Current Applied Science and Technology e-ISSN: 2586-9396

Curr. Appl. Sci. Technol. ….., Vol...(No...), e0267636

Researcharticle

Effect of Gradual Weaning on Survival and Growth of *Channa striata* (Channidae) Larvae under Different Feeding Regimes

Rubaiya Pervin[1], Nazifa Tasnim[1], Mojibur Rahman[1], Md. Rabiul Awal[2], Mohosena Begum Tanu[2] and Imran Parvez[1]*

[1]*Department of Fisheries Biology and Genetics, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh*
[2]*Bangladesh Fisheries Research Institute, Mymensingh-2201, Bangladesh*

Received: 17 May 2025,Revised:1 December 2025, Accepted: 17 March 2026 ,Published: 24 March 2026

Abstract

This study evaluated weaning methods for *Channa striata* larvae using a three-phase feeding trial with four treatments that included T_1 (control), T_2 (100% *Artemia*), T_3 (100% fish paste), and T_4 (50% formulated feed + 50% *Artemia*). In Phase I (Days 1-15), larvae were fed the respective treatments, followed by a gradual transition to formulated feed in Phase II (Days 16-30). By Phase III (Days 31-45), all groups received 100% formulated feed. Initial average length and weight were 3.26±0.23 cm and 0.56±0.07 g, respectively. Upon completion of the experiment, T_2 had the highest final survival rate (89%), with T_2 and T_3 showing significantly higher weight gain and specific growth rate (SGR). A strong positive correlation between dissolved oxygen and final weight ($r = 0.85$) highlighted the importance of oxygen for growth, while elevated ammonia concentrations negatively impacted growth ($r = -0.98$). The findings suggest that *C. striata* larvae can be effectively weaned to formulated feed either through initial exclusively live feeding followed by gradual transition or by using a combination of live and formulated feed from the beginning, both leading to enhanced survival and growth performance.

Keywords: *Channa striata*; Weaning methods; larvae feeding; growth performance; water quality parameters

1. Introduction

The domestication of new fish species for aquaculture heavily depends on developing effective larval rearing and nursing techniques. A critical phase in this process is the successful transition of larvae from live to formulated feeds. The weaning stage is essential in determining cultured species' survival, growth, and long-term performance (Qin& Fast, 1997; Kolkovski, 2001). Larval rearing success relies significantly on the availability of appropriate feeds that are readily ingested, easily digested, and nutritionally sufficient to promote optimal development and health (Kumar et al., 2008; Hamre et al., 2013).

*Corresponding author: E-mail: iparvez.fbg@tch.hstu.ac.bd
https://doi.org/10.55003/cast.2026.267636

appropriate feeds that are readily ingested, easily digested, and nutritionally sufficient to promote optimal development and health (Kumar et al., 2008; Hamre et al., 2013).

Several factors influence the success of weaning, including the larvae's age and initial size, feed type, feeding strategy, environmental conditions, and cannibalistic behavior (Kubitza &Lovshin, 1999). Since feeding strategies often vary with species-specific physiological and behavioral traits, tailored weaning protocols are crucial (Cahu& Infante, 2001). Given that weaning has a direct impact on hatchery efficiency, extensive research has been conducted to optimize weaning in a variety of fish species, including both carnivorous and omnivorous types (Gisbert &Williot, 2002).

Live feeds such as *Artemia*, rotifers, and zooplankton are commonly used in the early stages of larviculture due to their high palatability and digestibility (Dhert et al., 2001). However, large-scale application is limited by their high production cost, labour-intensive culture, and inconsistent quality (Le Ruyet et al., 1993; Sorgeloos et al., 2001). While microdiets have been developed as alternatives, their early introduction often results in reduced growth and survival, primarily due to the immature digestive system of larvae and inadequate attractants in formulated feeds (Kolkovski, 2001). Additionally, delayed acceptance of formulated feeds can exacerbate cannibalism, especially in carnivorous and piscivorous species (Baras & Jobling, 2002).

Channa striata, the striped snakehead, is a high-value freshwater fish species widely distributed in Southeast Asia and known for its air-breathing ability, medicinal value, and market demand (Courtenay & Williams, 2004;Aliyu-Paiko et al., 2010). In Thailand, India, and Vietnam, efforts to culture *C. striata* have moderately succeeded (Marimuthu &Haniffa, 2007; Marimuthu et al., 2007). In Bangladesh, however, commercial cultivation remains in its early stages, primarily due to poor quality fry, low spawning success, and limited knowledge of early life feeding and rearing practices (Mollah et al., 2009; Roy et al., 2020). Unlike carp species, the rearing of *C. striata* hatchlings and post-larvae poses more significant challenges due to their highly carnivorous and cannibalistic nature. These characteristics require carefully designed feeding protocols to prevent high mortality and improve performance (Qin & Fast, 1996).

From a practical and economic perspective, one of the primary considerations in snakehead farming is whether the prolonged use of expensive live feeds, which improves survival and growth, outweighs the cost-saving benefits of earlier transition to formulated feeds that may slightly compromise performance (Teshima et al., 2004). Therefore, the current study aimed to evaluate the effectiveness of different weaning strategies for *C. striata* larvae by gradually replacing live feed with formulated diets. The overarching goal was to develop a cost-effective and biologically sound weaning protocol to support the domestication and expansion of snakehead aquaculture in Bangladesh.

2. Materials and Methods

2.1 Ethics approval

The research was done with the permission of the University Ethical Committee of Hajee Mohammad Danesh Science and Technology University, No HSTU/ IRT 4361(1).

