The effect of variations in stocking density on the growth and survival of striped eel catfish *Plotosus lineatus* (Thunberg, 1787) fries

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Abstract. This present research aims to determine the effect of variations in stocking density on the growth and survival of striped eel catfish (*Plotosus lineatus*) fries reared in floating net cages. Data on length-weight growth and fry survival were collected every 7 days over a 49-day observation period. The research employed a completely randomized design (CRD) with three treatments and three repetitions, namely treatment A (stocking density 50 ind/2 m^3), treatment B (stocking density 75 ind/2 m^3), and treatment C (stocking density 100 ind/2 m^3). The fish fries in this experiment had an average initial total length of 7.44 cm and an initial weight of 2.55 g. Throughout the research, fish fries were fed shrimp (*Litopenaeus vannamei*) heads in the morning and evening. The results revealed that fries reared in low-density stockings (treatment A) exhibited superior growth and survival performance compared to those reared in higher-density stocking; the daily length growth rate was 0.04±0.05 cm day^{-1}, the specific growth rate was 0.94±1.37% day^{-1}, and the survival rate was 84.08%. Based on this finding, to achieve optimal growth and seed survival, eel catfish should be cultivated in a medium with a stocking density of 50 ind/2 m^3.

Key Words: cultivation, fishery, nutritional content, Plotosidae.

Introduction. The striped eel catfish (*Plotosus lineatus* Thunberg, 1787) belongs to the Plotosidae family and is known as 'ikan Lele Laut' or sea catfish in Indonesia. This fish is a demersal species often incidentally caught along the coast (Asriyana et al 2020). Sea catfish share a body shape similar to freshwater catfish but are distinguished by the three patellae on their dorsal and pelvic fins (Prithiviraj et al 2012; Wright 2012). This fish holds the potential to be cultivated and serve as a local food source, much like freshwater catfish. Its appeal extends beyond its delicious taste, as it also boasts high nutritional content. The striped eel catfish contains high levels of amino acids, including MUFA fatty acids, PUFA ω-6, PUFA ω-3, and other PUFA. These contents hold significance in pharmaceutical products, food supplements, and antioxidants. Furthermore, sea catfish are a source of carbohydrates, protein, and fat, making them a well-rounded nutritional option (Suganthi et al 2015; Osman et al 2001; Asriyana et al 2020; Asriyana et al 2022a, b).

The striped eel catfish is part of a small-scale fishery (Muhajirah et al 2018), typically caught incidentally during fishing in fishermen's gear. Their sizes when caught range from small to mature gonads. This unintentional capture raises concerns about its potential impact on the population's natural condition. The population of a similar relative, the gray eel catfish (*Plotosus canius*), is already classified as threatened in various areas (Asriyana & Halili 2021).

To ensure the sustainability of the striped eel catfish population, human intervention is crucial. One form of intervention involves cultivating and growing the fish fries. In cultivation, the stocking density plays a pivotal role in determining the success of cultivation efforts. Stocking density directly influences production, which is impacted by growth rate and survival rate. High stocking density can often lead to a decline in growth rate, feed, and survival rate (Muchlisin et al 2021).

The growth rate and survival rate of fish with different stocking densities are crucial to understand cultivation activities. This pertains to the fish's growth rate and its ability to survive in a controlled medium. Today, research about the stocking density of sea catfish in controlled media is limited. Existing studies mostly focus on the biological conditions of these fish in their natural environment (Palla et al 2018; Galanidi et al 2019; Asriyana et al 2020; Asriyana et al 2022a; Turan et al 2022; Ueng et al 2022; Shao et al 2023). There is a notable absence of research under controlled conditions, particularly concerning fish growth at different stocking densities. Thus, research regarding variations in stocking density and their impact on the growth and survival of striped eel catfish (*P. lineatus*) fries needs to be conducted.

Material and Method

Experimental design. Striped eel catfish fries that have been acclimatized for a week were put into treatment containers. The experiment was carried out for 49 days from July to August 2023 at the Field Laboratory of the Faculty of Fisheries and Marine Sciences, Halu Oleo University. The fish used in this experiment were in their fry stage, featuring a total length of 7.44 cm and a weight of 2.55 g. There were nine treatment containers, each with dimensions of 1x1x2 m^3. The stocking density was varied across treatments: 50 individuals per container for treatment A, 75 individuals for treatment B, and 100 individuals for treatment C.

