the standard methods of the Association of Official Analytical Chemists (AOAC)[28]. The P concentration was determined by a spectrophotometer (UV 160 A, Japan) using the molybdate-ascorbic acid method indicated by the Association of Official Analytical Chemists (AOAC)[28] at the Chemistry Laboratory of the University of Bung Hatta Padang, Indonesia. The results were expressed as absorbance at 400 mm. All samples were done in triplicates.

Estimation of N and P loads caused by each species in floating net cage cultures: The N and P loads from fish cultures ware estimated according to the method described by Ackefors and Enell[29]. The following parameters were analyzed according to the following Eq.:

$$\text{N load (kg of N)} = [(\text{Feed} \times \text{Feed}_N)\text{-}(\text{Fish} \times \text{Fish}_N)]$$

$$\text{P load (kg of P)} = [(\text{Feed} \times \text{Feed}_P)\text{-}(\text{Fish} \times \text{Fish}_P)]$$

Where:

Feed = Total feed used during the experiment
Fish = Wet weight of fish produced per harvest
Feed_N = N content of the feed
Feed_P = P content of the feed expressed as the percentage of dry weight
Fish_N = N content
Fish_P = P content of the fish expressed as the percentage of wet weight

$$\text{N and P loads from the production of 1 ton of fish} = (\text{Total feed used during the experiment} \times \text{FCR}) \times (\text{Feed}_{\text{N or P}})\text{-}(\text{1 ton fish} \times \text{Fish}_{\text{N or P}})$$

$$\text{N and P loads from 1 ton of feed consumption} = \frac{\text{1 ton feed} \times \text{N or P content of feed}}{\text{FCR}}$$

Statistical analysis: The mean values for the final weight, feed conversion ratio, mortality parameters of different treatments and monthly variations in water quality parameters were subjected to one-way ANOVA followed by Duncan's new multiple range test[30]. All statistical analyses were performed using SPSS software (version 16.0 for Windows; SPSS Inc., Chicago, IL). The standard deviation of each parameter and treatment was determined and expressed as the Mean±SD. The treatment effects were considered to be significant at $p<0.05$.

RESULTS

The results of certain growth parameters, FCR, FCE, mortality and chemical analyses from each feed type and fish are presented in Table 1. The different feed types had significant ($p<0.05$) effects on the final mean weights, WG (%), FCR and FCE (%). In this study, the water quality from each farm during September, October and November 2017 showed significant differences ($p<0.05$) in terms of water transparency, ammonia, alkalinity and total N and P (Table 2).

Table 3 summarizes the mass balance of N and P at the two farms, while Fig. 1 and 2 provide an estimation of the N and P loads from the production of 1 ton of fish and 1 ton of feed consumption, respectively.

Table 1: Growth parameters and chemical analyses of the two investigated farms

Floating net cages	Farm I		Farm II	
Type of feed	Floating	Drowned	Floating	Drowned
Parameter				
Initial mean weight (g)	56.79±1.77[a]	56.79±1.77[a]	56.79±1.77[a]	56.79±1.77[a]
Final mean weight (g)	182.45±2.00[a]	201.50±15.30[b]	184.25±3.00[a]	202.60±10.30[b]
WG (%)	221.40±6.49[a]	254.48±15.90[b]	224.54±4.83[a]	256.60±7.02[b]
FCR	1.51±0.10[a]	1.44±0.02[b]	1.49±0.15[a]	1.42±0.02[b]
FCE (%)	66.10±0.01[a]	69.20±0.02[b]	67.05±0.03[a]	70.15±0.02[b]
Mortality (%)	15.63±0.45[a]	15.92±0.36[a]	15.98±0.52[a]	15.30±0.30[a]
N content of fish (%)	4.18±0.05[a]	3.47±0.01[b]	4.20±0.09[a]	3.45±0.02[b]
P content of fish (%)	0.20±0.02[a]	0.18±0.02[a]	0.21±0.03[a]	0.20±0.02[a]
N content of feed (%)	6.26±0.29[a]	5.14±0.02[b]	6.26±0.29[a]	5.14±0.02[b]
P content of feed (%)	1.38±0.03[a]	1.45±0.02[b]	1.38±0.03[a]	1.45±0.02[b]

Means are listed within rows (Farm I and II) for each parameters, means with different superscript letters are significantly different (p<0.05)

