Journal of Aquaculture and Fish Health Vol. 14(2) - June 2025
P-ISSN: 2301-7309 / E-ISSN: 2528-0864
doi : 10.20473/jafh.v14i2.65654

Optimal Stocking Density of Catfish (*Clarias gariepinus*) Cultivated in Round Pond at a Small Scale

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Received : 2024-10-20
Accepted : 2025-02-04

Keywords :
Aquaculture, Productivity, Clarias sp., Density

Abstract

Increasing stocking density in catfish cultivation is one of efforts to increase production in order to fulfill the demand of catfish both nationally and internationally. The obstacles faced by the small scale cultivators when applying high stocking densities are poor water quality, high feed conversion, slow growth and high mortality. Many small scale novice cultivators are tempted by high production results by implementing very high stocking densities, however their comprehension of the cultivation techniques is still insufficient. This research aims to determine the optimal stocking density for cultivating catfish at a small scale using round tarpaulin ponds. The study used a completely randomized design of four treatments with three replications (250 fish/m^3, 500 fish/m^3, 750 fish/m^3 and 1000 fish/m^3). The cultivation container used is a tarpaulin pool with a diameter of 3 meters, and the fish were fed commercial feed with 28-33% protein. Production results were also analyzed using the business income analyst model. A stocking density of 500 fish/m^3 resulted the most optimal production values, namely absolute growth of 4.28 ± 0.02%/day, absolute length growth of 12.4 ± 0.9 cm, survival of 85.97 ± 0.56%, feed conversion of 0.95 ± 0.00, and production of 30.4 ± 0.57 kg/m^3 with operating income of Rp. 1,258,967,-. The results of the analysis of production and income values showed that treatment with a density of 500 fish/m^3 was the best stocking density for cultivating catfish on a household scale using tarpaulin ponds.

INTRODUCTION

Catfish is very familiar among people in Indonesia and abroad, both for consumption and cultivation. The main indicator of public acceptance of catfish can be seen from the level of demand and production of catfish which continues to

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increase, namely in 2015 it amounted to 722,623 tons (Sudaryati *et al.,* 2017). The demand for catfish is increasing over time, as can be seen from the increase in catfish production which is quite high but inadequate to fulfill the market demand. In order to increase catfish production, various technologies have been adopted by including super-intensive catfish stocking (Hastuti *et al.*, 2016), biofloc technology, and aquaponic systems (Diatin *et al.,* 2021).

Currently, the technology that is widely applied to Catfish cultivation is Biofloc technology. A technology that is considered capable of increasing catfish production with a fairly high stocking density of up to 2000 fish/m^2 and is environmentally friendly (Mokolensang and Manu, 2020). Biofloc technology is considered more effective in terms of accelerating maintenance time and feed efficiency (Arief *et al.,* 2014), and is more economically profitable (Sri *et al.*, 2022). However, in its application, biofloc technology produces different responses. It is not uncommon for cultivators to also experience cultivation failures such as high mortality rates due to poor water quality and fish disease attacks. Many failures in biofloc system catfish cultivation occur due to the lack of adoption of science and technology, especially by small scale farmers. The obstacles that are often faced are poor water quality characterized by foam and odor, flocs that are too dense, and problems with long-term power outages resulting in the oxygen supply stopping which results in fish death. Increasing optimal stocking density to increase production is still a hope for small scale fish farmers (Harahap *et al.,* 2023). Catfish reared with an aquaponic recirculation system with Azolla can grow optimally at a stocking density of 3000 - 4500 fish/m^3 (Mugo-Bundi *et al.,* 2024). Baßmann *et al.* (2023) also revealed that catfish can still grow optimally at a stocking density of 100 kg m$^{3-1}$.

However, it is different from the conventional stocking density of catfish. (Wiyoto *et al.,* 2023) revealed that the optimal stocking density of catfish is 250 fish/m^3. Many novice and small scale cultivators are tempted by the very high productivity of catfish by implementing a stocking density of 1000 - 2000 fish/m^3, without understanding in detail the technical readiness of the media and the capacity. So it is not uncommon to experience failure in fish cultivation, high mortality and slow fish growth. In order to overcome the failure of catfish cultivation, further research needs to be carried out on catfish stocking.

The research aims to determine the optimal stocking density for cultivating catfish in round tarpaulin ponds on a small scale. The results of this research can be a reference for farmers to determine the stocking density of the catfish cultivation business that will be carried out.

METHODOLOGY

Ethical Approval

All research procedures conducted in this study were in accordance with standards without damaging or polluting the environment and laboratory testing.