The research employed the completely randomized design (CRD) experimental method using 3 different treatments and 3 repetitions, totaling 9 experimental units. The treatments were as follows:

- treatment A = stocking density 50 ind/2 m^3;
- treatment B = stocking density 75 ind/2 m^3;
- treatment C = stocking density 100 ind/2 m^3.

During rearing, the fish fries were given heads of the *Litopenaeus vannamei* shrimp species in the morning and evening at 5% of their body weight. The total length and weight of the fish fry were measured every 7 days. The total length was measured using a scale ruler with a precision of 1 mm, while the weight was determined using a digital scale with an accuracy of 0.01 g.

Water quality. During the maintenance period, various water quality parameters, including temperature, pH, salinity, turbidity, dissolved oxygen (DO), and ammonia, were measured. These measurements were carried out simultaneously to the assessment of the total length and weight of the fish fries. Water temperature and pH were determined using a Hg thermometer and a pH meter (Hanna brand HI-98128). Salinity was gauged with a hand refractometer (Hanna brand HI96822), turbidity with a turbidimeter (WGZ-1B Portable Digital), DO with a DO meter (Lutron DO-5510 brand), and ammonia using an Ammonia Test Kit (Salifert brand).

Calculations and statistical analysis. Data were analyzed to calculate the daily length growth rate (DGRL; Jobling 2003), specific growth rate (SGR; Limbu 2020), and survival rate (SR; Aryani et al 2017; Limbu 2020). Differences in growth and survival rates between treatments were assessed through an analysis of variance (ANOVA) test with a significance level set at 0.05 (Sokal & Rohl 1995).

Results

Water quality. The water quality parameters during the seed-rearing period are outlined in Table 1. All parameters measured in the treatment media exhibited relative homogeneity [$p > 0.05$ ($\alpha = 5\%$, df = 2)].

Table 1

Water quality parameters in the rearing media

Parameters	Unit	Treatments		
		A (50 ind./2m^3)	*B (75 ind./2m^3)*	*C (100 ind./2m^3)*
Temperature	(°C)	29.32±0.33	29.25±0.27	29.60±0.05
Salinity	(‰)	32.67±0.29	32.58±0.43	32.33±0.54
Turbidity	(NTU)	2.24±0.59	2.77±0.83	2.15±0.11
pH	-	8.38±0.19	8.40±0.08	8.37±0.07
Dissolved oxygen	(mg L^{-1})	5.69±0.65	5.46±0.62	0.60±0.60
Ammonia	(mg L^{-1})	0.16±0.02	<0.15±0.00	<0.15±0.00
[p > 0.05 (a = 5%, df = 2)]				

Growth performance. The growth of the striped eel catfish seeds that were kept displayed varied patterns, as depicted in Figure 1a. The total length exhibited a gradual increase during rearing, whereas weight gain fluctuated, as illustrated in Figure 1b.

