Growth performance and survival rate of striped eel catfish (*Plotosus lineatus*) fingerlings in different microhabitats

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Abstract. Striped eel catfish (*Plotosus lineatus*) is an economically important fish species that can be domesticated to satisfy animal protein needs. This study aims to assess the growth performance and survival rate of striped eel catfish reared in different microhabitats. Data collection on weight gain, length gain, and survival rate of eel catfish juveniles were conducted once every fourteen days for 56 days of the rearing period. The experiment employed a completely randomized design which consisted of three treatments and five replications. The treatments were A (no substrate) as control, B (sand substrate), and C (mix of coral and sand substrates), whereby the fish density used was 5 fish per tank. Results indicated that the striped eel catfish can survive in a seawater culture pond. The fish that were reared in the medium with sand and coral mixed substrates demonstrated the highest growth performance compared to the control and sand substrate media with absolute length growth (Lm), daily length growth rate (DLGR), relative growth rate (RGR), and specific growth rate (SGR) of 1.72±0.70 cm; 0.04±0.05 cm day^{-1}; 0.04±0.06% day^{-1}; and 174%±2.77% day-1, respectively. Additionally, the fish reared in the sand and coral mixed substrate medium showed the highest survival rate (88.00±21.42%) compared to those reared in the sand substrate medium (53.33±32.33%) and the no substrate control medium (41.33±27.23%). From this study, it is evident that striped eel catfish rearing in a medium of mixed sand and coral substrates procure desirable growth and survival rate.

Key Words: domestication, microhabitat, specific growth rate, striped eel catfish.

Introduction. Striped eel catfish (*Plotosus lineatus* Thunberg, 1787), known as 'lele laut' or 'sembilang' in Indonesia, is a wild fish species that in recent times has undergone its initial process to be domesticated (Asriyana et al 2021, 2022b). Domestication is the attempt to adapt wild animals (or plants), including fish, from their nature into cultivated form in human-assumed controlled conditions (Asriyana et al 2021). Striped eel catfish is a demersal fish that holds important economic value because of its high nutrition content. In culinary terms, striped eel catfish tastes pleasant no less so than freshwater catfish. Striped eel catfish possesses high amino acid contents such as monounsaturated fatty acid (MUFA), polyunsaturated fatty acids (PUFA ω-6), and PUFA ω-3 that play a crucial role in pharmaceutical products, food supplements, and antioxidants. This is in addition to its carbohydrate, protein, and lipid contents (Manikandarajan et al 2014; Suganthi et al 2015; Asriyana et al 2020). Taking into account its high nutritive values contained in its flesh and oil, striped eel catfish hold great prospective as a local food source (Asriyana et al 2021).

Characterized by a body shape much like freshwater catfish, striped eel catfish has three rigid spines located on its dorsal fin and pectoral fin (Prithiviraj et al 2012;

Wright 2012). Besides, this type has a maximum length of 150 cm, but generally 80 cm. In the waters of Southeast Sulawesi, striped eel catfish was found with a maximum total length of 25.4 cm (Asriyana et al 2020) and 32.5 cm (Asriyana & Halili 2021). Striped eel catfish is characterized by a brownish body color with two small white stripes running down to the head (White et al 2013). This species inhabits coastal waters, reefs, and soft-substrate bottoms. Juvenile stages are often found in groups in seagrass meadows, while adult stages are more solitary and are generally found in reef areas (Asriyana et al 2022a). A different eel catfish species of the same genus, gray eel catfish *Plotosus canius*, has been domesticated in some countries such as India (Mijkherjee et al 2002), Malaysia (Usman et al 2013; Usman 2014; Samani et al 2016), Thailand (Musikasung 2015; Amornsakun et al 2018), and Bangladesh (Uddin 2014; Islam et al 2019). Compared to *P. canius*, *P. lineatus* is still in its preliminary process of domestication (Asriyana et al 2021).

