



Optimization of Stocking Density and Transport Duration for Transportation of Asian Seabass (*Lates calcarifer*) Fry and Fingerlings using Oxygenated Bags

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ABSTRACT

Background: Asian seabass, *Lates calcarifer* is a potential finfish for brackishwater aquaculture diversification. Transport of fry and fingerlings size seed without much stress is crucial for ensuring high survival and better economic returns. However, standardized protocols defining the optimum density against seed size and duration is lacking for mass scale seed transportation from the hatcheries to culture sites. This study evaluated optimum densities and transit durations for live transport of seabass fry (1.0-2.0 inch) and fingerlings (3.0 inch) in 30 L polyethylene bags (5 L water, 15.0 ppt salinity, oxygen-filled).

Methods: Three trials were conducted: Trial 1 with seabass 1-inch fry (2.6±0.01 cm; 0.30±0.01 g) at 20-100 fry L⁻¹; Trial 2 with seabass 2-inch fry (5.2±0.02 cm; 1.97±0.03 g) at 20-60 fry L⁻¹ and Trial 3 with seabass 3-inch fingerlings (7.5±0.02 cm; 5.03±0.07 g) at 10-30 fish L⁻¹. Survival and water quality were recorded after 6, 12, 18 and 24 h of transportation.

Result: Study revealed that seabass 1-inch fry (2.6 cm) survived (>99.0%) significantly best at densities of 80, 60, 40 and 20 fry L⁻¹ for 6-12, 18 and 24 h transport duration, respectively. Seabass 2-inch fry (5.2 cm) loaded at densities of survived (>94.3%) at 20 fry/L for 18-24 h, while higher densities (40-60 fry/L) were viable only for shorter durations (≤12 h). Seabass 3-inch fingerlings (7.5 cm) survived the best (97.3±2.3%) at 10 fish L⁻¹ for up to 6 h but survival declined drastically beyond this density and duration, indicating the need for lower densities and shorter transit times. Density, size and duration were interdependent factors affecting survival through changes in dissolved oxygen, pH and ammonia.

Key words: Density, Live transport, Seabass seeds, Survival, Water quality.

INTRODUCTION

The transportation of live fish is a crucial in commercial aquaculture, ensuring that hatchery-produced juveniles reach grow-out farms ensuring maximum survival for further cultivation. Live fish transportation has evolved over the years, moving from conventional clay pots and open boats to advanced systems that guarantee the survival and well-being of the fish. Large-scale live fish transportation was made possible with the introduction of artificial breeding and railroad infrastructure in the 19th century. Plastic bags have become the global standard for fry transportation due to their efficiency and practicality (Mirzargar *et al.*, 2022; Mousavi *et al.*, 2023). The standard protocols for fish live transportation in bags involves filling one-third of the bag's volume with water and pure oxygen replaces the air before stocking a prescribed biomass of fish. Extensive research has examined factors influencing live fish transport, including stocking density (Braun and Nuñez, 2014; Hong *et al.*, 2019; Hoseini *et al.*, 2019), transport duration (Sampaio and Freire, 2016) and packaging methods (Gomes *et al.*, 2006; Harmon, 2009).

Generally, a hatchery or fish seed production unit is situated far from fish rearing ponds, cages and farms. Transportation by train or flight can take a long time, ranging from hours to days to reach the destination. Mostly, the small sized seeds (1-3 inch) are transported in oxygenated

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bags, allowing safe transport at higher densities for short intervals. This method is cost-effective, minimizes handling stress and is a standard practice followed in aquaculture seed transportation. Throughout transportation, water quality may deteriorate due to factors like ammonia, pH fluctuations and dissolved oxygen levels, triggering varying degrees of stress responses and potentially leading to elevated

mortality rates (Gomes *et al.*, 2006). Similarly, excessive physiological stress is known to lower fish vitality and increase mortality. Transported fish exhibit physiological reactions indicative of stress, such as higher glucocorticoid (e.g., cortisol) levels and blood glucose content (Harmon *et al.*, 2009; Refaey *et al.*, 2018; Hong *et al.*, 2021).

Lates calcarifer (Bloch), commonly known as seabass, stands out as an exceptional species due to its euryhaline nature, protandrous hermaphroditism and carnivorous behavior (Khan *et al.*, 2023). This species showcases remarkable hardiness, tolerates crowded conditions and displays extensive physiological adaptability. It thrives in environments characterized by high turbidity, fluctuating salinities and a wide range of temperatures (Yue *et al.*, 2009). The versatility of *L. calcarifer* makes it well-suited for aquaculture, as it can be successfully cultured in marine ecosystems, freshwater, as well as brackish water ponds and cages (Mojjada *et al.*, 2013; Geetha *et al.*, 2025).

