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Impact of Stocking Size on Growth and Production Performance of Pearlspot (*Etroplus suratensis*) in Cage Culture: A Comparative analysis of Different Size Groups

Smina M. S.[1,2], Shoji Joseph[1*], Sunithakumari K.[1,2], and Priya N. P.[1,2]
[1] *ICAR-Central Marine Fisheries Research Institute, Cochin, Kerala, India*
[2] *Cochin University of Science and Technology, Cochin, Kerala, India*

Abstract

Initial stocking size plays a crucial role in cage aquaculture, directly influences fish growth, production, and economic returns. In this study, the impact of varying initial stocking sizes on the growth and yield of pearlspot (*Etroplus suratensis*) was evaluated in Enamavu Lake, located in the Thrissur district of Kerala, India. Pearlspot were stocked at a density of 1,500 fish per cage (4×4 m) across three size groups—T1 (0.39 ± 0.004 g), T2 (3.77 ± 0.87 g), and T3 (11.65 ± 2.11 g)—with three replicates per treatment. The trial was conducted over 332 days, during which the fish were fed commercial floating pellets containing 44% crude protein, administered twice daily at 5% of body weight. The results showed that initial stocking size significantly affected growth performance, feed conversion ratio (FCR), total biomass, and net profit ($p < 0.05$). Although T1 exhibited the highest specific growth rate (2.32 ± 0.03 %/day), a strong positive correlation ($r = 0.992$) was observed between initial stocking size and total yield. Mean yields were 2.83 ± 0.04 kg/m^3 for T1, 3.90 ± 0.031 kg/m^3 for T2, and 5.06 ± 0.01 kg/m^3 for T3, with statistically significant differences among treatments ($p < 0.05$). Despite T3 producing the highest biomass, the benefit-cost ratio was significantly higher for T2 (1.56 ± 0.00) and T1 (1.51 ± 0.01) compared to T3 (1.28 ± 0.01), indicating that T2 resulted in the greatest net profit ($p < 0.05$). These findings suggest that stocking medium-sized fingerlings (T2) is the best in terms of biological performance and economic viability for the commercial cage culture of pearlspot in Kerala.

Keywords: Benefit cost ratio, economic benefit, Enamavu Lake, *Etroplus suratensis,* growth performance

Introduction

Etroplus suratensis, commonly known as the "Pearlspot," is a highly valued cichlid, indigenous to the southern region of India and Sri Lanka (Padmakumar, Manu, & Bindu, 2009). It was the first Indian food fish to have been transplanted to a foreign country and is known for its excellent taste and nutritional value (Hornell, 1922). The pearlspot is an excellent candidate for commercial farming due to its wide acceptance as a food fish, and adaptability to various farming systems (Joseph & Ignatius, 2016), tolerance to salinity, compatibility with other fish species (Shilta, Chadha, Pandey, & Sawant, 2016), omnivorous feeding habits (Padmakumar et al., 2009), and high market value. Both large and small-scale farmers are interested in cultivating this fish in tanks of various sizes—from small setups to large, perennial, and seasonal farms, due to its high market price and steady demand in local markets.

Cage culture has gained significant popularity in the last decade due to its numerous technical and financial advantages over traditional methods of aquaculture. This technique involves rearing fish from fry to marketable size in their natural environments while enclosing them in net cages that allow free water flow (Beveridge, 1996). One of the main benefits of pearlspot culture in cages is that they do not spawn within the cages, which promotes better growth compared to pond culture where fish spawn even at relatively low weights of 110 g.

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Email: shojicmfri@gmail.com

Pearlspot grows well in cages and reach maturity with well-developed gonads, making cage culture a suitable method for broodstock development (Ignatius, Joseph, & Imelda, 2012), and hence is considered as an excellent candidate for commercial cage culture (Joseph & Ignatius, 2016), including co-culture with other fishes such as seabass, snappers, etc. However, reports indicate that the growth of pearlspot in cages varies depending on the initial stocking size. Therefore, this study aimed to determine the optimal initial stocking size of pearlspot in net cages through profitability analyses of three different initial stocking sizes. The present study anticipates that the results of these farm-based trials will help farmers decide the optimal initial size for stocking pearlspot in cage culture.