Knowledge of growth performance and survival rate is crucial in the attempt to domesticate a fish, particularly concerning its growth rate and survival in a controlled medium. Such supply of knowledge will determine the course of actions that would be involved to support the growth of the fish in cultivation and fish restocking strategies into the marine ecosystem. A microhabitat is a small distinct localized area in which an organism lives or sustained. A rearing medium is one form of microhabitat. Its conditions and maintenance will determine the growth and survival of the fish fingerlings it bears. As far as our knowledge is concerned, studies on microhabitats of striped eel catfish are still limited. Some former studies have discussed the ecological and biological aspects of the fish in their original habitat such as growth (Ya et al 2015; Farooq et al 2017; Palla et al 2018; Asriyana et al 2020); reproductive biology (Asriyana & Halili 2021; Ueng et al 2022); food habits and trait overlap (Arndt et al 2018; Ueng et al 2022); bioaccumulation of radionuclides (Suseno 2014); clinical effect (John et al 2015; Pachaiyappan 2015; Bentur et al 2018; Turan et al 2020; Bédry et al 2021; Ray et al 2022); domestication (Asriyana et al 2021); occurrence (Ali et al 2015; Doğdu et al 2016; Kolbadinezhad & Wilson 2018; Galanidi et al 2019; Asriyana et al 2022b), however, a study particularly concerned with the rearing of this fish in a different microhabitats is not yet available. This study aims to analyze the growth performance and survival rate of striped eel catfish reared in different microhabitats.

Material and Method

Research site. Striped eel catfish fries, which had been acclimated for one week, were placed into treatment containers. The experiment was conducted for 56 days in the field laboratory of the Faculty of Fisheries and Marine Science Halu Oleo University. Fingerlings of striped eel catfish used in this experiment were caught in the waters of Tanjung Tiram, southeast of Sulawesi, Indonesia. The striped eel catfish used in this experiment were in their fingerlings stage with an average length of 5.2-6.4 cm and 0.9-1.9 g initial body weight. The containers in which the fish were placed were concrete cylinders with a diameter of 45 cm and height of 40 cm. Each was filled with water to a height of 35 cm. In total, 15 container units were used to accommodate three treatments and five replications. The density of fish in each container for all treatments was five fish. The total number of fish used in this experiment refers to Asriyana et al (2021).

The experiment used a completely randomized design with three treatments and five replications adding up to 15 experimental units. The treatments were:

- treatment A = medium without substrate (control);
- treatment B = medium with sand substrate;
- treatment C = medium with a coral and sand mixed substrate.

During the experiment, the fish fingerlings were fed with rough fish, *Stolephorus commersonii*, twice a day (08.00 a.m and 04.00 p.m) with a feeding dosage of 10% of body weight. The total length and weight gain of the fish fingerlings were measured every 14 days. The total length of the fish fingerlings was measured using a scaled board with an accuracy of 1 mm and the fish body weight was measured using a digital balance with an accuracy of 0.01 g. At the end of the experiment, the total amount of fish fingerlings remaining was accounted for in each treatment.

Water quality. During the experiment, water quality parameters such as water temperature, pH, water salinity, and dissolved oxygen (DO) were measured in conjunction with the length and body weight measurements of the fingerlings. Water temperature and pH were measured using a mercury thermometer and pH meter (Hanna HI-98128). The water salinity was observed using a hand refractometer (Atago 2382), while DO was measured using a DO meter (Lutron DO-5510).

Calculations and statistical analysis. Data were analyzed to determine length growth (Lm), daily length growth rate (DLGR), and relative growth rate (RGR, Asriyana et al 2021); specific growth rate (SGR, Limbu 2020), and survival rate (SR, Aryani et al 2017; Limbu 2020). The difference in growth performance and survival rate between the microhabitats were assessed using analysis of variance (ANOVA) with a significance of 0.05 (Sokal & Rohl 1995).

Results

Water quality. The water quality parameters observed during fish rearing are presented in Table 1. Water temperature, pH, water salinity, and DO in the three different fish rearing media were relatively congruent [$p > 0.05$ (α = 5%, df = 2)].

