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Research Article

COMPARATIVE ZOOTECHNICAL PERFORMANCE OF *HETEROBRANCHUS LONGIFILIS* (BANDAMA STRAIN, CÔTE D'IVOIRE) LARVAE FED LIVE ZOOPLANKTON, INERT DIET, AND COMBINED FEEDING REGIME

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ABSTRACT

The present study was conducted to evaluate the growth performance of *Heterobranchus longifilis* larvae fed an inert diet, live prey, or a combined feeding regime (live prey + inert diet). Three-day-old larvae (mean weight: 2.89 ± 0.87 mg) were stocked at a density of 10 fish L^{-1} in aquarium tanks and reared for 28 days. Larvae were fed daily at feeding rates ranging from 25 to 100 % of their body weight. The zooplankton community collected from the pond consisted of nauplii, copepodites, adult copepods, cladocerans, and rotifers, with respective densities of 289.11 ± 19.5, 182.21 ± 24.04, 174.07 ± 9.34, 455.85 ± 44.76, and 255.47 ± 29.18 ind. L^{-1}. Larval survival rate was significantly higher in fish fed the combined diet (72.5 ± 4.45%) and lowest in those fed the inert diet (52.5 ± 4.5 %). The highest specific growth rate (SGR) was recorded in larvae fed the combined diet (19.79 ± 0.21 % day^{-1}), whereas the lowest was observed in fish fed the inert diet (18.91 ± 0.13 % day^{-1}). These results indicate that the combined feeding regime improves both survival and growth performance in *Heterobranchus longifilis* (Bandama strain) larvae.

Keywords: Catfish, Bandama Strain, Larvae, Live preys, Inert diet.

INTRODUCTION

Fish accounts for more than 50 % of the animal protein consumed in Côte d'Ivoire (Groga *et al*., 2025). The aquaculture and fisheries sector in Côte d'Ivoire are dominated by the Nile tilapia, *Oreochromis niloticus* (Anvo *et al*., 2025). Several other species are also produced under extensive, semi-intensive, and intensive farming systems. These include the African bonytongue *Heterotis niloticus*, the North African catfish *Clarias gariepinus*, and the vundu catfish *Heterobranchus longifilis* (Wognin *et al*., 2023). *Heterobranchus longifilis* (*H. longifilis*) is widely distributed across rivers, lakes, and other freshwater habitats throughout sub-Saharan Africa, including the Nile basin (Lalèyè *et al*., 2019). This species is regarded as an excellent candidate for aquaculture, owing to its omnivorous feeding behavior, fast growth rate, and capacity to tolerate suboptimal environmental conditions like *Clarias gariepinus* (Ezilrani & Godwin, 2016).

In Côte d'Ivoire, the limited availability of *H. longifilis* juveniles constitutes the primary bottleneck for the development of its culture. Larvae of this species have traditionally been reared almost exclusively on live Artemia nauplii (Kerdchuen & Legendre, 1994). This is a practice that is costly, labor intensive, and relies on an imported product not always accessible to fish farmers in developing countries (Pan *et al*., 2022). Starter dry feeds have been developed as alternatives to Artemia in fish larval rearing (Vandecan *et al*., 2011). However, their relatively high cost often limits their accessibility for small-scale producers. In addition, formulated diets do not always fully meet the

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nutritional requirements of fish larvae during early developmental stages (Khan & Rahman, 2025). Zooplankton constitute an essential food source for many aquatic species, particularly during their larval phase. Described as "living capsules of nutrition," live zooplankton are rich in essential amino acids, highly unsaturated fatty acids (DHA, EPA, ARA), carbohydrates, vitamins, minerals, and digestive enzymes that trigger larval feeding responses (Khan & Rahman, 2025). In line with their recognized ecological role in the natural diet of fish larvae, several studies have confirmed that *H. longifilis* larvae selectively feed on copepods and other zooplankton during the first days of life (Anvo et al., 2021), and that zooplankton can serve as an effective live feed for Clariidae larvae more broadly (Agadjihouédé *et al*., 2012). Despite these advances, comparative data on the zootechnical performance of *H. longifilis* larvae reared on a combined diet (live prey + inert feed) remain limited. Recent investigations on closely related species have suggested that the co-feeding strategy combining live and inert feeds significantly improves larval survival and growth compared to either diet used alone (Halpati *et al*., 2026). To identify the most effective nutritional strategy for optimizing growth and survival during the early larval stages of *H. longifilis*, the present study was conducted to compare the zootechnical performance of larvae fed live prey, an inert diet, or a mixture of both.