2.2Study area and study period

The study was conducted at the Fisheries Biology and Genetics Hatchery, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh.

The experiment was designed to replicate standard commercial fry production practices used in Southeast Asian countries. The feeding trial lasted six weeks and was carried out from June to July 2024.

2.3Fish larvae collection

Channa striata larvae were obtained through induced breeding of captive-bred broodstock maintained at the freshwater station of Bangladesh Fisheries Research Institute (BFRI), Mymensingh. Following hatching, larvae were initially fed with plankton soup after complete yolk sac absorption (approximately 3 days post-hatch) for 10 days. At 13 days of age, larvae were transported to the HSTU hatchery in oxygenated polyethylene bags. Upon arrival, they were acclimatized in circular tanks and fed boiled trash fish paste prior to the experimental setup. All larvae used in the experiment were from a single batch to ensure uniformity.

2.4 Fish stocking and rearing conditions

Larvae were stocked in 100-litres plastic tanks, each filled with 50 L of dechlorinated water. Fifty larvae were stocked per tank (1 fish/L). Prior to stocking, initial larval body length (3.26±0.23 cm) and weight (0.56±0.07 g) were recorded. The tanks were cleaned daily with partial water exchange (approximately two-thirds of the volume) before the first feeding. Residual feed and fecal matter were siphoned out daily. Dead fish were removed and recorded regularly.

2.5 Experimental design

The feeding trial consisted of three weaning phases over a total period of six weeks. Four dietary treatments were applied, with each treatment having three replicates (4 treatments × 3 replicates = 12 tanks). The treatment groups were as follows, T_1 (Control): 100% formulated feed throughout the trial; T_2: Initial 100% *Artemia*, gradually replaced with formulated feed; T_3: Initial 100% fish paste, steadily replaced with formulated feed, and T_4: Mixed live and formulated feed initially with gradual transition. The feeding regime and weaning schedule for each treatment group are summarized in Table 1.

2.6 Water quality monitoring

Water quality parameters were monitored weekly following standard methods (APHA, 2005). A portable multimeter (hm Digital COM-300) measured dissolved oxygen (DO), temperature, and pH. Total alkalinity was measured in the laboratory using the methyl orange indicator method. Ammonia, nitrite (NO_2^-), and nitrate (NO_3^-) concentrations were measured using a HACH water testing kit (Model: DR-210, USA). Water quality was maintained within optimal ranges for larval rearing.

Table 1. Experimental design of feeding trial for *C. striata* larvae

Phase	Treatment	Feeding Composition	Duration	Age of Fish (Days)	Feeding Rate
I	T_1 (Control)	100% Formulated feed	2 weeks	17–30 days	Up to satiation
	T_2	100% *Artemia*			
	T_3	100% Fish paste			
	T_4	50% Formulated + 50% *Artemia*			
II	T_1	100% Formulated feed	2 weeks	31–45 days	10% of body weight
	T_2	50% Formulated + 50% *Artemia*			
	T_3	50% Formulated + 50% Fish paste			
	T_4	75% Formulated + 25% *Artemia*			
III	All groups	100% Formulated feed	2 weeks	46–60 days	8% of body weight

2.7 Diet preparation

2.7.1 Formulated feed

A commercially available micro-particulate starter feed (Ultra Mash Powder, Tiger Brand, Eon Feed Ltd., Eon group) was usedas the primary larval feed. The feed contained fishmeal, soybean meal, wheat flour, vitamins, minerals, enzymes, and essential oils.Its proximate composition was as follows: protein 35%, moisture 12%, fat 6%, carbohydrate 28%, fiber 5%, ash 16%, calcium 2.3%, phosphorus 0.8%.Prior to feeding, the dry micro diet was mixed with filtrate hatchery water, kneaded into a uniform paste and sieved to obtain250-500 µm particles. The micro diet was then diluted to slurry using a 1:5 feed-to-water ratio, consistent with established micro diet preparation protocols (Blair et al., 2003).The slurry was dispensed gently across the tank surface with temporarily reduced water inflow to minimize particle loss and was prepared fresh before each feeding event.

2.7.2 *Artemianauplii*

Decapsulated *Artemia* cysts (Dancing Crane brand) were hatched following the standard protocols (Campton & Busack, 1989).Hatching occurred in conical flasks under constant aeration and intense illumination from a 1000-watt bulb. Salinity was maintained at 25-30 ppt, temperature at 30°C, and pH between7.5-8.5. Hatching occurred within 24-36 h, with an average hatching success rate of 90%. After hatching, nauplii were collected via siphoning and confirmed microscopically. Proximate composition (% of dry weight basis): protein 45.08%, moisture 7.09%, fat 0.16%, carbohydrate 45.53%, fiber 37.87%, and ash 2.14%.

2.7.3 Fish paste

Small trash fish were collected from a local market. Next, the fish were boiled and the bones removed manually.The boiled and deboned fish were then minced to form a fine paste suitable for larval ingestion. Proximate composition of the paste (% of wet weight basis)was: protein 21.12%, moisture 73.21%, fat 0.84%, carbohydrate 3.22%, fiber 1.3%, and ash 1.61%.