Materials and Methods

The current study was conducted at Enamavu Lake (10.5084° N, 76.0853° E), Thrissur district, Kerala, India. The water depth at the cage site was approximately three meters. The experimental setup consisted of three sets of rectangular floating GI cages (each treatment with three cages as triplicates), with a dimension of 4×4 metres. Each cage was provided with an inner net (18 mm mesh), an outer net (25 mm mesh). A catwalk railing facilitated regular management activities such as feeding and monitoring the fish and cage system. The cage nets were 2.5 meters deep with a flat bottom. A bird net was fixed on top of each cage to prevent birds from feeding on the fish.

Pearlspot used in this study were obtained from a private hatchery. Each cage was stocked with equal numbers of pearlspot i.e., 1500 fish per cage. Three size groups of pearlspot seeds were used for the experiment: T1 = small (0.39 ± 0.004 g and 1.95 ± 0.04 cm), T2 = medium (3.77 ± 0.87 g and 4.92 ± 0.04 cm), and T3 = large (11.65 ± 2.11 g and 7.02 ± 0.13 cm). The study lasted for one culture period of 332 days, from 18 August 2021 to 7 July 2022. The smaller fish (T1) were initially stocked in happas (0.5 mm) within the cage for two months before being transferred to an 18 mm inner net. Fish were fed twice daily with commercial floating pellets containing 44% crude protein, 7.5% crude fat, and

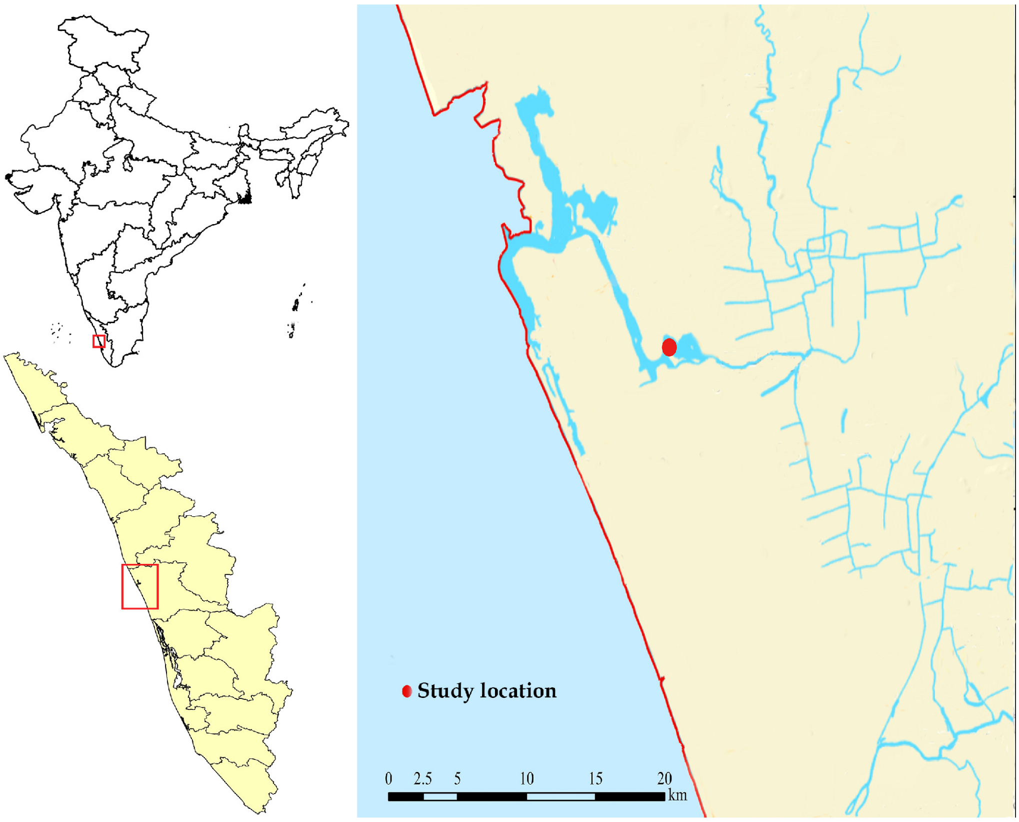

Fig. 1. Location of the experimental site at Manalur

3% crude fiber at a rate of 5% of their body weight.