MATERIALS AND METHODS

Heterobranchus longifilis larvae origin

Heterobranchus longifilis larvae were obtained through artificial reproduction following the protocol described by Gilles *et al*. (2001). Broodstocks used were collected from Lake Kan, located between latitudes 7°38'54.9"N and 7°41'59.5"N, and longitudes 5°02'16.3"W and 5°02'23.6"W, tributary of the Bandama River in Côte d'Ivoire. Hormonal induction and spawning were performed at the Research Station on Continental Fisheries and Aquaculture (SRPAC) of the National Centre for Agricultural Research (CNRA), Bouaké, Côte d'Ivoire.

Experimental diets

Heterobranchus longifilis larvae were fed three experimental diets: a Live zooplankton consisting of fresh zooplankton collected from earthen ponds, an inert commercial diet formulated for fish larvae (55 % crude protein), and a mixed diet combining both live prey and the inert diet.

Collection, taxonomic identification, and enumeration of zooplankton

Zooplankton were collected once daily at 08:00 h from 400 m² earthen ponds at the Research Station on Continental Fisheries and Aquaculture (SRPAC-CNRA) during the rainy season (July-August). The plankton net had a mouth diameter of 40 cm, a total length of 150 cm, and a mesh size of 35 µm. The net was towed horizontally just below the water surface over a distance of 18 m. Five major zooplankton groups were identified: Nauplii, Copepodites, adult Copepods, Cladocerans, and Rotifers. Identification was performed using standard taxonomic keys (Dussart, 1980; Kotov *et al*., 2012). Zooplankton density (ind.·L^{-1}) was calculated according to Agadjihouédè *et al*. (2011) using the following formula:

Zooplankton density (D) = (N / V1) X (V2 / V3)

where N = number of individuals counted; V1= volume of the filtrate collected (3 mL), V2 = volume of the concentrated filtrate (sample volume),

V3 = volume of filtered water = π x r^2x d

where d = The train distance of the plankton net in the water column (18 m), and R: the radius of the opening of the zooplankton net.

Experimental design and setup

Seven hundred and twenty *Heterobranchus longifilis* larvae (initial mean weight: 2.89 ± 0.87 mg) were used in this experiment. They were distributed among three dietary treatments, with three replicates per treatment. Larvae were stocked into nine aquaria (10 L each) at a density of 10 larvae·L^{-1}. The rearing period lasted 28 days. During the first week, larvae were fed ad libitum. Feeding rations were set at 75 % of total body biomass during the second week. They were reduced to 50 % during the third and fourth weeks. Uneaten feed, faeces, and dead larvae were removed daily by siphoning before each feeding. Every week, larvae from each replicate were counted and batch-weighed to the nearest 0.1 mg. Feed rations were adjusted accordingly. Individual dry weights of the zooplankton groups used as live prey were as follows (Legendre *et al*., 1987): rotifers, 0.18 µg·ind^{-1}; copepod nauplii, 0.08 µg·ind^{-1}; copepodites and adult copepods, 0.47 µg·ind^{-1}; and cladocerans, 1.32 µg·ind^{-1}. Water quality parameters were monitored throughout the experiment in situ using a HANNA HI 9828 multi-parameter.