Place and Time

September to November 2023 at the Fisheries Cultivation Laboratory, Faculty of Science and Technology, Ibrahimy University, located in Sumberejo Village, Banyuputih District, Situbondo Regency, East Java.

Research Materials

The fish used in this study were African catfish juveniles with a length of 7-8 cm and an average weight of 2.7 ± 0.2 g. Selection was carried out by observing the size, uniformity, completeness of organs and the fish health condition. Fish were obtained from a CPIB-certified catfish hatchery (UPR. Raja Lele Situbondo, No. 1699.2905.A1.B0-Form CPIB19). The pond used in this study was a catfish rearing pond, namely a tarpaulin pond with a diameter of 3 m and a height of 1 m. Salt was used as a sterilization material. The feed used was commercial feed containing protein of 30-32%.

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Research Design

This study was conducted in a tarpaulin pond with a diameter of 3 meters and a height of 1.2 meters. This study was conducted using various types of fish distribution, namely: A) 250 fish/m^3, B) 500 fish/m^3, C) 750 fish/m^3, and D) 1000 fish/m^3. Each treatment was repeated 3 times.

Work Procedure

This research conducted tests on different fish stocking densities in small-scale tarpaulin ponds. The maintenance containers used in this research were round tarpaulin pools with a diameter of 3 m with a water height of 0.8 m in a total of 12 pools (Figure 1). Pool preparation was carried out by cleaning with soap and washing until clean. Sterilization was also carried out by adding 2 kg of salt to each pool, leaving it for 1 day, then replacing it with new water.

The test fish were reared on commercial floating pellet feed with a minimum protein content of 31%. Feeding was carried out 3 times a day with the following details: DOC (Day of culture) 1 - 20 (6% of biomass/day), DOC 21-DOC 35 (4% of biomass/day), and DOC 36-DOC 80 (3% of biomass/day). The feed given was supplemented with probiotics at a rate of 10 mL/kg (Rachmawati *et al.,* 2006) by mixing it into the feed, and allowing it to dry slightly (± 5 minutes). The probiotics used were commercial probiotics containing microbes (*Lactobacillus casei* and *Saccharomyces cerevisiae*).

Figure 1. Tarpaulin pond used for catfish farming.

Fish Observation

Monitoring of fish growth, fish death and water quality was carried out once a week. Observations of fish growth include specific growth rate, absolute length growth, survival, feed efficiency and daily production. The sample used in this study was 2% of the total fish in each pond.

Specific growth rate

Calculation of specific growth rate refers to Steffens (1989) with the formula:

$$SGR = \left(\frac{\ln W1 - \ln W0}{t1 - t0}\right) x\ 100\%$$

Information:

SGR : Specific growth rate (% body weight/day)
Wt : Average weight of fish at the end of the rearing period (g)
W0 : Average weight of fish at the start of rearing period (gr)
T1 : Maintenance End Time (days)
T0 : Maintenance Start Time (days)

Absolute length growth

Absolute length growth was calculated using the formula referring to Effendi (1979):

P = Pt – Po

Information:

P : Absolute length growth (cm)
Pt : Average length of fish at the end of rearing (cm)
Po : Average length of fish at the start of rearing (cm)

Survival rate

The survival rate was calculated using the formula referring to Zonneveld *et al.* (1991):

$$SR = \left(\frac{Nt}{N0}\right) x100\%$$

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Information:
SR : Survival rate (%)
Nt : Number of fish at the end of rearing (gr)
No : Number of fish at the start of stocking (gr)

Feed conversion ratio

Calculation of feed conversion ratio or FCR refers to Stickney (1981) with the formula:

$$FCR = \frac{\sum Feed}{\Delta\ Biomass}$$

Information:
FCR : Feed conversion ratio (%)
∑Feed : Total weight of fish at the end of rearing (gr)
Δ Biomass : Total weight of fish at the beginning of rearing (gr)

Daily production

Cultivation production per unit square meter was calculated referring to Deswati *et al.* (2023):

$$Production(\frac{kg}{m^2}) = \frac{Wt - Wo}{L}$$

Information:
Wt : Final biomass (kg)
W0 : Initial biomass (gr)
L : Pool area (7,065 m^2)
t : Long maintenance

Business Income Analysis

The income value was analyzed by calculating a simple income model with working capital and income variables. Working capital was calculated by adding up all costs, namely seed costs, feed costs, medicine and probiotic costs. Income was calculated using the formula (Subangkit *et al.,* 2021):

$$Income = (Amount\ of\ production\ x\ Selling\ price) - Total\ Working\ Capital$$

Water Quality

The water quality parameters observed during the maintenance period were DO, pH, nitrate, ammonia, and turbidity.