Table 1

Water quality parameters of the striped eel catfish rearing media

Treatments	*Temperature (°C)*	*pH*	*Salinity (‰)*	*Dissolved oxygen (mg L^{-1})*
A	28.00±0.05	7.05±0.06	30.00±0.55	5.08±0.18
B	28.00±0.00	7.16±0.21	32.00±0.00	5.07±0.03
C	27.20±0.00	7.25±0.28	30.75±0.57	5.07±0.05
$p > 0.05$ (α = 5%, df = 2), ANOVA Test				

Growth performance. The fish fingerlings that had gone rearing showed good growth either through length or weight gain (Tables 2 and 3). Relative length growth could be seen in all treatments from each of the 14-day measurements. The highest increase in length recorded in treatment A (on day 42) was 1.00 cm, while for treatments B and C (on day 42) were 1.05 and 1.37 cm, respectively. The increase in weight of the fish fingerlings was varied. The highest increase in weight recorded in treatments A, B, and C were 0.93 g, 1.44 g, and 1.59 g, respectively.

The parameters for growth performance of the fish fingerlings observed in this study consisted of absolute Lm, DLGR, RGR, and SGR. As can be seen in Table 4, these parameters showed different results. Treatment C with its sand and coral mixed substrate indicated the highest growth performance compared to other treatments. Though it demonstrated the highest growth performance, ANOVA test indicated that the three treatments were not significantly different [$p = 0.963$ (α = 5%, df = 2).

Table 2

Increase in the length of the striped eel catfish fingerlings over the rearing period

Day	*Treatment A*		*Treatment B*		*Treatment C*	
	$\bar{L}$	$\Delta\bar{L}$	$\bar{L}$	$\Delta\bar{L}$	$\bar{L}$	$\Delta\bar{L}$
0	5.72		5.77		5.76	
14	5.93	0.21	5.84	0.07	5.81	0.06
28	6.00	0.07	5.95	0.11	6.10	0.29
42	7.00	1.00	7.00	1.05	7.48	1.37
56					7.76	0.29

Note: $\bar{L}$ = average length (cm); $\Delta\bar{L}$ = difference in average length to previous measurement (cm).

Table 3

Weight changes of the striped eel catfish fingerlings during the rearing period

Day	Treatment A		Treatment B		Treatment C	
	$\overline{W}$	$\Delta\overline{W}$	$\overline{W}$	$\Delta\overline{W}$	$\overline{W}$	$\Delta\overline{W}$
0	1.08		1.25		1.11	
14	1.16	0.08	1.15	-0.10	1.22	0.11
28	1.18	0.02	1.09	-0.06	1.25	0.02
42	2.10	0.93	2.53	1.44	2.84	1.59
56					2.95	0.11

Note: $\overline{W}$ = Average weight (g); $\Delta\overline{W}$ = difference in average weight to previous measurement (g).

Table 4

Growth performance of striped eel catfish fingerlings in different microhabitats

Treatments	Lm	DGRL	RGR	SGR
A	1.28±0.50	0.03±0.04	0.02±0.04	1.59±2.23
B	1.23±0.56	0.03±0.04	0.03±0.06	1.68±3.76
C	1.72±0.70	0.04±0.05	0.04±0.06	1.74±2.77
$p > 0.05$ (α = 5%, df = 2), ANOVA Test				

Note: L_m = absolute length growth (cm); DGRL = day growth rate in length (cm day^{-1}) ; RGR = relative growth rate (% day^{-1}); SGR= specific growth rate (% day^{-1}).

Survival rate. During rearing, the striped eel catfish fingerlings demonstrated different percentages of SRs. At the beginning (up until day 14), there were fish mortalities in treatments A and B. Whereas, in treatment C, 100% of the fish was able to be sustained until day 28. On day 56, all fish in treatments A and B had died, and some in treatment C had remained alive, demonstrating a percentage of SR of 56% (Figure 1). ANOVA test indicated that the SRs in the three treatments were significantly different [$p < 0.05$ (α = 5%, df = 2)].