Evaluation of zootechnical parameters

Mean weight gain, relative growth rate, specific growth rate, cannibalism and survival rate, coefficient of variation of individual weight and feed conversion ratio were used to express growth performances and mortality. Those parameters were calculated using the following formula:

Mean weight gain = (final weight - initial weight)/ Number of fish**;**

Specific growth rate = 100 [(ln final weight-ln initial weight) / Number of experimental days];

Survival rate (%) = 100 (final number/initial number);

Cannibalism rate (%) = 100 - [Survival rate (%) + Observed mortality (%)]**;**

Coefficient of variation of individual weight (%) = Standard deviation of final weight × 100/mean weight**;**

Food conversion ratio = Feed intake /Fish weight gain.

Statistical analysis

Statistical analyses were performed using STATISTICA version 7.1 software. Data are presented as mean ± standard deviation (SD) (n = 3). The effects of diet on the performance indices of *H. longifilis* larvae were assessed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test. Differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

The total zooplankton density recorded in the ponds of the Research Station on Continental Fisheries and Aquaculture (SRPAC-CNRA) was 1 356.73 ± 131.42 ind·L^{-1}. Five taxonomic groups were identified: Nauplii, Copepodites, adult Copepods, Cladocerans, and Rotifers. Cladocerans were the most abundant group (455.85 ± 44.76 ind·L^{-1}). They were followed by Nauplii (289.11 ± 19.50 ind·L^{-1}), Rotifers (255.47 ± 29.18 ind·L-1), Copepodites (182.21 ± 24.04 ind·L^{-1}), and adult Copepods (174.07 ± 9.34 ind·L^{-1}). The physicochemical parameters of the rearing water remained stable throughout the 28-day experimental period. Mean values recorded in the aquaria were: pH 7.02 ± 0.1; temperature 29.12 ± 0.167 °C; and dissolved oxygen 4.75 ± 0.23 mg·L^{-1}. Overall, the water quality parameters recorded in this study fell within the acceptable ranges reported for *H. longifilis* larval rearing.

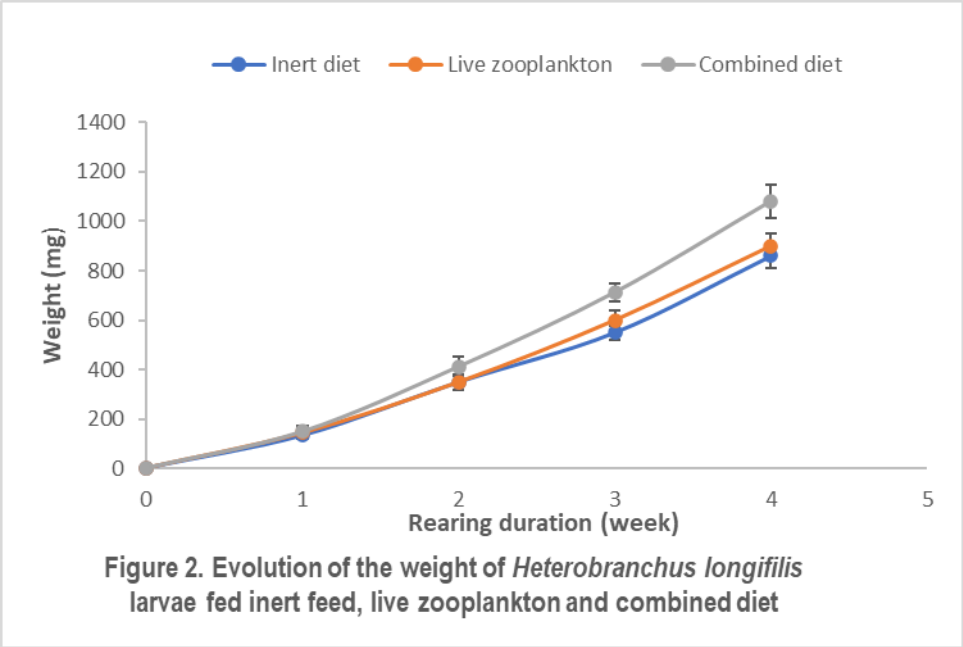

Figure 2. Evolution of the weight of *Heterobranchus longifilis* larvae fed inert feed, live zooplankton and combined diet