2.8 Sampling and growth monitoring

Weekly sampling (n = 10 per tank) was conducted to monitor growth and adjust feeding rates accordingly. Mortality and signs of cannibalism were recorded daily. Missing individuals were assumed to be victims of cannibalism. The following parameters were calculated:

Survival Rate (%)	= (No. of fish alive / No. of fish stocked) × 100
Weight Gain (g)	= Final weight − Initial weight
Specific Growth Rate (SGR, %/day)	= [(In Final weight − In Initial weight) / Number of days] × 100
Observed Mortality (%)	= (Dead fish with no sign of cannibalism / Total fish stocked) × 100
Cannibalism (%)	=[(Total dead − Observed mortality) / Total stocked] × 100
Total Mortality	= Observed mortality + Cannibalism

2.9 Statistical analysis

All the data sets were subjected to a normality test using the Shapiro-Wilk test(Shapiro & Wilk,1965) to ensure the assumptions of parametric analysis were met.To compare the growth and survival of larvae among the four treatment groups, a one-way analysis of variance (ANOVA)was conducted to determine if feeding control had a significant effect on the growth and survival performance of *C. striata*. Post-hoc comparisons (Tukey's HSD) were performed where significant differences were found (Tukey, 1953). Variables that satisfied the assumption of normality were further analyzed using Pearson's correlation coefficient (r) test (Pearson,1985) to assess the strength and direction of linear relationships between final weight and each independent variable. This analysis was performed using Python 3(Virtanen et al., 2020), which also provided p-values to assess statistical significance. All statistical visualizations, including correlation plots and ANOVA summary graphs, were created using Matplotlib(Hunter, 2007). The statistical significance was established at a 5% probability level.

3. Results and Discussion

This study evaluated the water quality parameters and the survival and growth performance of *C. striata* larvae under different dietary treatments, including varying combinations of formulated feed, live *Artemia* and fish paste. The results demonstrate how dietary strategies influence water quality and larval development, with significant variations in survival, growth, and cannibalism observed across the treatments.

3.1 Water quality parameters

Throughout the experimental period, water temperature remained within acceptable ranges for *C. striata* larval rearing (Table 2). The water temperature did not show significant variation across treatments (p>0.05), ranging from 29.13±0.59°C in T_2 to 29.36±0.59°C in T_4, indicating uniform thermal conditions in all experimental tanks.However, significant differences were observed in pH levels among treatments (p<0.05). The highest pH values were recorded in T_2 (7.68±0.12) and T_3 (7.67±0.13), both significantly higher than the control group T_1 (7.29±0.27). Treatment T_4 exhibited an intermediate pH value (7.50±0.24), which was not significantly different from T_1 and T_3. Dissolved oxygen (DO) levels also differed significantly among treatments (p<0.05). The highest DO was recorded in T_2 (6.90±0.48 mg/L), followed by T_3 (6.80±0.76 mg/L) and T_4 (6.69±0.85 mg/L), while the lowest was observed in T_1 (6.03±0.99 mg/L). Total alkalinity varied significantly between treatments (p < 0.05), with T_1 exhibiting the highest value (118.22±0.41 mg/L), followed by T_3 (116.51±0.50 mg/L), T_2 (115.96±0.33 mg/L), and the lowest in T_4 (115.21±0.66 mg/L). Ammonia (NH_3) levels were significantly higher in T_1 (0.04±0.017 mg/L) compared to other treatments (p<0.05). The lowest ammonia concentration was observed in T_2 (0.01±0.002 mg/L). T_3 and T_4 had intermediate values of 0.02±0.004 mg/L and 0.03±0.009 mg/L, respectively.In contrast, nitrate (NO_3^-) and nitrite (NO_2^-) levels did not differ significantly across treatments (p>0.05). Nitrate concentrations ranged from 4.39±0.49 mg/L in T_1 to 4.72±0.60 mg/L in T_2, while nitrite concentrations remained between 0.43±0.04 mg/L (T_1) and 0.47±0.07 mg/L (T_3). Overall, treatments incorporating live or mixed feeding strategies (T_2, T_3, and T_4) maintained better water quality parameters compared to the control (T_1), which relied solely on formulated feed.

Water quality is a crucial factor influencing the health and growth of aquatic organisms in aquaculture (Boyd &Tucker, 2012). In this study, water temperature remained consistent across treatments (29.13°C-29.36°C), well within the optimal range for *C. striata* larvae (28-30°C) (Do et al., 2021).The variations in pH among treatments with significantly higher values in T_2 and T_3 compared to T_1 suggested that live and semi-moist feeds like *Artemia* and fish paste may act as pH buffers (Das et al., 2014). This buffering effect could result from the organic matter in live feeds, which may neutralize acids produced during microbial degradation of organic waste (Das et al.,2014).Dissolved oxygen (DO) levels were significantly higher in treatments with live feeds (T_2 and T_3), which could be attributed to the improved water quality and reduced microbial load in these treatments (Zhou et al., 2022). In contrast, the lower DO observed in the control group (T_1) could be linked to the higher organic load resulting from uneaten formulated feed, leading to greater oxygen consumption due to microbial degradation (Hlaváčet al., 2014).The ammonia levels were also significantly lower in T_2, likely due to the lower nitrogenous waste produced by *Artemia,* which is known for its high digestibility and low nitrogen excretion (Morais et al., 2004). Ammonia accumulation is a significant concern in

Table 2. Water quality parameters during the feeding trial of *Channa striata* larvae under different treatments

Parameters	T_1 (Control)	T_2 (100% *Artemia*)	T_3 (100% Fish Paste)	T_4 (50% Formulated + 50% *Artemia*)
Temperature (°C)	29.26±0.61	29.13±0.59	29.13±0.72	29.36±0.59
pH	7.29±0.27^{b}	7.68±0.12^{a}	7.67±0.13^{a}	7.50±0.24^{ab}
DO (mg/L)	6.03±0.99^{b}	6.90±0.48^{a}	6.80±0.76^{ab}	6.69±0.85^{ab}
Total Alkalinity (mg/L)	118.22±0.41^{a}	115.96±0.33^{c}	116.51±0.50^{b}	115.21±0.66^{d}
NH_3 (mg/L)	0.04±0.017^{a}	0.01±0.002^{c}	0.02±0.004^{c}	0.03±0.009^{b}
NO_3 (mg/L)	4.39±0.49	4.72±0.60	4.62±0.31	4.59±0.39
NO_2 (mg/L)	0.43±0.04	0.47±0.05	0.47±0.07	0.46±0.06