In India, seabass hatcheries are predominantly concentrated along the east coast, particularly in the states of Tamil Nadu and Andhra Pradesh. Although there are a few notable hatcheries on the west coast, particularly in Karnataka, the overall distribution remains largely skewed toward the eastern coastline, leading to a significant dependency on long-distance transportation to supply farmers and aquaculture operators in other parts of the country. Despite the commercial success of seabass hatcheries in India, there is limited information on the optimal density-duration combinations for live transport of fry and fingerlings. Given the delicate nature of seabass fry and fingerlings, maintaining high survival rates during transportation is a critical aspect of the supply chain, necessitating meticulous handling, optimal packing techniques and stringent adherence to water quality parameters to minimize stress and mortality. The high cost of seabass seeds, coupled with significant mortality rates during live transportation, leads to considerable economic losses for both hatcheries and farmers involved in the brackishwater finfish industry. Hence, this study addresses this gap, by evaluating the optimum densities and transit durations for live transport of seabass fry (1-2 inch) and fingerlings (3 inch) in 30 L oxygen filled polyethylene bags.

MATERIALS AND METHODS

Experimental site

The study was conducted from July to September 2024 at the Brackishwater aquaculture research and demonstration farm, Navsari Gujarat Research Centre (NGRC) of ICAR-Central Institute of Brackishwater Aquaculture in Matwad, Navsari, Gujarat (20°55'13.89"N and 72°49'18.28"E).

Experimental animals

The seabass seeds (10000 nos, 2.0±0.2 cm) were procured from CIBA MES hatchery Chennai. Prior to the start of the experiment, seabass was acclimatized in hapa

nets installed in a nursery pond at a salinity of 15 ppt. To obtain the desired size classes for the experiment, the fish were grown out in the nursery hapas (3 × 2 × 1 m) for 4, 35 and 58 days to achieve 1-, 2- and 3-inch size groups, respectively. The experiment was conducted using nursery pond bleached brackishwater of 15 ppt salinity and dissolved oxygen in the range of 5.8-6.2 mg/L. Prior to the loading and packing in the bags, all fish were starved for 48 h to reduce metabolic waste production.

Experimental design

The experiment comprised of three different size group measuring 1-inch fry (2.6±0.2 cm), 2-inch fry (5.2±0.3 cm) and 3-inch fingerlings (7.5±0.4 cm) with varying stocking density for live transportation for that 10,000 seeds procured was distributed across all three experimental trials: For the study, seabass 1-inch fry (0.30±0.01 g and 2.6±0.01 cm) were packed @ 20 fry/L (100 fry/5L), 40 fry/L (200 fry/5L), 60 fry/L (300 fry/5L), 80 fry/L (400 fry/5L) and 100 fry/L (500 fry/5L); seabass 2-inch fry (1.97±0.03 g and 5.2±0.02 cm) were packed @ 20 fry/L (100 fry/5L), 40 fry/L (200 fry/5L) and 60 fry/L (300 fry/5L) and seabass 3-inch fingerlings (5.03±0.07 g and 7.5±0.02 cm) were packed @ 10 fingerlings/L (50 fingerlings/5L), 20 fingerlings/L (100 fingerlings/5L) and 30 fingerlings/L (150 fingerlings/5L) into 30 L plastic bags filled with 5 liters of 15 ppt salinity water for live transportation for four transportation durations 6, 12, 18 and 24 h. Following this, the bags packed with seabass fry and fingerlings were oxygenated, securely tied with rubber bands and packed within Thermocol boxes for transportation at ambient temperature via four-wheel pick-up vehicle to simulate real-time seed transportation conditions. Each treatment was performed with three replicates.

Sampling and analysis

Upon completion of the designated transportation period, the respective density bags were unsealed separately at 6, 12, 18 and 24 h respectively. The post-transport survival was determined by counting live and dead fishes (no opercular movement) immediately after opening each bags. The water temperature (°C), pH, salinity (ppt) and dissolved oxygen (mg/L) were measured using Eutech cyber scan series 600 portable meter. Subsequently, water samples were collected from the bags and refrigerated until analysis. Ammonia (ppm) levels were determined utilizing standard meters (Hanna).

Statistical analysis

All experiments employed a completely randomized design. Treatment means were compared using One-way Analysis of Variance (ANOVA) (Statistical package SPSS 16 version) and differences among means were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

The current study demonstrates that stocking density and transport time significantly affect the survival of seabass

Table 1: The survival rate of seabass 1-inch fry loaded at densities of 20, 40, 60, 80, and 100 fry/L and transported for 6, 12, 18 and 24 h, respectively.

Duration	Density				
	20 fry/L	40 fry/L	60 fry/L	80 fry/L	100 fry/L
6 h	100±0.0 ^a	100±0.0 ^a	99.9±0.1 ^a	99.2±0.1 ^a	90.5±1.3 ^b
12 h	99.3±0.0 ^a	99.2±0.0 ^a	99.2±0.1 ^a	98.3±0.1 ^a	87.7±0.8 ^b
18 h	99.0±0.1 ^a	99.2±0.2 ^a	99.1±0.1 ^a	89.0±1.2 ^b	71.3±1.6 ^c
24 h	99.0±0.3 ^a	98.5±0.0 ^a	90.7±0.1 ^b	75.5±1.7 ^c	62.4±1.1 ^d

Values are expressed as mean±SE of three replicates per treatment (n=3) and values with different superscript letters are significantly different ($p<0.05$) among treatments: h: Hours, L: litre.