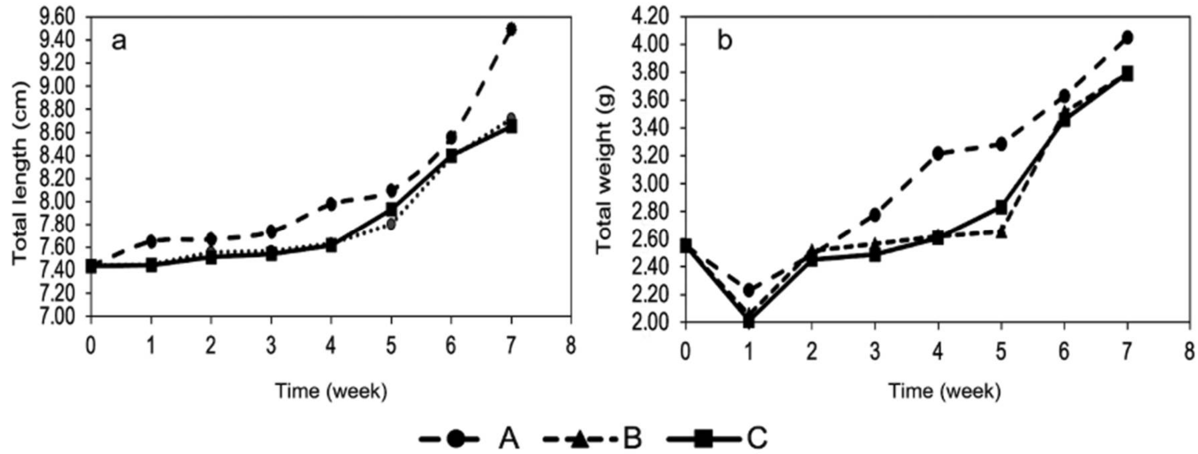

Figure 1. Growth in length (a) and total weight (b) of striped eel catfish fry under varied stocking densities.

The DLGR of seeds from the initiation of cultivation remained relatively uniform. During the first week (7th day), the growth rate in length was relatively low until the 5th week (as presented in Table 2). Subsequently, the growth rate began to increase at the 6th week or 42nd day after rearing in floating net cages for all the three treatments, A, B and C respectively.

Table 2

Daily length growth rate of striped eel catfish fry across various stocking densities

Time (week)	*Daily length growth rate (cm day^{-1})/Treatments*		
	A	*B*	*C*
0	-	-	-
1	0.03	0.00	0.00
2	0.00	0.02	0.01
3	0.01	0.00	0.00
4	0.03	0.01	0.01
5	0.02	0.02	0.04
6	0.07	0.08	0.07
7	0.13	0.05	0.04
p > 0.05 (a = 5%, df = 2), the ANOVA Test			

The percentage growth rate of the weight of striped eel catfish seeds each week is presented in Table 3. Initially, there was a decrease in seed weight across all treatments, particularly notable for seeds reared in treatment C. Subsequently, the percentage rate of weight gain increased gradually, only to decrease again by the 5th week.

Table 3

The specific growth rate of striped eel catfish fry across varied stocking densities

Time (week)	*Specific growth rate (% day^{-1})/Treatments*		
	A	*B*	*C*
1	-1.91	-3.07	-3.39
2	1.53	2.89	2.83
3	1.60	0.27	0.20
4	2.10	0.32	0.68
5	0.29	0.18	1.17
6	1.43	4.00	2.86
7	1.56	1.07	1.32
$p < 0.05$ (a = 5%, df = 2), the ANOVA Test			

Survival rate. During the rearing period, varying survival percentages were observed for striped eel catfish fry, as depicted in Figure 2. Seed survival remained high (100%) from the 1st week to the 4th week, followed by a drastic decrease during the 5th week until the end of the maintenance period.

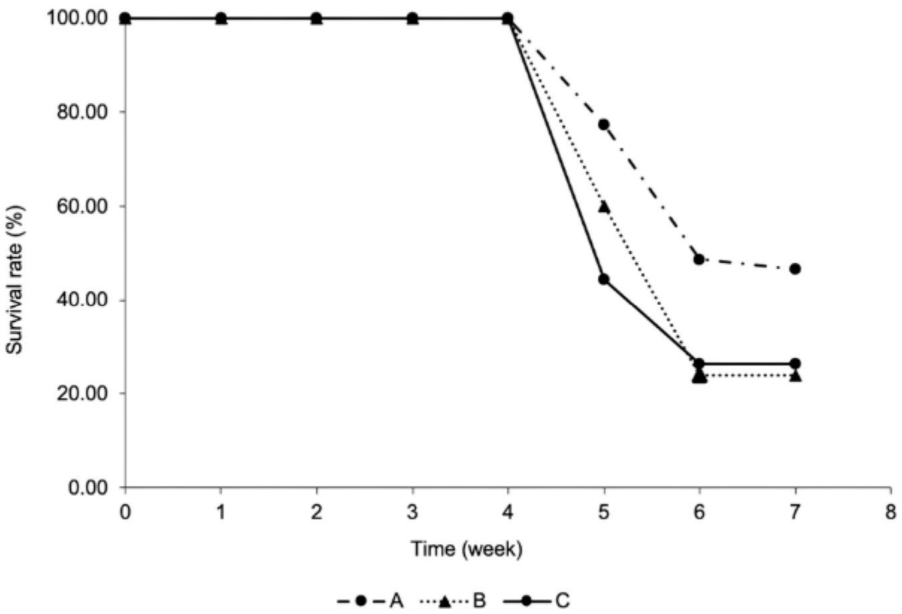

Figure 2. Survival rate of striped eel catfish fry throughout the rearing period.