Water quality was monitored monthly by collecting samples from both the cage site and a reference location. Parameters measured included temperature, pH, dissolved oxygen, salinity, phosphate, nitrate, nitrite, and ammonia, following APHA (1981) guidelines. Each month, 20 fish per treatment group were sampled to record length and weight. Feed was adjusted based on the body weight of the fish in each cage. Regular visual inspections were conducted to detect any signs of disease. Growth parameters including daily growth rate, specific growth rate, feed conversion ratio, weight gain, and feed conversion efficiency were calculated using standard formulas based on body measurements.

Weight gain (g) = Final weight – Initial weight

$$\text{Daily growth rate (DGR, g/day)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Days}}$$

$$\text{Specific growth rate (SGR, g\%/day)} = \frac{\text{In (Final weight)} - \text{In (Initial weight)}}{\text{Days}} \times 100$$

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

$$\text{Food conversion ratio (FCR)} = \frac{\text{Total weight of dry feed given}}{\text{Total weight gain by fish}}$$

Gross yield (kg/m^3) = Number of fish caught X average final weight/ Cage volume ($m^{3)}$

Net yield (kg/m^3) = Number of fish caught X average weight gain/ Cage volume (m^3)

After the completion of the experiment, an economic analysis was conducted to assess the net return and benefit-cost ratio (BCR) for the different initial stocking sizes of *E. suratensis*. Benefit and BCR were calculated as follows:

Net benefit = Gross return – Total cost

BCR = Gross return / Total cost

Upon completion of the experiment, all specimen were sold at the local market price.

The results from all treatments were compared using one-way analysis of variance (ANOVA), with a statistical significance level of $p < 0.05$. Mean differences were determined using Tukey's Honestly Significant Difference (HSD) test. Statistical analyses were performed using SPSS version 16.

Results and Discussion

No significant differences were observed in water quality parameters among the treatments during the experimental period. Among the physicochemical parameters, only dissolved oxygen (DO) showed a significant difference between the cage and control sites (n=72, $p < 0.05$, Tukey test). The mean DO concentrations were 6.19 ± 1.20 mg/L in cages and 7.47 ± 1.35 mg/L at the control site. However, no significant differences were detected in the mean DO values among the experimental cages during the culture period. The remaining water quality parameters showed similar pattern between the cages and the control site, with no significant differences observed (n = 72, p = 0.05, Turkey's test). The mean water temperature, pH, dissolved oxygen, nitrite, nitrate, phosphate, and ammonia levels were within acceptable ranges for fish production. The water temperature ranged from 26.5ºC in June to 31.5ºC in March and May. The pH values ranged from 6.9 to 7.7, with maximum values recorded in February and May and minimum values in November. The cage sites had moderate dissolved oxygen levels, with monthly variations ranging from 4.62 mg/L to 7.5 mg/L. Salinity varied from zero to 35 ppt throughout the study period. The maximum nitrite concentration was recorded in October (0.51 mg/L) and the minimum in January (0.004 mg/L). Phosphate content varied from zero to 0.25 mg/L. Nitrate levels varied between 0.008 to 3.15 mg/L, and ammonia ranged from zero to 0.092 mg/L.

Table 1 presents the mean final weight, mean weight gain, percentage survival rate, and FCR of fish in all treatments at harvest. The initial stocking size had significant effects on the growth and production performance of pearlspots in cage culture. The mean final weights of fishes in T1, T2, and T3 were 85.81 ± 5.40 g, 110.37 ± 7.25 g, and 135.99 ± 6.95 g respectively. The mean final weights in T3 and T2 were significantly greater than in T1 (Fig. 2). The highest mean final length was observed in T3 (17.46 ± 1.02 cm), followed by T2 (16.45 ± 1.30 cm) and T1 (14.97 ± 1.15 cm) (Fig. 3). Specific growth rate (SGR) varied between 0.74 and 1.62 g%/day (Table 1). T1 (1.62 ± 0.03 g%/day) and T2 (1.02 ± 0.09 g%/day) had significantly higher specific growth rates ($p < 0.05$)

Table 1. Growth and production performance of *E. suratensis* in different treatments.