Table 2: Monthly variations in water quality at the two different farms (±SD)

Parameter	Farm	September, 2017	October, 2017	November, 2017
Water transparency (cm)	I	185.33±2.51[a]	170.67±2.08[a]	174.00±2.00[a]
	II	208.00±2.00[b]	204.33±1.53[b]	199.00±1.00[b]
Water temperature (C)	I	28.50±0.50[a]	28.50±0.50[a]	27.00±1.00[a]
	II	27.33±0.57[a]	27.33±0.57[a]	28.00±1.00[a]
Dissolved oxygen (mg L^{-1})	I	6.70±0.03[a]	6.40±0.04[a]	6.21±0.08[a]
	II	7.10±0.28[a]	6.24±0.05[a]	6.18±0.05[a]
pH	I	7.69±0.07[a]	7.68±0.03[a]	7.86±0.07[a]
	II	7.62±0.07[a]	7.63±0.02[a]	7.58±0.07[a]
Ammonia (mg L^{-1})	I	0.26±0.01[a]	0.31±0.01[a]	0.23±0.01[a]
	II	0.16±0.02[b]	0.26±0.01[b]	0.15±0.01[b]
Alkalinity (mg L^{-1})	I	80.51±0.07[a]	76.00±1.00[a]	76.68±0.79[a]
	II	88.26±0.64[b]	78.50±0.50[b]	81.50±0.50[b]
Hardness (mg L^{-1})	I	61.64±0.55[a]	62.80±0.60[a]	63.83±0.76[a]
	II	66.00±1.00[a]	66.93±0.07[b]	76.16±1.25[b]
Total N (mg L^{-1})	I	0.94±0.04[a]	0.86±0.01[a]	0.73±0.02[a]
	II	1.32±0.02[b]	1.09±0.04[b]	1.16±0.01[b]
Total P (mg L^{-1})	I	0.21±0.01[a]	0.34±0.04[a]	0.42±0.02[a]
	II	0.26±0.01[b]	0.40±0.02[b]	0.60±0.15[b]

Means are listed within rows (farm I and II) for each parameters, means with different superscript letters are significantly different (p<0.05)

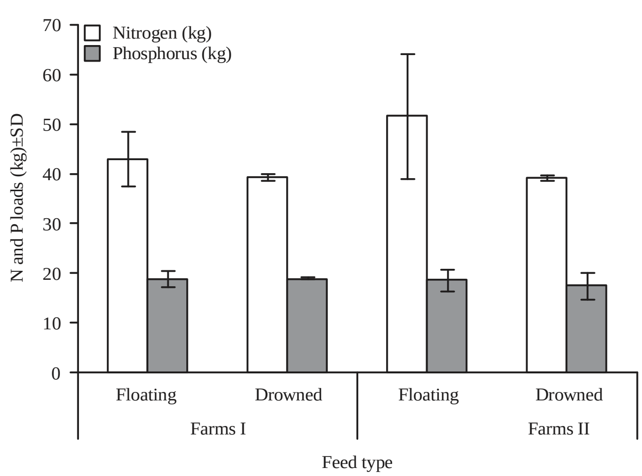

Fig. 1: N and P loads from the production of one ton of fish in Lake Maninjau

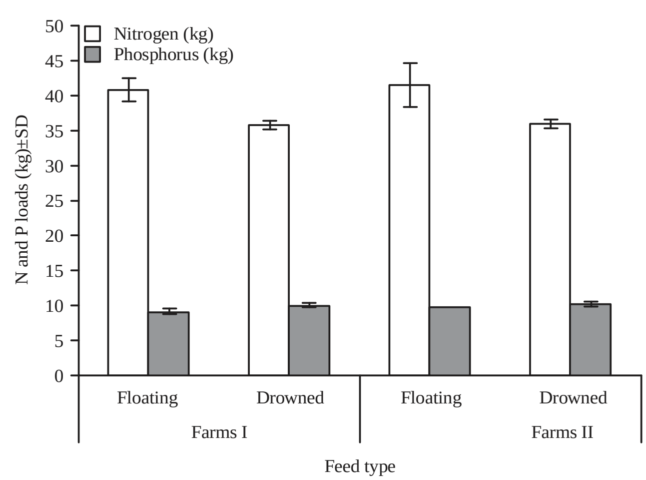

Fig. 2: N and P loads released into Lake Maninjau from one ton of feed consumption