Table 2: The survival rate of seabass 2-inch fry loaded at densities of 20, 40 and 60 fry/L and transported for 6, 12, 18 and 24 h, respectively.

Duration	Density		
	20 fry/L	40 fry/L	60 fry/L
6 h	99.3±0.3 ^a	99.2±0.2 ^a	98.2±0.5 ^b
12 h	99.0±0.6 ^a	96.5±0.3 ^a	87.4±1.3 ^b
18 h	97.0±0.6 ^a	66.2±1.3 ^b	55.3±2.3 ^c
24 h	94.3±0.3 ^a	37.2±2.8 ^b	19.2±1.3 ^c

Values are expressed as mean±SE of three replicates per treatment (n=3) and values with different superscript letters are significantly different ($p<0.05$) among treatments: h: Hours, L: litre.

fry and fingerlings as well as water quality. The initial biomass density for each treatment in seabass 1-inch fry was 6, 12, 18, 24 and 30 g/L, corresponding to stocking densities of 20, 40, 60, 80 and 100 fry/L, respectively. High survival rates of seabass 1-inch fry were observed at 6-12 h intervals at loading densities from 20, 40, 60 and 80 fry/L respectively and lower in 100 fry/L. During 6-12 h intervals transportation, no significant differences ($p>0.05$) were found among the lower densities (20-80 fry/L), while the highest density group (100 fry/L) showed a statistically lower survival rate ($p<0.05$) (Table 1).

In 18 h transportation, high survival rates of seabass 1-inch fry were observed at loading densities from 20, 40 and 60 fry/L respectively, which was significantly higher than 80 and 100 fry/L, respectively. After 24 h duration transportation, seabass 1-inch fry survival decreased notably in 60, 80 and 100 fry/L, respectively. Significantly higher survival was obtained in 20 and 40 fry/L, respectively. Decreased survival of seabass 1-inch fry was observed with increasing density and transport durations. However, when densities exceeded this range, a decline in survival was observed, highlighting the physiological stress associated with overcrowding (Li *et al.*, 2023). This pattern suggests that overcrowding results in stress, elevated ammonia levels and reduced dissolved oxygen, leading to higher mortality (Đinh and Nguyễn, 2022). A study by Chatterjee *et al.* (2010) observed a significant effect of packing density (40 or 80 g/L) on the survival of *Labeo rohita* fry. Seabass 1-inch fry packed at 40 g/L had significantly higher survival rates after 12, 24 and 36 h of transport compared to those packed at 80 g/L.

The lowest survival was recorded in the group transported at 80 g/L for 36 h.

The initial biomass density for each treatment in seabass 2-inch fry was 39.4, 78.8 and 118.2 g/L, corresponding to stocking densities of 20, 40 and 60 fry/L, respectively. Duration of transportation and stocking density had a significant impact on the survival rate of seabass 2-inch fry. Results showed that, as the seabass 2-inch fry density and transportation time increased, the survival gradually decreased ($p<0.05$). At 6 and 12 h transport duration there is no significant difference between survival rates at 20 and 40 fry/L observed, whereas a significantly lower survival was recorded at 60 fry/L. After 18 h, a notable decline in survival was noted. At 18 h, there is a significant difference ($p<0.05$) between survival between 20, 40 and 60 fry/L. By 24 h, the survival rate further declined and significantly different among the treatment 20, 40 and 60 fry/L (Table 2) indicating that larger fry necessitates lower stocking densities to reduce transport stress.

A study by Chen *et al.* (2021) demonstrated that increasing transport density and duration led to deteriorated water quality and reduced survival rates in juvenile Asian seabass. The authors recommend maintaining transport densities below 21 kg/m³ for 24-h durations to optimize survival and health.

The initial biomass density for each treatment in seabass 3-inch fingerlings was 50.3, 100.6 and 150.9 g/L, corresponding to stocking densities of 10, 20 and 30 fingerling/L, respectively. Seabass 3-inch fingerlings survival rates were greatly affected by the stocking densities. After the 6 h transport duration lower density 10 fingerlings/L had the highest survival rate as compared to the 20 and 30 fingerlings/L with significant differences among treatments ($p<0.05$). Survival rates kept going down after 12 h as the duration increased and there is a significant difference ($p<0.05$) between the 10, 20 and 30 fingerlings/L. Transporting for more than 12 h proved inadequate. At 18 h, survival at 10 fingerlings/L dropped a lot to 9.3±2.9% and there was no survival at either 20 or 30 fingerlings/L (Table 3).