Parameters	T1	T2	T3
Initial length (cm)	1.95 ± 0.34^{a}	4.92 ± 0.53^{b}	7.02 ± 0.43^{c}
Final length (cm)	14.97 ± 1.15^{a}	16.45 ± 1.30^{b}	17.46 ± 1.25^{c}
Initial weight (g)	0.389 ± 0.004^{a}	3.77 ± 0.87^{b}	11.65 ± 0.61^{c}
Final weight (g)	85.81 ± 5.40^{a}	110.37 ± 7.25^{b}	135.99 ± 6.95^{c}
Weight gain (g)	85.42 ± 5.32^{a}	106.60 ± 6.90^{b}	124.35 ± 7.05^{c}
Average daily weight gain (g/day)	0.258 ± 0.27^{a}	0.321 ± 0.02^{b}	0.374 ± 0.09^{c}
Specific growth rate (g%/day)	1.62 ± 0.03^{c}	1.02 ± 0.09^{b}	0.74 ± 0.09^{a}
Food conversion ratio (FCR)	3.18 ± 0.00^{a}	3.19 ± 0.00^{a}	4.14 ± 0.04^{b}
Survival (%)	87.88 ± 1.07^{a}	94.22 ± 0.77^{b}	99.33 ± 0.07^{c}
Total yield (kg/m^3)	2.83 ± 0.04^{a}	3.90 ± 0.03^{b}	5.06 ± 0.01^{c}
Net yield (kg/m^3)	2.81 ± 0.03^{a}	3.77 ± 0.03^{b}	4.63 ± 0.04^{c}

The data represent the mean±standard deviation (SD) of three replicate cages. Means with different superscripts differ significantly (p<0.05) across rows.

than T3 (0.74 ± 0.09 g%/day).

All treatment groups showed survival rates above 85%, with variations observed across stocking sizes, likely due to natural factors. The highest survival rate was recorded in T3 (99.33%), followed by T2 (94.22%), while T1 had the lowest survival rate at 87.88%.

Feed conversion ratio (FCR) was calculated based on the total feed provided to each treatment group, as accurate measurement of feed loss was not feasible in the cage system within the natural water body. FCR values ranged from 3.18 to 4.14 and showed an increasing trend with larger initial stocking sizes. Although the lowest FCR was obtained in T1 (3.18 ± 0.00), followed closely by T2 (3.19 ± 0.00), and then T3 (4.14 ± 0.04), statistical analysis indicated no significant difference in FCR between the small and medium groups. Similarly, total and net yields increased with increasing stocking size. However, total revenue was significantly higher (pÂ0.05) in T3 (INR 101312.55 ± 67.99), followed by T2 (INR 78013.18 ± 653.72) and T1 (INR 50906.78 ± 620.64) (Table 2). Net revenue was significantly higher in T2 (INR 27970.68 ± 832.45) ($p < 0.05$) than in T3 (INR 22320.05 ± 612.56) and T1 (INR 17126.78 ± 365.21). According to the benefit-cost ratio analysis, BCR was significantly higher ($p < 0.05$) in T2 (1.56 ± 0.00) and T1 (1.51 ± 0.01) than in T3 (1.28 ± 0.01). However, total expenditure varied significantly ($p < 0.05$) across treatments, with the highest cost observed in the larger-sized groups. Economic analysis indicates that while both medium and large

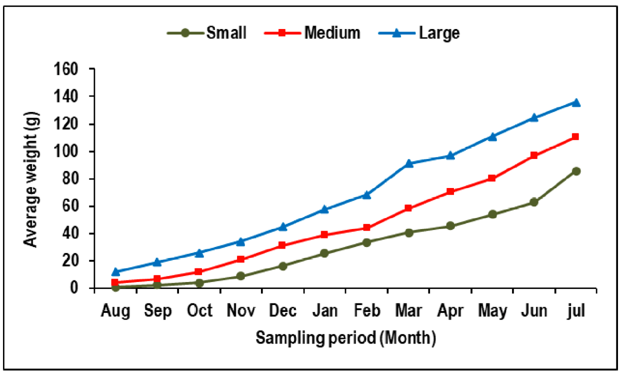

Fig. 2. Variation in mean weight of *E. suratensis* in different treatments during the study period