Note: Values are presented as mean ± standard deviation. Different superscript letters (a, b, c, d) within the same row indicate significant differences among treatments (Tukey HSD, $p<0.05$).

aquaculture, as highconcentrations can be toxic to larvae, affecting their survival and growth (Shiwanand & Tripathi, 2013). The significant difference in ammonia levels highlights the importance of incorporating live feeds in reducing nitrogenous waste in the initial stage of weaning.

3.2 Growth and survival of *C. striata* larvae

The growth performance and survival of *C. striata* larvae varied significantly among the different treatment groups after six weeks (Table 3 and Figure 1). Initial length and weight were consistent across all treatments (3.26±0.23 cm and 0.56±0.07 g, respectively), indicating uniformity at the beginning of the trial. Upon completion of the experiment, survival rates ranged from 66% to 89%, with the highest survival observed in treatment T_2 (89%), followed by T_3 (86%) and T_4 (82%). The lowest survival with highest mortality, both total and observedmortality,was recorded in T_1 (66%). This was likely due to the poor palatability,digestibility, or nutritional adequacy in this treatment. Cannibalism was relatively low and uniform, suggesting that the feeding regime had a greater effect on survival than aggression-related mortality. The survival rates observed in this study highlight the beneficial effects of live and semi-live feeds at the beginning. Treatment T_2 (100% *Artemia*) demonstrated the highest survival (89%) at the end of the experiment with low cannibalism, consistent with previous studies that show live feeds such as *Artemia* enhanced the survival of fish larvae by improving nutritional intake and reducing stress (Joshua et al., 2022). In contrast, the control group (T_1) exhibited significantly lower survival (66%) and the highest mortality and cannibalism, which aligned with findings from Kalaiselvan et al. (2024), who noted that reliance on formulated feed alone could lead to poor survival and increased competition and cannibalism among larvae. The reduced survival and higher cannibalism in T_1 could also be linked to the poor nutritional quality of formulated feeds compared to live prey, which provides essential fatty acids and other nutrients critical for larval development (Salze & Davis, 2015). This was in agreement with Ciji and Akhtar (2021), who showed that *Artemia*and other different live feeds improved the overall survival and behavior of fish larvae by reducing stress and aggressive interactions.

Table 3. Growth parameters (mean±SD) of *C. striata* larvae in different treatments after Phase III

Treatment	Survival (%)	Initial Length (cm)	Initial Weight (g)	Final Length (cm)	Final Weight (g)	Weight Gain (g)	SGR (%/day)
T_1	66	3.26 ±0.23	0.56 ±0.07	7.10 ±0.24 ^{b}	1.52 ±0.21 ^{b}	0.96 ±0.14 ^{b}	2.38 ±0.14 ^{b}
T_2	89	3.26 ±0.23	0.56 ±0.07	8.10 ±0.18^{a}	2.70 ±0.34 ^{a}	2.14 ±0.27 ^{a}	3.75 ±0.27 ^{a}
T_3	86	3.26 ±0.23	0.56 ±0.07	8.04 ±0.16 ^{a}	2.46 ±0.26 ^{a}	1.9 ±0.19 ^{a}	3.52 ±0.19 ^{a}
T_4	82	3.26 ±0.23	0.56 ±0.07	7.05 ±0.22 ^{b}	1.79 ±0.55 ^{b}	1.23 ±0.48 ^{b}	2.76 ±0.48 ^{b}

Values are presented as mean±standard deviation. Different superscript letters (a, b) within the same column indicate significant differences among treatments (Tukey HSD, $p < 0.05$)

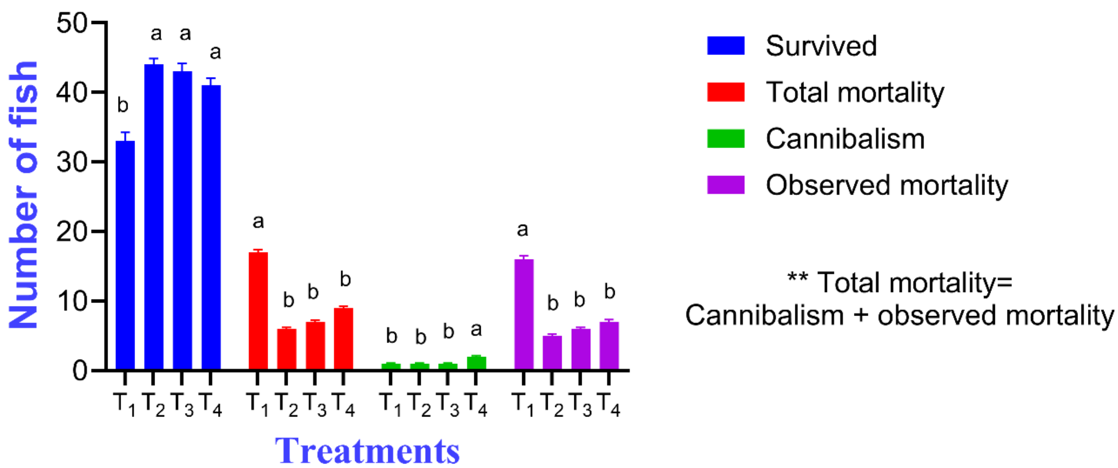

Figure 1. Survival, total mortality, cannibalism, and observed mortality of fish under different treatments (T_1–T_4). Bars represent the mean±SD of the number of fish in each category. Different letters above the bars indicate statistically significant differences between treatments ($p<0.05$).