All of the fingerlings died during 24 h transportation. These results show that seabass fingerlings are very sensitive to both being crowded and being transported for a long time. Even at the lowest density, survival after 12 h

was very low. This means that transportation should only happen for shorter periods of time with lower loading densities to keep fingerlings alive. Our results show that lower densities and shorter transport durations increase survival rates, which aligns with previous live fish transportation studies (Chatterjee *et al.*, 2010; Pongsetkul *et al.*, 2022). Generally, larger size fish are transported at lower stocking densities as absolute oxygen consumption and space requirements increases with size. The metabolic rate in fish fingerlings is higher than that of fry, resulting in a more rapid consumption of dissolved oxygen in closed transport systems. This increased metabolic activity also leads to a greater accumulation of waste products, such as ammonia, which can pose challenges for maintaining water quality and survival.

At the start of the experiment, water quality parameters were uniform across treatments, with salinity (15 ppt), temperature ($28.4 \pm 0.15^\circ\text{C}$), pH (7.9 ± 0.10), dissolved oxygen (13.6 ± 0.10 mg/L) and ammonia (0.0 ± 0.01 ppm), indicating optimal baseline conditions. During transport of seabass 1-inch fry, temperature increased slightly but significantly different at certain densities and time points ($p < 0.05$). At 6 and 12 h, temperatures across densities did not differ significantly ($p > 0.05$). At 18 h, temperature showed significant differences, with the highest densities 80 and

100 fry/L observed increase in temperatures compared to 20, 40 and 60 lower densities (Fig 1). After 6 h of transit DO is in the ranged from 9.1 ± 0.15 mg/L (20 fry/L) to 7.9 ± 0.06 mg/L (100 fry/L). As the transport duration extended to 24 h, DO levels dropped further, reaching 4.9 ± 0.15 mg/L (20 fry/L) and a minimum of 3.8 ± 0.06 mg/L (100 fry/L) (Fig 2). At most time points and densities, pH differences were not significant. However, at later time points, especially at 24 h and higher densities (100 fry/L) pH dropped significantly indicating acidification with prolonged transport and higher density (Fig 3). At 6 h there is no significant different between the level of ammonia among treatments (Fig 4). As the duration and increase in the size there is significant difference in the level of ammonia among lower densities and higher densities.

In seabass 2-inch fry transportation, after 6, 12, 18 and 24 h time duration there is no significance difference ($p > 0.05$) among the treatments in the temperature of water in the bags (Fig 5). DO levels showed a decreasing trend from 8.3 ± 0.20 mg/L (20 fry/L) to 7.1 ± 0.12 mg/L (60 fry/L) at 6 h of transportation, but they were still within acceptable ranges. By 24 h, DO had significantly decreased with prolonged transport; it was as low as 3.8 ± 0.06 mg/L at 60 fry/L and 5.3 ± 0.06 mg/L at 20 fry/L, indicating significant oxygen depletion in high-density treatments (Fig 6). The pH values also showed a decline (Fig 7). The pH declined slightly from at 24 h, but differences among densities were not significant ($p > 0.05$). Ammonia remained negligible up to 18 h without significant variation, but at 24 h, 60 fry/L showed a significant increase ($p < 0.05$) compared to 20 and 40 fry/L (Fig 8).

After 6 h of seabass 3-inch fingerlings transportation, water temperature of bags with 20 and 30 fingerlings/L were significantly higher than bags with 10 fingerlings/L, with this trend continuing until 24 h when the highest temperature was observed at 30 fingerlings/L (Fig 9). Elevated water temperatures accelerate fish metabolic activity and oxygen depletion, while moderate temperature reductions help to stabilise water quality and prolong survival during live transportation (Pramod *et al.*, 2010).

Table 3: The survival rate of seabass 3-inch fingerlings loaded at densities of 10, 20 and 30 fingerlings/L and transported for 6, 12, 18 and 24 h, respectively.

Duration	Density		
	10 fingerlings/L	20 fingerlings/L	30 fingerlings/L
6 h	97.3 ± 2.3^a	53.3 ± 5.3^b	16.4 ± 4.7^c
12 h	52.7 ± 3.3^a	22.7 ± 2.9^b	1.8 ± 0.5^c
18 h	9.3 ± 2.9^a	0	0
24 h	0	0	0

Values are expressed as mean $\pm$ SE of three replicates per treatment ($n=3$) and values with different superscript letters are significantly different ($p < 0.05$) among treatments: h: Hours, L: litre.