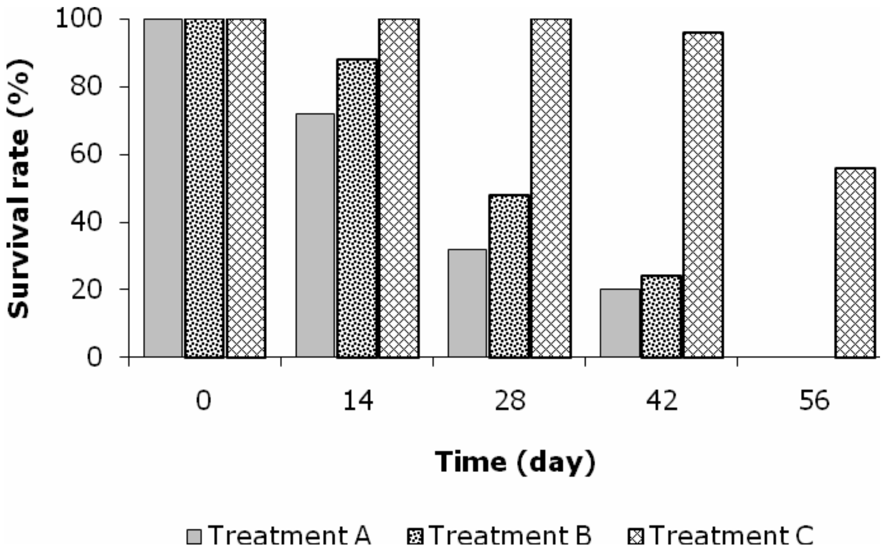

Figure 1. The survival rate of striped eel catfish throughout the rearing period.

Discussion. The water quality parameters of the fish rearing media were relatively uniform (Table 1). Previous studies have shown that optimum water quality can support the growth and survival rate of striped eel catfish, particularly when it is similar to that of the water quality conditions where the fish originated (Kolbadinezhad & Wilson 2018; Asriyana & Halili 2021).

Knowledge of the growth and survival rate of a fish species in water will lay down grounds for the appropriate action in their culture and inherent water management. Growth is a natural process that occurs in an organism, which can manifest in changes in terms of length and weight over time. The striped eel catfish fingerlings reared in the different microhabitats as set up in this study demonstrated variations in length and weight growth rates throughout. This is because the fish fingerlings were yet well adapted to the environmental water conditions in the treatments. In the initial stage, the fish fingerlings were consuming little from the feed offered and this would mean that their energy intake was relatively small. Of their small energy intake was not sufficient to satisfy their basal energy, and even less so for the energy required for growth. As a consequence, growth in length was low initially, and there were negative changes to the weight of the fingerlings. Namely, the fish fingerlings that were reared in the sand substrate medium (Table 3) demonstrated decreases in weight of 0.10 g and 0.06 g on days 14 and 28 of rearing.

A decrease in weight during fish rearing has also been reported by Nyamweha et al (2017) in North African catfish (*Clarias gariepinus*) that was reared and fed with different feeds. The fish reared were consuming little feed and this resulted in a weight decrease. Fish growth is dependent upon the energy available from diet and energy used to conduct activities daily. That is, the energy required to support daily bodily functions and activities would be satisfied first. Whatever is left as excess will then be utilized for growth as stated by Guillaume et al (2001). Furthermore, Karimah et al (2018) reported that deprivation in food source for the fish would reduce growth performance and encourages disease and fish mortality.

The highest absolute Lm, DLGR, RGR, and SGR of the striped eel catfish fingerlings were observed in sand and coral mixed substrate rearing medium. The absolute Lm of the striped eel catfish in treatment C was 1.72±0.70 cm after 56 days of rearing. This value is lower than that of barramundi fingerlings (*Lates calcarifer*) fed with high protein feed, having an absolute length growth of 1.74±0.45 cm (Jaya et al 2013). The DLGR serves to calculate the percentage of length growth each day. The DLGR of the striped eel catfish in this study was 0.04±0.05 cm, lower than the results reported by Anggrailiana (2017) in African catfish of 6.31% day^{-1}.