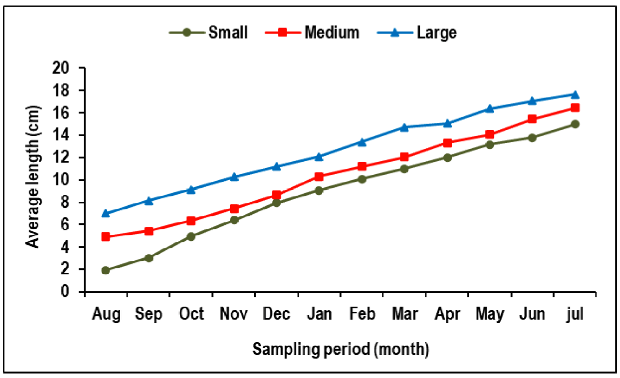

Fig. 3. Variation in mean Length of *E. suratensis* in different treatments during the study period

initial stocking sizes are profitable, the medium stocking size yields the highest net revenue, making it the most economically viable option among the treatments.

Water quality factors within net cages directly influence fish production and well-being (Kubitza, 2003; Sapkota et al., 2008). The water temperatures recorded at both the cage and control sites did not differ significantly and were within a range suitable to support aquatic life and fisheries. The findings are consistent with studies conducted by Antwi (1990), Ofori-Danson and Ntow (2005), & Karikari, Akpabey, and Abban (2013). The pH values recorded at the cage and control sites were also appropriate for the survival and productivity, as fish can grow and survive in water with pH values ranging from 5.0 to 9.0 (Jobling, 1995) which aligns with the pH measured in this study. Significant differences in DO concentrations between cages and open water sites may indicate fish respiration and/or degradation of biological deposits (fish faeces and untreated feed) to some extent. According to ASI (1999), a 4 kg Atlantic salmon demands around 20 g of oxygen per day; therefore, oxygen consumption by a large number of fish in a cage can be significant (EAO, 1996). Similarly, Cornel and Whoriskey (1993), Veenstra, Nolen, Carroll, and Ruiz (2003), & Mrcelic and Sliskovic (2010) also reported low oxygen level inside cage waters. However, Kilambi, Hoffman, Brown, Adams, and Wickizer (1976); Sunithakumari, Joseph, Ajithkumar, Smina, and Priya (2020); & Priya, Shoji, Ajithkumar, Sunithakumari, and Smina (2021) found no significant impact on DO levels at cage sites in sea bass cage farms. DO can be influenced by the suspended and dissolved substances and by nutrient remobilization from sediments due to fish movements. Pearlspot are not active feeders like seabass, increasing the chance of excess feed remaining in the cages. The release of nutrients from fish farms into aquatic ecosystems is a concern due to their potential environmental harm (Azevedo et al., 2011). Phosphate concentrations at both cage and control sites varied within a range of 0.001 to 0.42 mg/L, consistent with values reported by Asmah, Karikari, Abban, Ofori, and Awity (2014), and similar to the range of 0.34 to 0.50 mg/L documented by Ofori-Danson and Ntow (2005).

As there was no significant difference in phosphorus concentrations between the cages and control sites in Enamavu Lake, we concluded that fish respiration was the primary factor contributing to the lower DO levels within the cages. The ammonia concentrations recorded at both the cage and control sites were consistent with those reported by Ofori-Danson and Ntow (2005); Karikari et al. (2013); and Asmah et al. (2014). According to Chapman (1992), ammonium levels in unpolluted water are typically less than 0.1 mg/L, though they may sometimes reach 0.2 mg/L. Concentrations exceeding this threshold suggest contamination by domestic sewage, agricultural, or industrial waste. In the present study, no detectable impact of nitrate, nitrite, ammonia, or phosphate on water quality was observed. Similarly, Hays (1980) reported no significant effects on nitrite, nitrate, turbidity, carbon dioxide, pH, alkalinity, or conductivity in cage farming systems in the Bull Shoals Reservoir in Alabama.