Final length and weight of larvaedifferedsignificantlyamongtreatments ($P<0.05$). The highest final length (8.10±0.18 cm) and final weight (2.70±0.34 g) wereobserved in T_2, followedclosely by T_3 (8.04±0.16 cm; 2.46±0.26 g). These values weresignificantlygreaterthanthoserecorded in T_1 (7.10±0.24 cm; 1.52±0.21 g) and T_4(7.05±0.22 cm; 1.79±0.55 g). Weight gain and specificgrowth rate (SGR) followed a similar trend. T_2exhibited the highestweight gain (2.14±0.27 g) and SGR

(3.75±0.27%/day), whichwassignificantlyhigherthan T_1 and T_4 ($P<0.05$). Following T_2, T_3alsoshowedhigherweightgain performance (1.90±0.19 g; 3.52±0.19%/day), whichwas not significantlydifferentfrom T_2,but significantlyhigherthan the othertwotreatments. T_1recorded the lowestweight gain (0.96±0.14 g) and SGR (2.38±0.14%/day), whichweresignificantlylowerthan T_2 and T_3. T_2 (100% *Artemia*) and T_3 (100% fish paste) were the most effective treatments for maximizingsurvival and minimisingmortality (Figure 1). Theseresultssuggestedthat live *Artemia* and fish paste provides a high-qualityprotein source essential for larvalgrowth. Thesefindings are consistent withthose of Akbary et al.(2010),whoreportedsuperiorgrowth performance in fishlarvaefed live or semi-live feedscompared to thosefedsolelyformulatedfeed.

The growthdifferencesbetweentreatmentsmayalsoberelated to the digestibility and nutritional composition of the feeds. Live *Artemia*, whichcontains high levels of essential fattyacids and proteins, isknown to improve the growth of fishlarvae by providing more bioavailablenutrientsthanformulatedfeeds (Léger et al.,1987). In contrast, T_1, whichreliedsolely on formulatedfeed, provided suboptimal nutrition for the larvae, resulting in lowerweight gain and SGR, consistent with the findings of Sales (2011).

Overall, treatment T_2 demonstrated the most favorable combination of high survival and superior growth performance, suggesting its effectiveness in promoting the growth and survival of *C. striata* larvae during weaning.

3.3 Relationship of growth and survival rate with water quality parameters

A correlation analysis was conducted to assess the relationship between the final weight of *C. striata* larvae and key water quality parameters as well as survival rate across treatments (Figure 2). A robust positive correlation was observed between dissolved oxygen and final weight ($r = 0.85$), indicating that higher levels of dissolved oxygen significantly supported larval growth. Similarly, survival rate also exhibited a strong positive correlation with final weight ($r = 0.92$), suggesting that treatments with higher survival outcomes were also associated with improved growth performance. In contrast, ammonia concentration showed a strong negative correlation with final weight ($r = -0.98$), implying that elevated ammonia levels adversely affected larval growth. Additionally, pH had a strong positive correlation with final weight ($r = 0.95$), reflecting that pH levels closer to optimal values were beneficial for larval development.

The correlation analysis in this study provided valuable insights into how the water quality parameters and survival rates affect the growth performance of *C. striata* larvae under different weaning regimes. A strong positive correlation between dissolved oxygen (DO) and final weight highlights the essential role of oxygen availability in larval growth. Adequate DO is essential for supporting metabolic functions, feed assimilation, and overall physiological development in fish larvae (Buentello et al., 2000). Previous studies have also demonstrated that low DO levels can impair growth and increase stress sensitivity in the early life stages of many freshwater species (Boyd & Tucker, 1998). However, a significant negative correlation was associated between ammonia concentration and final weight, indicating that even slight elevations in ammonia adversely affected larval growth. Ammonia, especially in its un-ionised form (NH_3), is toxic to fish and can disrupt osmoregulation and gill function (Randall & Tsui, 2002). This also aligns with the reports of Azim and Little (2008), who noted that maintaining low ammonia levels is crucial for larval rearing success in intensive aquaculture systems. Further, the strong positive correlation between pH and final weight suggests that maintaining pH within an optimal range (around 7.5-7.8) favors larval development.

Extremes in pH are known to affect enzyme activity, ion exchange, and nutrient availability, thereby impacting growth and survival (Boyd, 1990). Although all treatments in this study maintained pH within an acceptable range for tropical freshwater species, even slight differences appeared to influence growth outcomes.

In addition, the strong positive correlation between survival rate and final weight highlights the links between survival and growth performance. Higher survival often indicates favorable environmental and nutritional conditions, which, alongside support better weight gain. This observation is consistent with the findings of Hieu et al. (2022), who reported a positive link between survival and biomass yield in larval rearing of *Channa* spp. The best-performing treatment in this study, T2 (100% *Artemia*), demonstrated both the highest survival and growth, suggesting that early-stage feeding with live prey not only improves nutrient uptake but also mitigates cannibalism and stress. Collectively, these findings demonstrate the importance of maintaining optimal water quality parameters especially dissolved oxygen and ammonia during the critical weaning phase. The results also indicate that incorporating live feed, such as *Artemia*, into early weaning strategies enhances both survival and growth performance in *C. striata* larvae. These findings also align with the broader body of literature on the advantages of live feeds in the early larval stages of various fish species (Morais et al., 2004; Zhou et al., 2022).