Discussion. In the cultivation of fish seeds, water quality conditions are a pivotal factor influencing fish growth and survival. Stocking density and water changes play a fundamental role in shaping fish growth. High stocking densities and a lack of water changes in cultivation activities may adversely affect the health and physiology of fish. Compromised fish health and physiology can dampen appetite, leading to a reduction in growth (Sundh et al 2019).

Throughout the research, there were no water changes in the experimental media as the medium was a floating net cage allowing water to circulate in and out of the net. However, to maintain water quality conditions, daily siphoning was conducted to remove debris or residual food at the cage bottom. During the maintenance period, the water quality parameters remained relatively uniform [$p > 0.05$ (α = 5%, df = 2)]. These parameters included temperature, salinity, turbidity, pH, DO, and ammonia content (refer to Table 1). These six parameters exhibited minimal variations from the environmental conditions of striped eel catfish in their natural habitat or rearing media from prior studies (Kolbadinezhad et al 2018; Asriyana & Halili 2021; Asriyana et al 2022a).

Fish growth is influenced by various factors, including fish type, genetic characteristics, feed utilization ability, disease resistance, and environmental factors such as water quality, feed, and stocking density (Hepher & Pruginin 1981; Muchlisin et al 2021). The stocking density of fish in the rearing media significantly determines the growth and survival of cultivated fish.

Throughout the rearing period, the total length and total weight of the fish exhibited varying patterns of increase (refer to Figure 1). The total length displayed a gradual increase, as evident from the DLGR (see Table 2), which exhibited a relatively variable rate of increase. Conversely, fish weight gain fluctuated from the first week to the 5th week (Figure 1b). During the initial week or 7th day, fish weight decreased in all treatment media. This could be attributed to the fries adjusting to the conditions of the rearing medium. The rearing medium, functioning as a microhabitat, is a crucial factor in determining the growth and survival of seeds (Asriyana et al 2022b).

In the initial phase of rearing, length, and weight growth rates in all treatments were relatively slow. This slow growth can be attributed to the fries not adapting well to the experimental environmental conditions. During this early stage, the fries consumption of the provided food was minimal, resulting in a relatively low energy obtained from the consumed food. This low energy fails to meet the energy needs for basic activities such as physiological maintenance, movement, and other fundamental functions, leading to low or even nonexistent energy remaining for growth. This condition results in slow growth in length and, in some cases, even a decrease in fry weight. Additionally, fish fries are believed to experience stress in conditions of high density, diverting their energy toward surviving stressful conditions rather than growth. Fish growth occurs when the amount of nutrient-rich feed digested and absorbed by the fish surpasses the amount needed for body maintenance (Wiyoto et al 2023). The low increase in fry weight was also reflected in the SGR of the seeds (refer to Table 3).

The growth in length and weight exhibited variations across all stocking density treatments. The growth rate in both length and weight appeared to be higher in treatment A, characterized by low stocking density, compared to treatments with higher stocking densities, namely treatments B and C. Stocking density plays a fundamental role in influencing growth, evident in the greater DLGR (0.04 ± 0.05 cm day^{-1}) and SGR (0.94 ± 1.37% day^{-1}) observed in the treatment A compared to higher stocking densities (treatments B and C).

The lower increase in DLGR and SGR in fish fry reared in media with high stocking density is attributed to competition for space and food utilization among the fish. Lower densities allow fish to take more efficiently food without competition, promoting better growth. Consistent with this, Long et al (2019) reported that high stocking densities negatively impact growth, stress, and immune responses in Chinese sturgeon (*Acipenser sinensis*).

In addition to affecting the movement space of the reared fries, high stocking density leads to increased feed use compared to fries reared at lower densities. Excess feed, if not optimally consumed by the seeds, settles at the bottom of the rearing media. The amount of feed consumed by the seeds also influences the metabolic and excretory waste released, impacting the water quality of the media. In this experiment, the metabolic waste in the form of ammonia remained within tolerable limits for seeds, approximately $< 0.15\pm0.02$–0.16 ± 0.02 mg L^{-1}. Ammonia concentrations above 1.5 mg L^{-1} are considered toxic to farmed fish, and in some cases, the acceptable concentration is as low as 0.025 mg L^{-1} (Chen et al 2006; Cheng et al 2015; Wahyuningsih & Gitarama 2020; Asriyana et al 2021).