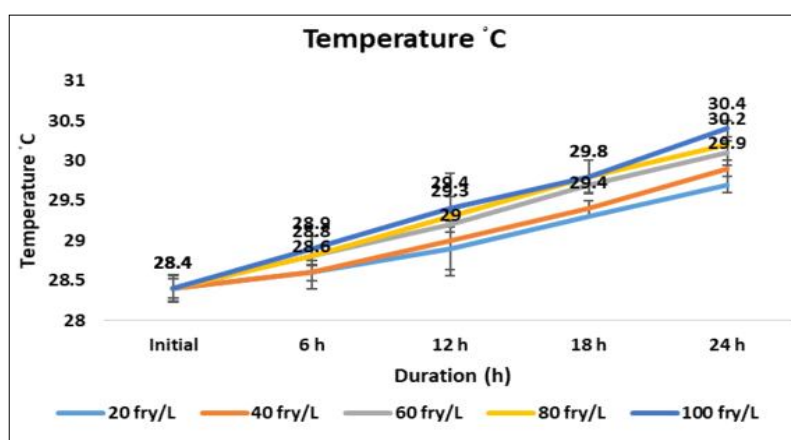


Fig 1: Temperature of seabass fry (2.6 ± 0.01 cm) in polythene bags during transportation with reference to duration and packing density.

The most important factor for the live fish transportation is an adequate amount of oxygen for the fish. The amount of oxygen required depends on the packing system and the number of fish, as well as the size of the fish (Ross and

Ross, 2009). Dissolved oxygen (DO) concentrations below 3-4 mg/L are considered critical for fish transport, as such levels induce hypoxic stress, impair metabolic functions and increase mortality risk. (Wu *et al.*, 2002). Dissolved

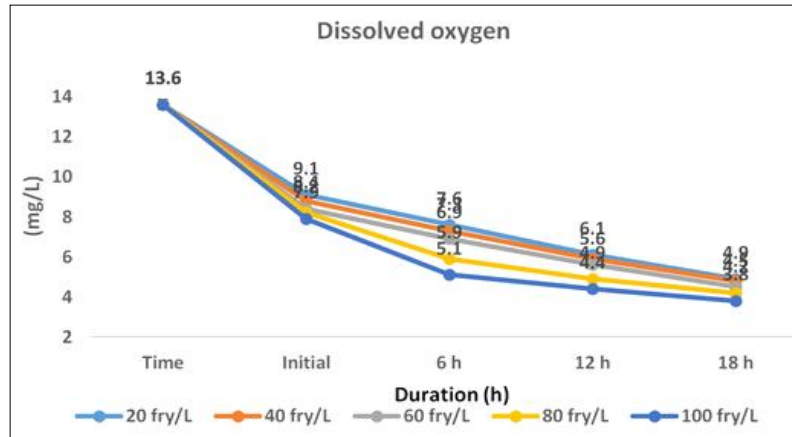


Fig 2: Dissolved oxygen of seabass fry (2.6±0.01 cm) in polythene bags during transportation with reference to duration and packing density.

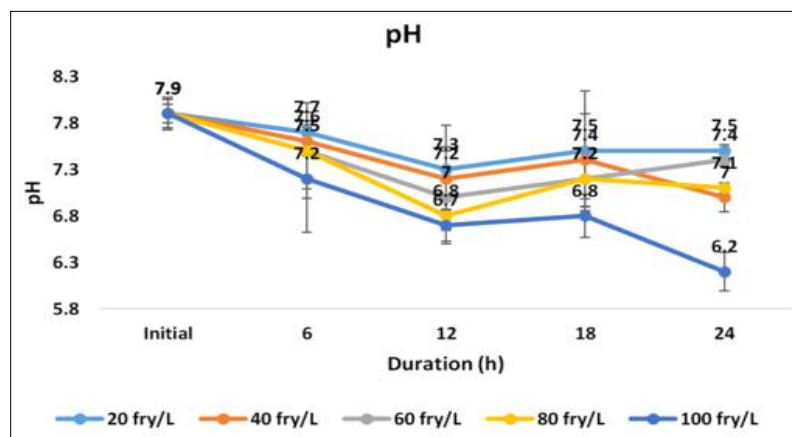


Fig 3: pH of seabass fry (2.6±0.01 cm) in polythene bags during transportation with reference to duration and packing density.

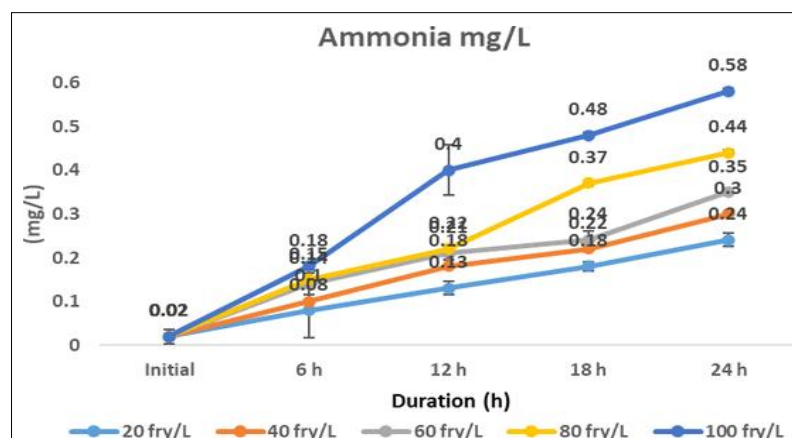


Fig 4: Ammonia of seabass fry (2.6±0.01 cm) in polythene bags during transportation with reference to duration and packing density.