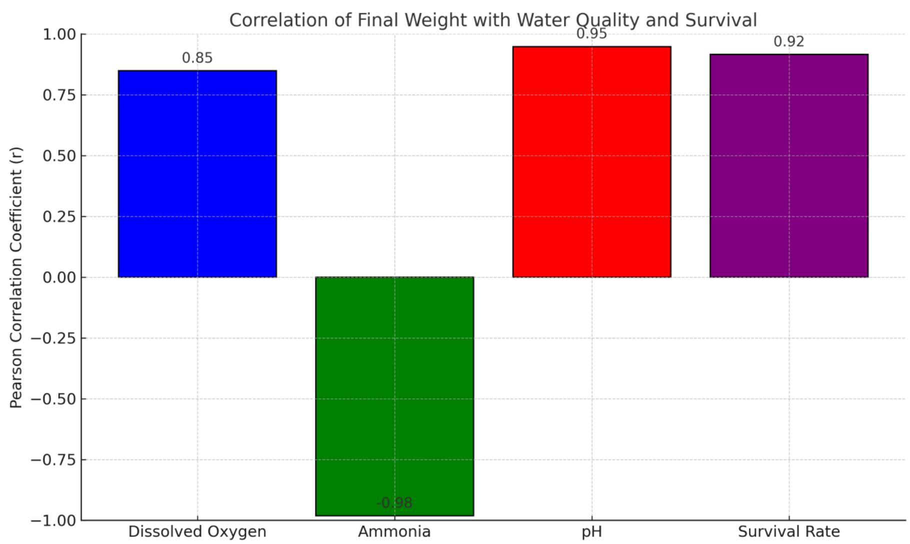

Figure 2. Pearson correlation coefficients between final weight and water quality parameters (dissolved oxygen, ammonia, pH) as well as survival rate

4. Conclusions

The results of this study underscore the importance of incorporating live or semi-live feeds, particularly *Artemia* and fish paste, into the early stages of larval rearing for *C.striata*. These feeds improve survival and growth performance and contribute to better water quality by reducing organic waste and nitrogenous compounds. Therefore, switching from live or mixed feeding to formulated feed might be a more practical way to rear *C. striata* larvae in aquaculture. This study also shows how important it is to keep good water quality and to include live feeds during weaning to improve growth and survival. The results provide helpful information on weaning methods that could help improve aquaculture practices for this species, leading to increased production efficiency and sustainability in intensive farming. Future research should look at the long-term effects of different feeding strategies on the development of *C. striata*, such as their effects on juvenile growth, stress tolerance, and disease resistance.

5. Acknowledgements

We sincerely thank Institute of Research and Training, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200, Bangladesh for ethical approval and logistic support of the research. We also appreciate the Department of Fisheries Biology and Genetics, HSTU, for laboratory support, and the Bangladesh Fisheries Research Institute (BFRI) for the *Channa striata* larvae and other assistance.

6. Authors' Contributions

Rubaiya Pervin, Imran Parvez designed research; Rubaiya Pervin, Nazifa Tasnim,Mojibur Rahman performed research; Rubaiya Pervin, Imran Parvez contributed new reagents/analytic tools; Rubaiya Pervin, Imran Parvez, Md. Rabiul Awal analyzed data;Imran Parvez,Mohosena Begum Tanu coordinated research; and Rubaiya Pervin, Imran Parvez wrote the paper.

ORCID

Rubaiya Pervin https://orcid.org/0000-0002-9870-8845

Nazifa Tasnim https://orcid.org/0009-0008-6798-4194

Md. Rabiul Awal https://orcid.org/0009-0004-8587-7908

Iman Parvez https://orcid.org/0000-0001-6785-6792

7. Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Akbary, P., Hosseini, S. A., Imanpoor, M., Sudagar, M., &Makhdomi, N. M. (2010). Comparison between live food and artificial diet on survival rate, growth and body chemical composition of *Oncorhynchus mykiss* larvae. *Iranian Journal of Fisheries Sciences*, *9*(1), 19-32.

Aliyu-Paiko, M., Hashim, R., & Shu-Chien, A. C. (2010). Influence of dietary lipid/protein ratio on survival, growth, body indices and digestive lipase activity in Snakehead (*Channa striatus*, Bloch 1793) fry reared in re-circulating water system. *Aquaculture Nutrition*, *16*(5), 466-474. https://doi.org/10.1111/j.1365-2095.2009.00683.x

APHA, 2005. *Standard methods for the examination of water and wastewater*. 21st ed. American Public Health Association.

Azim, M.E., & Little, D.C. (2008). The biofloc technology (BFT) in indoor tanks: Water quality, biofloc composition, and growth and welfare of Nile tilapia (*Oreochromis niloticus*). *Aquaculture,283*, 29-35. https://doi.org/10.1016/j.aquaculture.2008.06.036

Baras, E., & Jobling, M. (2002). Dynamics of intracohort cannibalism in cultured fish. *Aquaculture Research*, *33*, 461-479. https://doi.org/10.1046/j.1365-2109.2002.00732.x

Blair, T., Castell, J., Neil, S., D'Abramo, L., Cahu, C., Harmon, P., & Ogunmoye, K. (2003). Evaluation of microdiets versus live feeds on growth, survival and fatty acid composition of larval haddock (*Melanogrammus aeglefinus*). *Aquaculture, 225*(1-4), 451-461. https://doi.org/10.1016/S0044-8486(03)00309-0

Boyd, C.E. (1990). *Water quality in ponds for aquaculture*. Alabama Agricultural Experiment Station, Auburn University.