The SGR of striped eel catfish fingerlings in this study was observed to be 1.59±2.23-1.74±2.77% day^{-1} (Table 4). This SGR was lower than that of striped catfish fingerlings (*Pangasianodon hypophthalmus*) with a value of 3.82±0.04% day^{-1} (Naomi et al 2020). However, compared to other catfish such as North African catfish with values of 1.26±0.02-1.29±0.02% day^{-1} (Jamabo et al 2015), 0.89±0.30-1.44±0.29% day^{-1} (Orire et al 2019); and striped eel catfish of 0.09±1.07-1.63±1.74% day^{-1} (Asriyana et al 2021) the result was higher. SGR value can differ depending on factors such as fish size (Asriyana et al 2021); protein contained in feed (Jamabo et al 2015; Orire et al 2019; Ojewole et al 2022); and rearing medium (Naomi et al 2020).

The size of fish is one of the determining factors that affect fish growth rate. Asriyana et al (2021) reported that striped eel catfish fingerlings reared in a controlled medium demonstrated that smaller-sized (3.5-4.0 cm) fingerlings experienced more growth than bigger-sized (7.0-8.0 cm) fingerlings in terms of absolute Lm, DLGR, RGR, and SGR. Similar results were also found in *Siganus guttatus* fingerlings (Lante et al 2011), whereby smaller fingerlings (3.00-3.50 cm) had a higher DLGR than bigger fingerlings (4.10-5.00 cm). The length growth rate of a fish will decrease with an increase in the length size of the fish following the von Bertalanffy curve (Asriyana et al 2020, 2021).

Protein content in the fish diet also affects fish growth. *P. hypophthalmus* fingerlings fed with commercial feed, PF-1000, with a protein content of around 39-41% (Naomi et al 2020) demonstrated higher growth (3.82±0.04% day^{-1}) than striped eel catfish (1.59±2.23-1.74±2.77% day^{-1}) fed with anchovies containing protein of only 11.54% (Tohata et al 2021). Similarly, juvenile barred knifejaw (*Oplegnathus fasciatus*) demonstrated the highest growth when fed with a diet containing higher protein (CP). Fish fed with CP45, CP50, and CP60 diets generally exhibit higher SGR (2.07±0.01-2.12±0.02% day^{-1}) than fish fed with CP35 and CP40 diet (1.90±0.03% day^{-1}) (Kim et al

2016). Protein contains essential amino acids required by the fish to promote bodily functions and optimum growth, as well as an energy source for fish.

Likewise, rearing media is also a determining factor in fish growth. As demonstrated in this study, striped eel catfish fingerlings reared in a microhabitat of sand and coral substrate mixture showed a higher SGR (1.74±2.77% day^{-1}) than the fingerlings reared in a medium with no substrate (control treatment) (1.59±2.23% day^{-1}). This can be attributed to the fact that this mixed medium mimics much of the natural habitat of the striped eel catfish in the sea. Striped eel catfish is a fish species that associates itself with coral reefs, estuary, or seagrass areas. Rocks and vegetations provide a protected area for juveniles from predators as well as a nursery ground. This form of the substrate also provides niches whereby the fish can be concealed among the corals and rocks, particular when approaching the spawning season (Galanidi et al 2019; Asriyana et al 2020; Asriyana & Halili 2021; Asriyana et al 2022a). Additionally, fish rearing of *P. hypophthalmus* by Naomi et al (2020) in an aquaponic setup, equipped with a fine bubble diffuser at 5.5 atm under pressure demonstrated a higher SGR (6.68±0.43% day^{-1}) than fingerlings reared without fine bubbles (3.82±0.04% day^{-1}). Based on these, it is evident that rearing media affect the growth performance of fingerlings reared in a controlled media.