Table 2. Production details of different treatments

Parameters	Treatments		
	T1	T2	T3
Fry cost	9000	15000	21000
Feed cost	24255 ± 255.55 ^{a}	33592.50 ± 272.79 ^{b}	56542.50 ± 604.99 ^{c}
Others	525	1450	1450
Total expenditure	33780 ± 255.55 ^{a}	50042.50 ± 272.79 ^{b}	78992.50 ± 604.99 ^{c}
Price/kg	450	500	500
Total revenue	50906.78 ± 620.64 ^{a}	78013.18 ± 653.72 ^{b}	101312.55 ± 67.99 ^{c}
Net revenue	17126.78 ± 365.21 ^{a}	27970.68 ± 832.45 ^{c}	22320.05 ± 612.56 ^{b}
BCR	1.51 ± 0.01 ^{b}	1.56 ± 0.00 ^{c}	1.28 ± 0.01 ^{a}

All the parameters are expressed in Indian Rupees (INR). The data represent the mean ± standard deviation (SD) of three replicate cages. Means with different superscripts differ significantly ($p < 0.05$) across rows.

The current study aimed to determine the optimal stocking size for Pearlspot in an open-water cage farming system for profitable farming. Growth parameters such as final length, final weight, weight gain, and average daily growth rate were significantly higher in fish stocked at larger initial sizes compared to medium and small stocking sizes. These findings are consistent with those of Castillo-Vargasmachuca, Ponce-Palafox, Ortíz, and Arredondo-Figueroa (2007) for spotted rose snapper and Dikel, Alev, and Ünalan (2004) for Nile tilapia under cage culture. In contrast, Akbulut, Sahin, T., Aksungur, and Aksungur (2002) reported higher growth rate in smaller stocking sizes for rainbow trout. The initial weights and growth factors of most fish have a significant relationship (Wohlfarth & Moav, 1993). This relationship was found to influence the development of some species (Jorgensen et al., 1993), but not others (Xie, Cui, Yang, & Liu, 1997).

Padmakumar et al. (2009) reported that the fish with an initial weight of 6 g attained a weight of 180 g after 197 days in brackish water cages in Vembanadu Lake, India, despite the diet provided containing 20% crude protein and stocking density being 200 fish/m^3. Parakkandi, Das, Saha, Leela, and Gunasekharan (2021) observed that a pearlspot with an average body weight of 5.9 g gained 90 g in seven months on a 32% crude protein diet when reared in freshwater. It is widely accepted that growth is not uniform and that a number of environmental factors, such as temperature, stocking size of fish, stocking density, availability of food, water exchange, and salinity, may influence food intake and growth rate (Jobling, 1995). The effect of initial body weight on growth and production has also been demonstrated in catfish (Chapman, 2000), rainbow trout (Akbulut et al., 2002), goldfish (Stone, McNulty, & Park, 2003), Nile tilapia (Dikel et al., 2004), and spotted rose snapper (Castillo-Vargasmachuca et al., 2007).

As expected, the highest daily growth increments were recorded in larger-sized fishes. However, Akbulut et al. (2002) reported the highest daily growth rates in smaller fish at the beginning of their study of Nile tilapia in floating cages. Although absolute weight gain was highest in the large-size group (T3), specific growth rate (SGR) declined with increasing initial weight. The specific growth rate of fish is found to change depending on its size; smaller fish grow faster than larger ones (Sumpter, 1992). Jobling (1994) found an inverse relationship between SGR and fish weight, and suggested that as fish weight increases, SGR decreases, and the findings of this study are consistent with the previous reports. Growth rate is considered an important economic characteristic for all aquaculture species. Rapid growth rates promote production turnover in aquaculture (Gjerde, 1986). According to the results, the difference in initial weights had a significant impact on the specific growth rate and feed conversion ratio of the pearlspots. Kestemont (1995) also observed that the initial stocking size is a crucial factor influencing the culture duration, feed conversion ratio, and final weight.

Feed and feeding are the most expensive aspects in cage culture operations (Diana, Yi, & Lin, 2004). In this study, a 44% crude protein-containing floating pellet feed was well accepted by the fish among all the treatment groups and the FCR expressed the ability of fish to effectively convert feed into body flesh. Lower FCR values indicate that the fish effectively converted the consumed feed into body flesh (Abaho et al., 2020). Therefore, the higher FCR values observed in this study, which increased with increasing initial stocking size, indicated inefficient feed utilization. The higher feed conversion ratio (FCR) observed in T3 can be attributed to the combination of larger initial stocking size and the high survival rate (99.33%) throughout the experiment. Larger fish typically require more energy for growth and maintenance, which can lead to a higher feed intake relative to the weight gained. According to Storebakken and Austreng (1987), the feed conversion ratio increased with increasing fish weight and was the best in the small groups. The FCR values observed in this study is very similar to the values reported by Dehadrai, Pal, Choudhury, and Singh (1975); Kumaraiah, Parameswaran, and Sukumaran (1986); Sukumaran, Raghavan, Rahman, Ayyappan, and Parameswaran (1986); and Padmakumar et al. (2009) and much lower than Luchini and Quiros (1990); Rowland, Allan, Hollis, and Pontifex (2004); but higher than Kappen et al. (2016) and Parakkandi et al. (2021).