Boyd, C.E., & Tucker, C.S. (1998). *Pond aquaculture water quality management*. Springer Science & Business Media.

Boyd, C.E., & Tucker, C.S. (2012). *Pond aquaculture water quality management*. Springer Science & Business Media.

Buentello, J.A., Gatlin, D.M., & Neill, W.H. (2000). Effects of water temperature and dissolved oxygen on daily feed consumption, feed utilization and growth of channel catfish (*Ictalurus punctatus*). *Aquaculture*, *182*, 339-352.https://doi.org/10.1016/S0044-8486(99)00274-4

Cahu, C.L., & Infante, J.L. (2001). Substitution of live food by formulated diets in marine fish larvae. *Aquaculture, 200*, 161-180. https://doi.org/10.1016/S0044-8486(01)00699-8

Campton, D. E., & Busack, C. A. (1989). Simple procedure for decapsulating and hatching cysts of brine shrimp (*Artemia* spp.). *The Progressive Fish-Culturist*, *51*(3), 176-179. https://doi.org/10.1577/1548-8640(1989)051<0176:SPFDAH>2.3.CO;2

Ciji, A., & Akhtar, M. S. (2021). Stress management in aquaculture: A review of dietary interventions. *Reviews in Aquaculture*, *13*(4), 2190-2247. https://doi.org/10.1111/raq.12565

Courtenay, W.R., & Williams, J.D. (2004). Snakeheads (Pisces, Channidae): A biological synopsis and risk assessment (USGS Circular No. 1251). U.S. Geological Survey. https://doi.org/10.3133/cir1251

Das, P., Mandal, S. C., Bhagabati, S. K., Akhtar, M. S., & Singh, S. K. (2014). Important live food organisms and their role in aquaculture. In J. K. Sundaray, M. Sukham, R. K. Mohanty, & S. K. Otta (Eds.). *Frontiers in aquaculture* (pp 69-86). Narendra Publishing House. https://doi.org/10.13140/RG.2.2.21105.07523

Dhert, P., Rombaut, G., Suantika, G., & Sorgeloos, P. (2001). Advancement of rotifer cultureand manipulation techniques in Europe. *Aquaculture*, *200*(1-2),129-146. https://doi.org/10.1016/S0044-8486(01)00697-4

Do, T. T. H., Nguyen, T. K. H., Nguyen, T. E., Tang, M. K., Yasuaki, T., & Nguyen, T. P. (2021). Effects of temperature on growth performance, survival rate, digestive enzyme activities and physiological parameters of striped snakehead (*Channastriata*) at fry stage. *Can Tho University Journal of Science*, *13*(Special issue: Aquaculture and Fisheries), 10-20. https://doi.org/10.22144/ctu.jen.2021.012

Gisbert, E., & Williot, P. (2002). Advances in the larval rearing of Siberian sturgeon. *Journal of Fish Biology*, *60*(5), 1071-1092. https://doi.org/10.1111/j.1095-8649.2002.tb01705.x

Hamre, K., Yúfera, M., Rønnestad, I., Boglione, C., Conceição, L.E.C., & Izquierdo, M. (2013). Fish larval nutrition and feed formulation: Knowledge gaps and bottlenecks for advances in larval rearing. *Reviews in Aquaculture*, *5*, S26-S58. https://doi.org/10.1111/j.1753-5131.2012.01086.x

Hieu, T. K., Van, V. T. T., Thien, P. C., & Diep, D. X. (2022). Effects of different stocking densities on growth and survival rate of Dau Nhim snakehead (*Channa* sp.)

fingerlings. *Aquaculture, Aquarium, Conservation and Legislation Bioflux*, *15*(3), 1124-1132.

Hlaváč, D., Adámek, Z., Hartman, P., & Másílko, J. (2014). Effects of supplementary feeding in carp ponds on discharge water quality: A review. *Aquaculture International*, *22*(1), 299-320.https://doi.org/10.1007/s10499-013-9718-6

Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. *Computing in Science and Engineering, 9*, 90-95. https://doi.org/10.1109/MCSE.2007.55

Joshua, W.J., Kamarudin, M.S., Ikhsan, N., Yusoff, F. M., & Zulperi, Z. (2022). Development of enriched *Artemia* and *Moina* in larviculture of fish and crustaceans: a review. *Latin American Journal of Aquatic Research, 50*(2), 144-157. https://doi.org/10.3856/vol50-issue2-fulltext-2840

Kalaiselvan, P., Ranjan, A., Nazir, M. I., Suresh, E., Thangarani, A. J., & Malarvizhi, K. (2024). Effect of different early weaning diets on survival, growth, and digestive ontogeny of *Channa striatus* (Bloch, 1793) larvae. *Animals*, *14*(19), Article 2838. https://doi.org/10.3390/ani14192838

Kolkovski, S. (2001). Digestive enzymes in fish larvae and juveniles—implications and applications to formulated diets. *Aquaculture, 200*, 181-201. https://doi.org/10.1016/S0044-8486(01)00700-1

Kubitza, F., & Lovshin, L.L. (1999). Formulated diets, feeding strategies and cannibalism control during intensive culture of juvenile carnivorous fishes. *Reviews in Fisheries Science and Aquaculture*, 7(1), 1-22. https://doi.org/10.1080/10641269991319171

Kumar, D., Marimuthu, K., Haniffa, M. A., & Sethuramalingam, T. A. (2008). Effect of different live feed on growth and survival of striped murrel *Channa striatus* larvae. *Ege University Journal of Fisheries and Aquatic Sciences*, *25*(2), 105-110.