oxygen (DO) levels declined significantly with an increase in time and density, decreasing from 2.4 ± 0.06 mg/L in 20 fingerlings/L to 1.1 ± 0.10 mg/L in 60 fingerlings/L density group over 24 h, underlining higher oxygen consumption

under crowded conditions (Fig 10). In most fish species, Oxygenated transport using sealed bags is generally preferable for short- to medium-duration transport at higher stocking densities, as it ensures stable dissolved oxygen

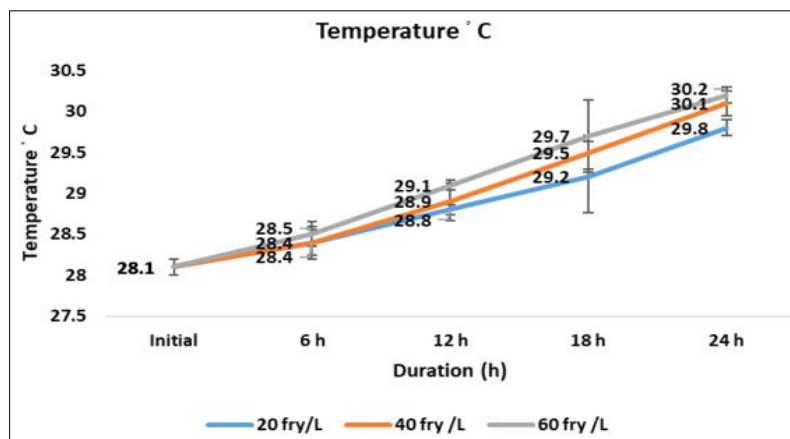


Fig 5: Temperature of seabass fry (5.2 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

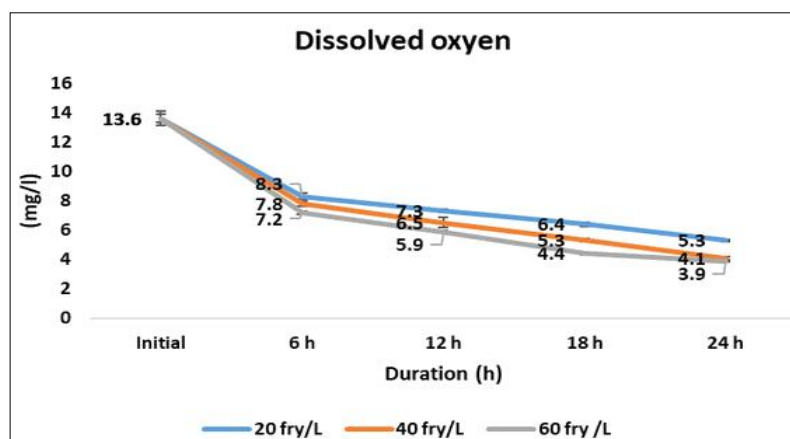


Fig 6: Dissolved oxygen of seabass fry (5.2 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

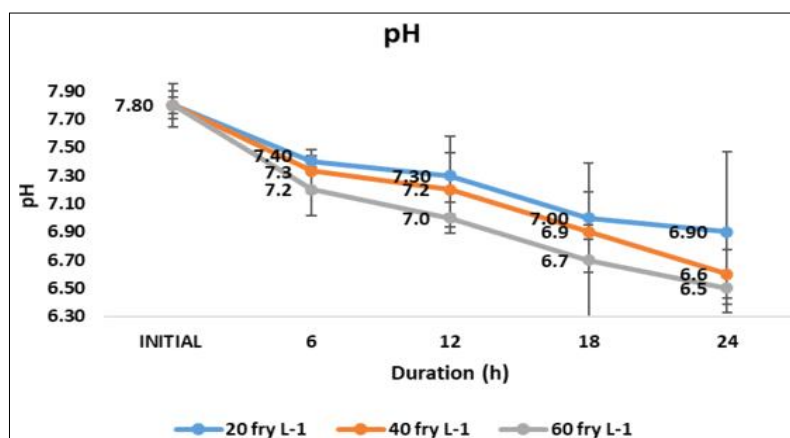


Fig 7: pH of seabass fry (5.2 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

levels and minimizes handling stress without the need for continuous aeration. In contrast, aerobic transport systems with open containers and mechanical aeration are more suitable for longer-duration transport or larger-sized fish,

where waste accumulation and temperature regulation become critical and periodic water exchange is possible. The pH values exhibited a continuous decline across all treatments as transportation time progressed, with