The SR of fingerlings in fish culture greatly determines the success of aquaculture. In addition, it also designates the fish restocking scheme for the sea. Restocking is a strategy taken to increase and restore the supply of wild-caught fish, often endangered by overfishing (Kartamihardja 2015; Wang et al 2021). Striped eel catfish fingerlings' resilience or SR in a particular microhabitat is affected by their ability to adapt to the rearing media, fish size, and the duration of fish rearing. As previously mentioned, rearing media largely establishes the SR of fingerlings, whereby the more similar it is to the original habitat, the higher the SR. Similar results were also reported by Kusuma et al (2020) on fiveband barb fish (*Desmopuntius pentazona*), which prefer rearing media that exhibit colors much like their environment in the wild.

It was revealed that fingerling size influences SR. Asriyana et al (2021) discovered that striped eel catfish sized 4.9-5.6 cm had a higher SR than smaller-sized fingerlings (3.5-4.0 cm), having a SR of 46.25±2.50%. In comparison, bigger-sized fingerlings (7.0-8.0 cm) had a higher SR of 65.00±4.08%. The bigger the size of the fish the better the resilience or ability of the fish to adapt to the rearing media. Similar results were reported in brook trout *Salvelinus fontinalis* (Hutchings 1994), in Pacific salmon *Oncorhynchus* spp. (Bradford 1995), and in striped catfish *P. hypophthalmus* (Andriani et al 2019).

The duration of rearing appeared to also influence the ability of the fish to adapt and stay alive in the rearing media (Figure 1). On day 28, the fingerlings in treatment C were able to demonstrate a SR of 100%, which was not the case in other treatments. This SR, however, experienced a decrease to 56% on day 56. By then, the fish in treatments A (no substrate) and B (sand substrate) had all died. This outcome may be attributed to the water quality conditions of rearing media in both of these treatments. Although water quality parameters such as temperature, water pH, salinity, and DO were similar among the treatments (Table 1), the ammonium level contained in the water might have differed significantly. The presence of ammonia in the water can originate from metabolic by-products as well as unconsumed feed. During the experiment, ammonia content in the rearing media was not measured. Ammonia content in the water is presumed to affect the survival of the fingerlings during rearing. Tolerance to ammonia may vary depending on the species, age, and physiological status of the fish. Fish that are more mature or are in their adult stage are more tolerant to changes in ammonia content than fish in their fingerling and juvenile stages (Dauda et al 2019). Exposure to excessive ammonia levels can disrupt the excretion of ammonia from the fish body, resulting in the accumulation of it in the body and possible mortality (Sinha et al 2012).

Conclusions. Among the three treatments, the highest survival rate and growth performance of the striped eel catfish fingerlings were found in the rearing medium with sand and coral substrate mixture. This type of medium has demonstrated that it is suitable and optimal to be applied in striped eel catfish culture as well as a means of restocking strategy of the fish into the wild. Accordingly, the water condition in which the striped eel catfish is released should have sand and coral substrate to ensure their growth and survival.

Acknowledgements. The authors would like to express their gratitude to the Ministry of Education, Culture, Research and Technology Republic of Indonesia for funding this experiment through the 2022 Applied Research Scheme, Number: 108/E5/PG.02.00.PT/ 2022 entitled "Fingerling and broodstock production in the domestication of striped eel catfish (*Plotosus* sp.) resources to support for self-sufficiency in food sustainability". The author would like to thank the students and undergraduate alumni of FPIK UHO (Risko Arsyad, S.Pi.; Raudhatul Madhaniah S.Pi.; Murni Astuti, S.Pi.; Heriandi; and Dicky Ardiansyah) that have helped with the data collection in the laboratory, as well as the Faculty of Fisheries and Marine Science, Halu Oleo University for the support and facilities given to complete this experiment.

Conflict of interest. The authors declare that there is no conflict of interest.

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Received: 27 September 2022. Accepted: 22 October 2022. Published online: 08 November 2022.
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How to cite this article:
Asriyana A., Halili H., Balubi A. M., Asrari A., Kurnia A., 2022 Growth performance and survival rate of striped eel catfish (*Plotosus lineatus*) fingerlings in different microhabitats. AACL Bioflux 15(6):2775-2784.