Data Analysis

This research was designed using a completely randomized design (CRD) with four treatments and three replications. The data obtained were analyzed using analysis of variance with a confidence level of 95%. Then a t difference test was carried out using the Duncan test.

RESULTS AND DISCUSSIONS

In general, stocking density has an impact on the growth and production of catfish, which is in line with the results of research (Toko *et al.,* 2007) which revealed that different stocking densities produce different production on cultivation media of the same size. The research results (represented in Table 1) showed that a stocking density of 250 ind/m^3 produced a specific growth rate that was 24% better than a stocking density of 1000 ind/m^3.

Table 1. Data from observations of variables influencing catfish stocking density.

Treatment	Specific Growth (%day^{-1})	Absolute Length Growth (cm)	Survival Rate (%)	Feed Conversion Ratio	Production (kg/m^3)
A (250 ind m^{3-1})	4.78 ± 0.05^a	14.3 ± 0.70^a	92.10 ± 2.49^a	0.91 ± 0.00^a	22.8 ± 0.96^a
B (500 ind m^{3-1})	4.28 ± 0.02^{ab}	12.4 ± 0.9^{ab}	85.97 ± 0.56^b	0.95 ± 0.00^{ab}	30.4 ± 0.57^{ab}
C (750 ind m^{3-1})	3.97 ± 0.01^b	12.1 ± 1.4^b	77.07 ± 1.08^c	1.02 ± 0.05^b	35.7 ± 0.34^b
D (1000 ind m^{3-1})	3.65 ± 0.01^b	10.2 ± 0.8^b	67.07 ± 3.30^c	1.12 ± 0.02^c	36.9 ± 0.24^b

Note : The same superscript letter behind the standard deviation indicates not significantly different ($P<0.05$).

A stocking density of 250 fish/m^3 resulted in 29% better absolute length growth than a stocking density of 1000 fish/m^3. Apart from that, stocking density also influenced survival, feed conversion, and production of catfish. The best survival value of 92.1% was shown in the 250 fish/m^3 treatment, while the 1000 fish/m^3 treatment had the lowest survival value, namely 67.07%. The best feed conversion value was seen in the 250 fish/m^3 treatment, which was 18% better than the 1000 fish/m^3 treatment which produced a value of 1.12 which indicated

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the lowest feed conversion results. The highest production value obtained was seen in the 1000 fish/m^3 treatment with a production of 36.9 kg/m^3, while the lowest production value was in the 250 fish/m^3 treatment with a value of 22.8 kg/m^3.

The treatment of catfish stocking density also had an impact on the income of catfish farming businesses. In simple terms, it is shown in Table 2 that the higher the fish stocking density, the higher the impact on capital. A stocking density of 1000 fish/m^3 produces the highest fish production, namely 261 kg, but shows the lowest business income, namely Rp. 514.067 (Table 3). Meanwhile, the best business income was seen in the treatment of 500 fish/m^3 with an income of Rp. 1.258.967,-.

Table 2. Working capital for cultivating catfish with different stocking densities.

Treatment	Fry (ind)	Fry Costs	Feed Costs	Cost of Probiotics and Medications	Total Working Capital
A	1766	IDR 353.250	IDR 1.870.000	IDR 100.000	IDR 2.323.250
B	3533	IDR 706.500	IDR 2.183.200	IDR 150.000	IDR 3.039.700
C	5299	IDR 1.059.750	IDR 2.670.400	IDR 200.000	IDR 3.930.150
D	7065	IDR 1.413.000	IDR 3.041.600	IDR 250.000	IDR 4.704.600

Table 3. Income from cultivating catfish with different stocking densities.

Treatment	Fish Production (kg)	Gross Income	Total Working Capital	Net income
A	161.16	IDR 3.223.333	IDR 2.323.250	IDR 900.083
B	214.93	IDR 4.298.667	IDR 3.039.700	IDR 1.258.967
C	252.90	IDR 5.058.000	IDR 3.930.150	IDR 1.127.850
D	260.93	IDR 5.218.667	IDR 4.704.600	IDR 514.067

Very high stocking densities also have the risk of increasing the mortality rate of catfish due to increasingly limited space for movement and smaller opportunities to get food, which also has an impact on decreasing growth rates and increasing the cannibalism of catfish (Dai *et al.,* 2011). Baßmann *et al.* (2023) also revealed that very high stocking density is a limiting factor that can cause stress and increase the number of catfish mortalities. In another study also conducted by (Wang *et al.,* 2017) it was shown that the higher the fish distribution, the lower the expression of growth hormone mRNA which resulted in fish growth tending to be slow and the feed conversion value was higher.