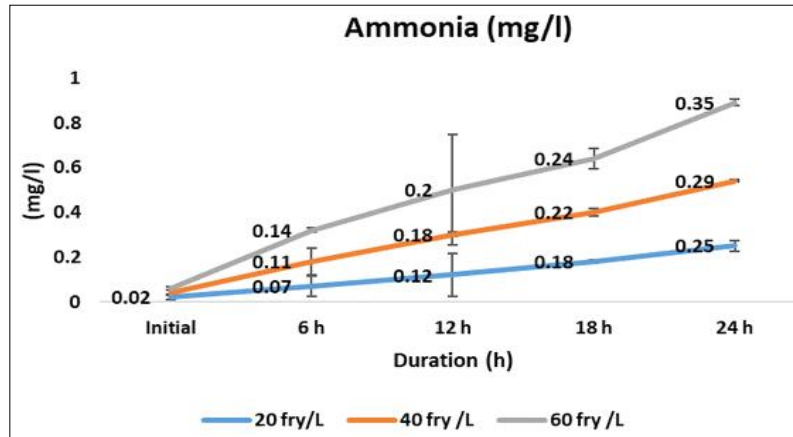


Fig 8: Ammonia of seabass fry (5.2 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

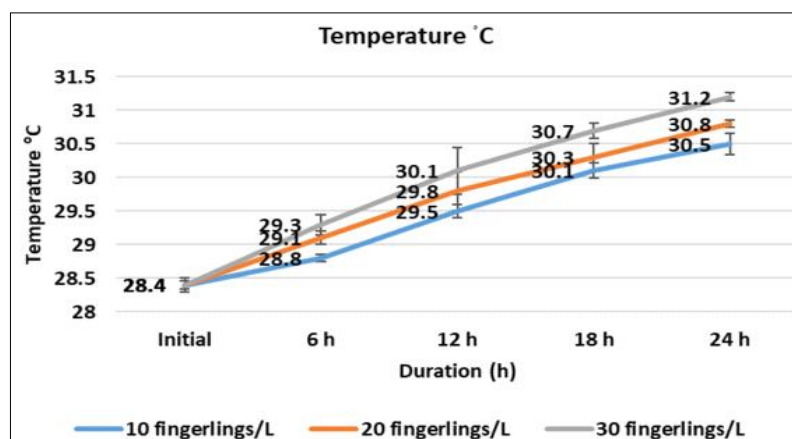


Fig 9: Temperature of seabass fingerlings (7.5 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

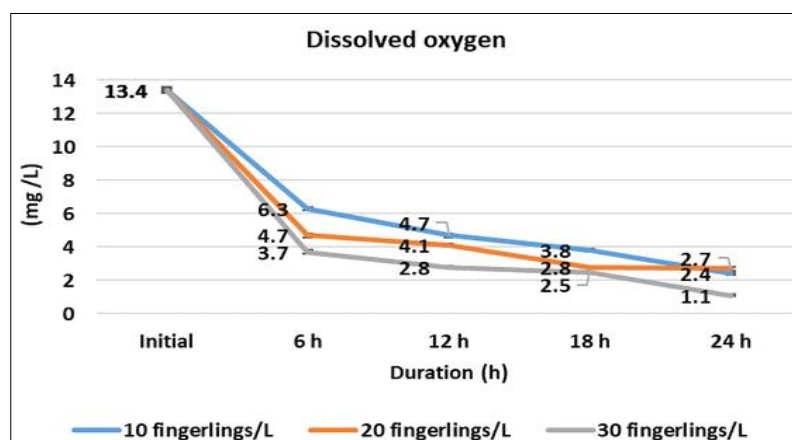


Fig 10: Dissolved oxygen of seabass fingerlings (7.5 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

significant differences ($p < 0.05$) evident at each interval (Fig 11). Lower pH levels were consistently associated with higher stocking densities, indicating stronger acidification effects under crowded conditions. Ammonia concentrations, which were negligible at the start, showed a steady increase over time and differed significantly ($p < 0.05$) among densities at every interval. Ammonia exceeded critical levels (> 1 mg/L) beyond 12 h, contributing to mass mortality (Fig 12).

Over time, the concentration of ammonia nitrogen rises, while the pH and dissolved oxygen in the water significantly drop (Bui *et al.*, 2013; Zeppenfeld *et al.*, 2014; Salbego *et al.*, 2015). Ammonia nitrogen, dissolved oxygen, pH and other water quality characteristics can all impact fish health, stress and survival during transport (Harmon, 2009). A study by Hong *et al.* (2019) found that pH dropped and ammonia nitrogen rose compared to the initial value, regardless of fish population in golden pompano (*Trachinotus ovatus*) fingerlings. This acidification mainly results from an increased concentration of carbon dioxide in seawater caused by fish respiratory activity (Lim *et al.*, 2003). The decrease in pH is due to fish under transit stress excreting more carbon dioxide (Parodi *et al.*, 2014).