Several studies indicate that high stocking density does not always result in low growth rates for the reared fries. de Barros et al (2019) reported that stocking density influences fish aggressiveness. Higher stocking density increased the aggressiveness of matrinxã, *Brycon amazonicus* fish, but up to 72 days after hatching no other parameters were affected. Interestingly, beyond the 72nd day after hatching, aggressiveness no longer seems to be influenced by density. Instead, density increased biomass and production.

This finding aligns with the observations of Soedibya et al (2018). In one experiment with North African catfish fries (*Clarias gariepenus*), those reared at low stocking densities exhibited lower growth values, whereas those at high stocking densities showed higher growth. This phenomenon is believed to be attributed to the availability of ample space for movement, encouraging increased activity, which, in turn, utilizes a significant amount of energy for activities and metabolic processes rather than growth. The high energy consumption for metabolic processes reduces the portion of energy reserved for growth.

Based on this research, it can be concluded that high fish stocking densities will likely suppress the growth of fish of the *P. lineatus* and *A. sinensis* types. Conversely, for the *C. gariepenus* and *B. amazonicus* types, increasing stocking densities contributes to higher biomass and production in these fish

In addition to influencing the growth of striped eel catfish seeds, stocking density also impacts their survival. At the onset of the study, fries in all treatments exhibited a 100% survival rate until the 4th week (Figure 2). However, during the 5th week, several individuals experienced mortality, particularly in the high stocking density treatment (treatment C) compared to the low stocking density treatment (treatment A). Seeds reared at low stocking densities (treatment A) demonstrated a higher average survival percentage, specifically 84.08±24.93%, than treatmentc B and C, which recorded 76.00±35.33% and 74.63±35.03%, respectively (Figure 2).

The superior survival at low stocking densities can be attributed to reduced competition among individual fry for space and available food. In such conditions, the more ample space mitigates stress, leading to more efficient feed utilization, as was reported by Long et al (2019) for juvenile *A. sinensis*. High stocking densities contribute to decreased fish growth and increased serum adrenocorticotropic hormone (ACTH), triggering the release of cortisol from the adrenal glands. Cortisol regulates body metabolism and blood pressure. During the fifth week, changes in environment such as waves and high tides due to the east monsoon induced stress in the fish. This is aggravated by the lack of shade in the cages, resulting in stress-related mortality. Environmental stress can elevate cortisol levels, increasing the fish's vulnerability to disease and ultimately leading to death (Tahir et al 2018). Sinaga et al (2020) reported that stocking density during the fry-rearing stage influenced the survival rate of Siamese catfish (*Pangasianodon hypophthalmus*).

Increasing stocking density in fish farming does not consistently lead to a decrease in survival rates, as noted by various researchers (Afia & David 2019; Sinaga et al 2020). In Siamese catfish (*P. hypophthalmus*), for instance, the survival rate reached 100% in the high stocking density treatment (100 ind/fiber) compared to other treatments. The response of fries in rearing containers varies based on the provided feed. Not all seeds in containers may effectively utilize feed, and they might be less aggressive in feeding under low stocking density conditions. Similar observations were reported by Afia & David (2019) in hybrid catfish (*Heteroclarias*). This particular fish species demonstrates ease of adaptation to high stocking densities without serious effects on health status, provided adequate measures are taken during management. Differences in survival rates in fish due to variations in stocking density are not only influenced by the type of fish and its age but are also impacted by the specific cultivation system employed.

Conclusions. The success of a cultivation business is significantly impacted by the stocking density of cultivated organisms. Striped eel catfish fry exhibit superior growth and survival when maintained at a lower stocking density (50 ind/2 m^3), specifically 0.04±0.05 cm day^{-1} (DGRL), 0.94±1.37% day^{-1} (SGR), and 84.08% (SR), compared to stocking densities of 75 and 100 ind/2 m^3.

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Conflict of interest. The author declares that there is no conflict of interest.

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