Le Ruyet, J. P., Alexandre, J. C., Thébaud, L., & Mugnier, C. (1993). Marine fish larvae feeding: Formulated diets or live prey? *Journal of the World Aquaculture Society*, *24*(2), 211-224. https://doi.org/10.1111/j.1749-7345.1993.tb00010.x

Léger, P., Bengtson, D. A., Sorgeloos, P., Simpson, K. L., & Beck, A. D. (1987). The nutritional value of *Artemia*: A review. In P. Sorgeloos, D. A. Bengtson, W. Decleir, & E. Jaspers (eds.). *Artemia Research and its Applications Vol 3* (pp 357-372).Universa Press.

Marimuthu, K., &Haniffa, M. A. (2007). Embryonic and larval development of the striped snakehead *Channa striatus*. *Taiwania*, *52*(1), 84-92. https://doi.org/10.6165/tai.2007.52(1).84

Marimuthu, K., Kumar, D., &Haniffa, M. A. (2007). Induced spawning of striped snakehead, *Channa striatus*, using Ovatide. *Journal of Applied Aquaculture*, *19*(4), 95-103.https://doi.org/10.1300/J028v19n04_06

Mollah, M. F. A., Mamun, M. S. A., Sarowar, M. N., & Roy, A. (2009). Effects of stocking density on the growth and breeding performance of broodfish and larval growth and survival of shol, *Channa striatus* (Bloch). *Journal of the Bangladesh Agricultural University*, *7*(2), 427-432.https://doi.org/10.3329/jbau.v7i2.4756

Morais, S., Conceição, L. E., Dinis, M. T., & Rønnestad, I. (2004). A method for radiolabeling *Artemia* with applications in studies of food intake, digestibility, protein and amino acid metabolism in larval fish. *Aquaculture*, *231*(1-4), 469-487.https://doi.org/10.1016/j.aquaculture.2003.09.005

Pearson, K. (1894). II. Mathematical contributions to the theory of evolution. II. Skew variation in homogeneous material. *Proceedings of the Royal Society of London*, *57*(340-346), 257-260. https://doi.org/10.1098/rspl.1894.0147

Qin, J., & Fast, A. W. (1996). Effects of feed application rates on growth, survival, and feed conversion of juvenile snakehead *Channa striatus*. *Journal of the World Aquaculture Society*, *27*(1), 52-56. https://doi.org/10.1111/j.1749-7345.1996.tb00593.x

Qin, J., & Fast, A. W. (1997). Food selection and growth of young snakehead *Channa striatus*. *Journal of Applied Ichthyology*, *13*(1), 21-25. https://doi.org/10.1111/j.1439-0426.1997.tb00093.x

Randall, D. J., & Tsui, T. K. N. (2002). Ammonia toxicity in fish.*Marine Pollution Bulletin*, *45*, 17-23. https://doi.org/10.1016/S0025-326X(02)00227-8

Roy, P., Chandan, C. S. S., Roy, N. C. & Islam, I. (2020). Feed types affect the growth, survival and cannibalism in early juvenile of striped snakehead (*Channa striata* Bloch.). *Egyptian Journal of Aquatic Research*, *46*(4), 377-382. https://doi.org/10.1016/j.ejar.2020.08.009

Sales, J. (2011). First feeding of freshwater fish larvae with live feed versus compound diets: A meta-analysis. *Aquaculture International*, *19*(6), 1217-1228. https://doi.org/10.1007/s10499-011-9424-1

Salze, G. P., & Davis, D. A. (2015). Taurine: A critical nutrient for future fish feeds. *Aquaculture, 437*, 215-229. https://doi.org/10.1016/j.aquaculture.2014.12.006

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, *52*, 591-611. https://doi.org/10.1093/biomet/52.3-4.591

Shiwanand, A., & Tripathi, G. (2013). A review on ammonia toxicity in fish. *Asia Pacific Journal of Life Sciences*, *7*(2), 193-232.

Sorgeloos, P., Dhert, P., & Candreva, P. (2001). Use of the brine shrimp, *Artemia* spp., in marine fish larviculture. *Aquaculture*, *200*(1-2), 147-159. https://doi.org/10.1016/S0044-8486(01)00698-6

Teshima, S.-I., Koshio, S., Ishikawa, M., Alam, M. S., & Hernandez, L. H. H. (2004). Effects of protein and lipid sources on the growth and survival of red sea bream *Pagrus major* and Japanese flounder *Paralichthys olivaceus* receiving micro-bound diets during larval and early juvenile stage. *Aquaculture Nutrition*, *10*(4), 279-287. https://doi.org/10.1111/j.1365-2095.2004.00303.x

Tukey, J. W. (1953). *The Problem of Multiple Comparisons*. Chapman & Hall.

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., van der Walt, S. J., Brett, M., Wilson, J., Millman, K. J., Mayorov, N., Nelson, A. R. J., Jones, E., Kern, R., Larson, E.,... van Mulbregt, P. (2020). SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature Methods*, *17*(3), 261-272. https://doi.org/10.1038/s41592-019-0686-2

Zhou, X., Wang, J., Huang, L., Li, D., & Duan, Q. (2022). Modelling and controlling dissolved oxygen in recirculating aquaculture systems based on mechanism analysis and an adaptive PID controller. *Computers and Electronics in Agriculture*, *192*, Article 106583. https://doi.org/10.1016/j.compag.2021.106583