Table 3: Mass balance of nitrogen (N) and phosphorus (P) for the two different types of feed

Farms	Type of feed	N from feed (kg)	N retained in fish (kg)	N load (kg)	P from feed (kg)	P retained in fish (kg)	P load (kg)	Retained in fish (%)		Load (%)	
								N	P	N	P
I	Floating	94.05±4.12	41.67±3.26	52.38±0.86	20.92±0.31	2.02±0.14	18.67±0.31	44.25±1.52	9.76±0.47	55.74±1.52	90.23±0.47
	Drowned	77.10±0.30	39.26±4.86	37.84±5.12	21.75±0.30	2.01±0.12	19.73±0.12	50.93±6.49	9.25±0.28	49.07±6.49	90.74±0.58
II	Floating	91.95±2.75	42.50±3.39	51.54±7.50	20.70±0.45	2.10±0.09	18.59±0.36	45.35±5.60	10.39±0.50	54.65±5.59	93.17±5.60
	Drowned	77.10±0.30	35.77±1.81	40.66±0.42	21.75±0.3	2.06±0.19	19.68±0.10	45.72±3.62	9.47±0.76	54.82±2.94	90.52±0.76

DISCUSSION

The growth of cultured fish is highly dependent upon the fish species, feeding rate, overstocking, stocking of premature fish and feed quality, including pelleted and extruded feed[14,15,24,26]. Our results indicated that *C. carpio* fed the drowned feed obtained higher growth rates than did fish fed the floating feed. The result may be related to the FCR value, because the FCR in the drowned feed is lower than floating feed (Table 1). The FCR is usually used to estimate the efficiency of converting feed into body mass. Although there were significantly differences ($p<0.05$) in the growth, FCR and FCE of *C. carpio* fed floating feed and drowned feed, however there were no significant differences ($p>0.05$) between the two farms.

In the present study, the FCE values for cultured *C. carpio* fed floating feed in farms I and II were 66.10±0.01 and 67.05±0.03%, respectively (1 kg feed fish resulted in 0.66 and 0.67 kg of fish x 100), while the FCE values for fish fed drowned feed were 69.20±0.02 and 70.15±0.02%, respectively. The different FCE values may have been caused by the proximate composition of the feed types and the feed intake of the *C. carpio*. On the other hand, Desai and Singh[25] stated that FCE values for *C. carpio* cultured in temperatures between 28 and 32°C with a feeding rate of 4% body weight per day were 44.36±0.80 and 40.98±1.75%, respectively. Meanwhile, for cultured tilapia, the FCE value is approximately 59%[26]. In contrast, the FCE of Nile tilapia cultured in Lake Malawi was about 37.54±6.48%[15].

In this study, there were no significant effects on water quality caused by the FCE of *C. carpio* in Lake Maninjau. Because, there were no differences between the two farms in terms of water temperature, dissolved oxygen (DO) and pH (Table 2). Other researchers stated that the FCE values can be affected by the DO level[18] and the water temperature[25,31]. Meanwhile, in aquaculture production system, the percentage of applied feed that is consumed by the cultured animals obviously depends on the feed quality, feeding practices, temperature, species, stocking density and appetite of the animals[32,26,33]. However, other factors may influence the feed intake of aquatic animals, such as physiological factors, nutritional factors, environmental factors and husbandry factors[18].

An inappropriate feed type may reduce the growth of fish and increased the quantity of feed waste released into the environment. Therefore, the consideration of feed type is necessary when managing the production of fish. According to Gondwe *et al.*[15], the feed quality, feed quantity and how it is provided to reared fish are important aspects that should be considered in fish farming because the harvest from cages is directly related to the quality and quantity of the supplied feed. In present study, the levels of N and P from the floating feed retained by *C. carpio* were 44.25±1.52% (Farm I) and 45.35±5.60% (Farm II), respectively and 9.76±0.47% (Farm I) and 10.39±0.50% (Farm II), respectively. These values were slightly higher than the levels measured for the drowned feed (Table 3). Nevertheless, the yielded data were lower than those reported by Asir and Pulatsu[14]. These different results may cause by the different fish species evaluated and different levels of N and P in the feed types. The observed N and P loads were also lower than those reported by Boyd and Queiroz[1]. Approximately 60-80% of N and P from feed was released from the aquaculture operation as waste[9,12].