The results of this research were different from the results of research conducted by Soedibya *et al.* (2017), which showed the optimal stocking density for catfish is 1500 fish/m^3. The differences are possible due to differences in the technology used, where in this study the traditional method was used without additional aeration and did not use biofloc technology. Providing aeration can increase dissolved oxygen in waters, and the use of bioflocs can minimize water pollution and increase feed efficiency (Hermawan *et al.,* 2014).

The quality of cultivation water during the maintenance period also showed different water quality fluctuations. Fluctuations in water quality over a fairly wide range can be seen at a stocking density of 1000 fish/m^3 with dissolved oxygen values of 2.53-5.41 ppm and pH 5.8-8.0 (Table 4).

Table 4. Water quality for raising Catfish.

Indicator	Treatment			
	A	B	C	D
Temperature (^{O}C)	28-31	28-31	28-31	28-31
Dissolved oxygen (ppm)	4.60 - 6.04	4.35 - 6.00	4.35 - 6.00	2.53 - 5.41
pH	6.2 - 8.0	6.2 - 8.0	6.2 - 8.0	5.8 - 8.0
Nitrate (ppm)	1.6 - 6.0	1.6 - 6.0	1.6 - 6.0	1.6 - 6.0
Ammonia (ppm)	0.08 - 0.2	0.08 - 0.3	0.08 - 0.3	0.08 - 0.4
Turbidity (KTU)	0.4 - 3.5	0.4 - 3.8	0.4 - 3.7	0.4 - 4.2

The results of observations for 80 days showed that the higher the density of catfish stocking, the lower the growth rate of weight, absolute length, and survival rate, and the rate of feed conversion increased. The results of water quality monitoring were seen to fluctuate, but these figures were still classified as good catfish tolerance levels in treatments A, B, and C. However, the most visible difference was the Dissolved Oxygen value in treatment D, the lowest value was 2.53 ppm and the ammonia content was 0.4 ppm which was periodically found during morning water quality monitoring. This condition was greatly influenced by the very high density of fish stocking, the amount of feed which caused the accumulation of organic matter from leftover feed.

According to Harianty *et al.* (2018), the higher the density of catfish stocking, will narrower the space for fish to move, and increased competition in obtaining food and dissolved oxygen. The decrease in dissolved oxygen and the increase in ammonia cause a less than ideal environment for catfish, thus inhibiting their physiological functions and reducing resistance to pathogens (Tumwesigye *et al.*, 2022). Directly, low oxygen levels can cause asphyxia (shortness of breath), while high ammonia levels can damage gill tissue, causing systemic poisoning (Bhatnagar and Devi, 2013). This is the main cause of the low growth rate, survival rate, and production value of catfish in treatment D. Hermawan *et al.* (2014) also revealed that the higher the stocking density will affect the behavior and physiology of fish, resulting in fish tending to experience decreased growth and productivity. The same thing was also expressed by (Wang *et al.,* 2017) who stated that high stocking density affected the risk of increasing fish stress and affected the increasing energy needs of fish that should be used for catfish growth.

This study also showed that the higher the stocking density of catfish, the greater the income generated. The best results were at the optimal stocking density of 500 fish/m^3. According to Mugo-Bundi *et al.* (2024), optimal stocking density can affect production which has an impact on optimal income value. Stocking density can indeed increase the value of fish production. However, in conditions that exceed capacity, fish stocking density will increase the number of deaths, high feed conversion values, and increased feed costs which cause higher business risks and decrease fish farmer income.

CONCLUSION

Different stocking treatments have very significant differences in specific growth, absolute length growth, survival, FCR, and business income. The optimal stocking density for cultivating catfish in round tarpaulin ponds on a small scale is 500 fish/m^{3,} with the best income, namely IDR 1,258,967.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTION

The contribution of each author is as follows, Ach. Khumaidi; Conceptualization, collected the data, drafted the manuscript, and designed the table as well as the graph. Abdul Muqsith, Abdul Wafi and Siti Nur

Aisyah Jamil; devised the main conceptual ideas and conducted a critical revision of the article. All authors discussed the results and contributed to the final manuscript.

ACKNOWLEDGMENTS

The author would like to thank the Faculty of Science and Technology, Ibrahimy University, which has supported all research activities and facilities during the research.

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