As the stocking density and transportation duration increased and also the increase in the size of the fish, the dissolved oxygen level in seabass fry and fingerlings packed in a plastic bag decreased. Das *et al.* (2025) investigated the effects of stocking density and transport duration on water quality and survival of rohu (*Labeo rohita*) fry transported in oxygenated polythene bags, recommends maximum transport durations of 24 h at 200 fry per bag, 20 h at 250 fry per bag and 8 h at 300 fry per bag, balancing fry survival, DO levels and water quality. These results emphasize that optimizing density and duration is essential to maintain water quality and minimize mortality in live fry transport. The pronounced mortality observed in seabass fingerlings compared to fry is likely size-related rather than species-specific. Larger fingerlings possess higher absolute metabolic and oxygen demands and produce greater amounts of metabolic wastes, which can rapidly deteriorate water quality under confined transport conditions.

Several mitigation strategies have been shown to improve survival during live fish transport. The use of sedatives such as anesthetics can reduce fish activity and metabolic rate, lowering oxygen consumption and waste

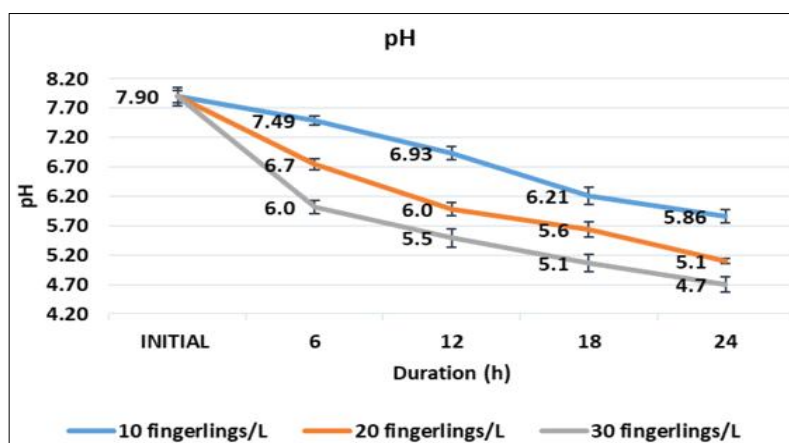


Fig 11: pH of seabass fingerlings (7.5 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

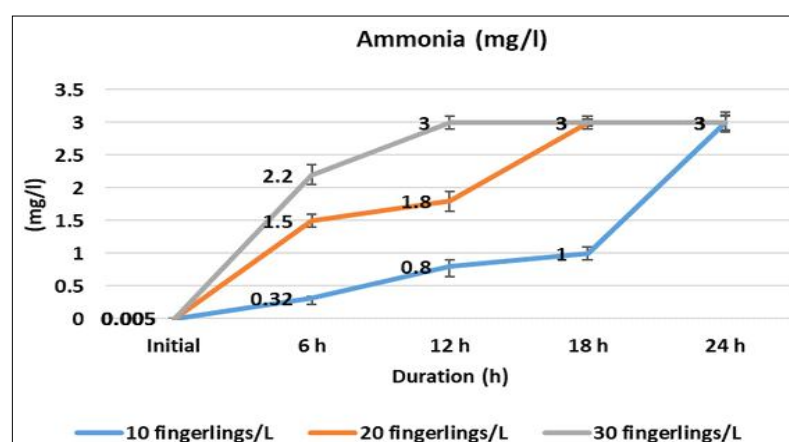


Fig 12: Ammonia of seabass fingerlings (7.5 ± 0.02 cm) in polythene bags during transportation with reference to duration and packing density.

production (Navarro *et al.*, 2016). Water conditioners and additives have also been explored to help maintain water quality and reduce stress responses during transport (Vanderzwalmen *et al.*, 2020). Cooling the water is a major strategy because lower temperatures reduce the fish's metabolism and need for oxygen (Harmon *et al.*, 2009).

CONCLUSION

The present study demonstrates that stocking density, seed size and transport duration are critical determinants of survival in live transportation of Asian seabass (*L. calcarifer*) seed. For seabass 1-inch fry, densities of 40-60 fry/L were found suitable for transport up to 18 h, whereas 20-40 fry/L supported higher survival for 24 h. The seabass 2-inch fry loaded at density of 20 fry/L found suitable for 18-24 h transport duration, while higher densities (40-60 fry/L) were viable only for shorter durations (≤ 12 h). However, seabass 3-inch fingerlings survived well at 10 fish/L for 6 h, but later survival declined drastically beyond this density and duration, indicating the need for lower densities and shorter transit times. While lower stocking densities during transport improve survival and reduce stress, they also increase operational costs by requiring more trips or larger transport containers to move the same quantity of seed. Across trials, elevated density and longer transport caused deterioration of water quality (decline in dissolved oxygen and pH, rise in ammonia), leading to stress and mortality. These findings provide the standardized densities for live transportation of seabass seed in closed system in India and will aid hatcheries and farmers in minimizing transit losses, ensuring efficient seed distribution and promoting the expansion of seabass farming.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Ethical approval

The study was undertaken with the approval of the statutory authorities of the Central Institute of Brackishwater Aquaculture, Chennai, India.

Conflict of interest

No conflict of interest was reported by the author(s).

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