Negative environmental impacts of cage aquaculture operations have been reported in many parts of the world[4,34-38]. In this study, the N loads from each farm was estimated to average 42.95±5.49 kg and 51.69±12.61 kg t^{-1} of fish production, respectively. In contrast, the loads from the drowned feed were 39.31±0.64 kg and 39.17±0.60 kg t^{-1} of fish production, respectively. Furthermore, the P loads from the floating feed were between 18.85±1.63 kg and 18.52±2.21 kg t^{-1} of fish production, respectively. While, the results from the drowned feed were between 19.07±0.20 kg and 17.44±2.76 t^{-1} of fish production, respectively (Fig. 1). In other studies, cultured rainbow trout fed pelleted and extruded feeds had N loads between 59.46 and 29.72 kg t^{-1} of fish production and the P loads were between 11.42 and 7.64 kg t^{-1} fish production[14]. The N loads arising from cultured *C. carpio* fed floating and drowned feed were found to be higher than those from *Oncorhynchus mykiss* fed pelleted and extruded feed. In comparison, rainbow trout farms had estimated higher N releases from 125-127 kg t^{-1} of fish production and P releases were from 24-25 kg t^{-1} of fish production in the eastern Mediterranean Sea[39]. Guo and Li[20] stated that the production of 1 ton of fish from the cage system produced 65 kg of N and 35 kg of P. Some authors also reported the similar results of N releases between 82 and 124 kg t^{-1} of fish production and P releases between 23 and 29 kg t^{-1} of fish production[40,41]. Conversely, Phillips *et al.*[42] reported that the P release was 56 kg t^{-1} of fish production.

In this study, the total N and P loads into the surrounding water body was different for each ton of feed type consumed by Nile tilapia (Fig. 2). The difference also caused by the FCR values and feed composition. The FCR values of floating feed were 1.49±0.15 and 1.51±0.10, respectively and the FCR values for drowned feed were 1.42±0.02 and 1.44±0.02, respectively (Table 1). The N and P levels in the feed used and the FCR values in the farms directly affected the N and P loads in the water body. The mean load of N released into Lake Maninjau from floating feed was 40.95±1.69 and 41.63±3.11kg t^{-1}, respectively and the mean load of N released from drowned feed was 35.88±0.65 and 36.03±0.62 kg t^{-1}, respectively. In contrast, the mean load of P released from floating feed was 9.15±0.41 and 9.67±0.03, respectively and the mean load of P released from drowned feed was 10.06±0.28 and 10.17±0.35 kg t^{-1}, respectively (Fig. 2). Furthermore, other researchers stated the releases of N and P per ton of feed consumed by rainbow trout into the Kesikköprü Dam Lake were 44.78 and 8.60 kg, respectively[14]. The feed composition and feed conversion of the aquaculture operations primarily had negative effects on the environment conditions. In addition, the integrated model of aquaculture, the size of fish, the feeds, the feeding rates, the feeding practices at each farm and the species of cultivated fish should also be considered as important factors affecting the aquaculture[2,24,43].

CONCLUSION

The current research found clear evidence supporting that different feed types used for *C. carpio* in floating net cages can release different amounts of total N and P into Lake Maninjau. *Cyprinus carpio* fed with drowned feed showing a better of growth rate and Feed Conversion Efficiency (FCE) compared than floating feed. The estimated N and P loads from the production of 1 ton of fish were significantly lower in drowned feed rather than floating feed. Additionally, the estimated load of N and P from 1 ton of feed consumption was significantly lower in drowned feed compared to floating feed. The loading of N and P can be reduced by adjusting the amount of drowned feed used, managing the feeding regimes and timing of fish aquaculture. These techniques will help reduce the negative effects on the lake and have a positive effect to water quality.

SIGNIFICANCE STATEMENT

This study discovers that drowned feed type is beneficial for aquaculture of *C. carpio*. The N and P loads of drowned feed were significantly lower than those of floating feed. This study will help the researcher to uncover that *C. carpio* fed with drowned feed have the higher growth rate, the better feed conversion ratio and feed conversion efficiency which previous research were not able to explore. Thus, the new experiments have advantage for aquaculture operation and able to reducing N and P load release to water bodies.

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