The mean survival rate in all three treatment groups was higher than the 52.2%, 81%, and 82.6% reported for pearlspot in cages by Datta and Dasgupta (2007); Kappen et al. (2016), & Parakkandi et al. (2021), respectively. Sial, Kund, and Satapathy (2021) also reported a survival rate ranging from 80-93% in shallow water cages stocked with sub-adult pearlspots. However, the findings of this study are consistent with Padmakumar et al. (2009), who noted that larger initial sizes improved survival which ranged from 45 to 100%. The survival rate observed in this investigation is higher than the figures reported by Santhanam et al. (1983); & Lazarus and Nandakumaran (1986) for pearlspot farming in the pond and brackish water pen respectively.

Gross production was found to increase with an increase in initial stocking size. However, when the stocking size increases, fingerling and feed costs increase (Kunda, Pandit, and Harun-Al-Rashid, 2021). Feed costs account for approximately 67.12%–71.8% of the total costs. The greater the fry and feed requirements for larger stocking sizes, the lower the BCR and economic sustainability. To achieve profitability, it is essential to reduce the cost of fingerlings, feed, and labour both individually and in combination. Smaller fingerlings might be purchased at cheaper prices, thereby reducing the initial cost. Using even higher stocking densities would potentially produce larger harvest yields and presumably more profit. However, in the case of pearlspot high-density culture is not advisable due to the prolonged growth period, and other areas where expenditure can be minimized need to be sought. A one-person cage operation (owner-operator model) reduces labour costs and the subsequent effect on return (Wallat, Tiu, Rapp, & Moore, 2004). The current study recorded the highest fish production in T3 (large stocking size), followed by T2 (medium stocking size) and T1 (small stocking size). However, the benefit-cost ratio (BCR) for T3 was lower compared to T2 and T1, indicating that higher production does not necessarily translate to greater economic efficiency. The mean BCR value observed in this experiment was 1.45, which aligns with many previous studies but contrasts with the findings of Valsalan, Kripa, Padua, Narayanakumar, and Vysakhan (2020), who reported a significantly higher BCR of 3.38 for pearlspot cultured in cages in Kerala.

However, according to Oladei and Ofoezie (2006), an investment is profitable if the benefit-to-cost ratio is greater than one. In the present study, the lowest economic return was recorded in T1, likely due to its smaller size, low total production and selling price. The medium group (T2) exhibited significantly higher production, growth performance, and economic profit. Therefore, in the current study, the medium treatment (T2) was found to be the most effective of the three treatments in terms of growth, survival rate, production, and economic return.

Cage farming of finfish in open waters is a rapidly growing aquaculture practice in India. In brackishwater aquaculture, 4×4 m cages are commonly used, and co-culture systems with species like sea bass and pearlspot are popular. While these cages have a production capacity ranging from 37.5 to 45/ kg/m^3, pearlspot often underperforms due to its relatively slow growth rate and reduced efficiency under high-density conditions. Despite these challenges, Pearlspot remains a preferred choice for farmers due to its high demand, premium price and ease of marketing. Many farmers continue farming pearlspot without assessing profitability and seek guidance for improving production efficiency. This study was conducted in open cages to optimize the initial stocking size of pearlspot for sustainable production and economic viability. Results indicate that the medium stocking size (T2) is optimal for achieving sustainable production with higher revenue. Although the larger stocking size (T3) yielded higher gross returns, the high cost of seeds significantly increased operational expenses, thereby reducing net returns and rendering it a non-viable option for commercial cage farming. Further studies are recommended to explore other critical factors such as feed optimization, water quality management, and integrated systems to enhance productivity and profitability.

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