Survival rate (SR) was significantly affected by diet type. Larvae fed the combined diet (72.5 ± 4.45 %) and the Live zooplankton (71.0 ± 3.5 %) showed significantly higher survival than those fed the inert diet (52.5 ± 4.5 %) ($P < 0.05$). Survival rates did not differ significantly between the combined and Live zooplankton groups ($P > 0.05$). The growth performance and nutrient utilization indices of *H. longifilis* larvae fed the three experimental diets are presented in Table 1. Initial weights were similar across all dietary groups. The initial mean weight (IMW) ranged from 2.87 ± 0.8 mg to 2.90 ± 0.9 mg. No significant differences were observed among treatments at the start of the experiment ($P > 0.05$). The evolution of larval weight of *H. longifilis* across the three dietary treatments is presented in Figure 1. Larval weight increased progressively in all groups throughout the 28-day rearing period. Initial mean weights were similar across treatments. During the first week, weight gain was comparable among the three groups. From week 2 onward, larvae fed the combined diet showed significantly higher weights than those of the two other treatments ($p < 0.05$). At the end of the trial (week 4), the combined diet group reached 1 080 ± 70 mg, compared to 900 ± 50 mg (live prey) and 860 ± 50 mg (inert diet). Throughout the rearing period, larvae fed the Live zooplankton and those fed the inert diet exhibited similar weight trajectories ($p > 0.05$). Mean weight gain (MWG) followed the same pattern. The combined diet yielded the highest MWG (1077.66 ± 75.1 mg). The inert (842.1 ± 50.28 mg) and live prey (897.1 ± 58.7 mg) diets produced significantly lower MWG values. Specific growth rate (SGR) was highest in larvae fed the combined diet (19.79 ± 0.21 % day^{-1}). The Live zooplankton yielded an intermediate SGR (19.2 ± 0.14 % day^{-1}). The lowest SGR was recorded in the inert diet group (18.91 ± 0.13 % day^{-1}). Feed conversion ratio (FCR) did not differ significantly among treatments. Values ranged from 4.38 ± 0.28 (inert diet) to 4.47 ± 0.43 (combined diet).

Coefficient of variation (CV) for individual weight ranged from 5.66 ± 0.35 % to 6.48 ± 0.21 %. No significant differences were detected among groups (P > 0.05), indicating relatively uniform growth within each treatment. Cannibalism rate (CR) was low across all treatments. The combined diet showed the lowest CR (4.80 ± 0.38 %). The inert and Live zooplanktons recorded CR values of 5.50 ± 0.5 % and 5.56 ± 0.5 %, respectively. No significant differences were observed among groups (P > 0.05).

Table 1. Growth performance and nutrient utilization indices of *Hetrobranchus longifilis* larvae fed experimental diets.

	Diets		
Indices	**Inert diet**	**Live zooplankton**	**Combined diet**
IMW (mg)	2.9 ± 0.9	2.87 ± 0.8	2.89 ± 0.9
FMW (mg)	845 ± 51.8[a]	905.38 ± 61.02[a]	1081 ± 76.7[b]
MWG (mg)	842,1±50.28 [a]	897.1±58.7[a]	1077.66±75.1[b]
FCR	4.38 ± 0.28	4.44± 0.31	4.47± 0.43
SGR (% day^{-1})	18.91 ± 0.13	19.2 ± 0.14	19.79 ± 0.21
CV (%)	5.91 ± 0.26	5.66 ± 0.35	6.48 ± 0.21
CR (%)	5.5± 0.5	5.56± 0.5	4.8± 0.38
SR (%)	52.5±4.5 [a]	71± 3.5[b]	72.5± 4.45[b]

Data are mean values ± SD (n=3); means in the same row with the same superscript are not significantly different (*P*>0.05). IMW: initial mean weight, FMW: final mean weight, MWG: mean weight gain, FCR: feed conversion ratio, SGR: specific growth rate, CV: coefficient of variation of individual weight, CR: cannibalism rate and SR: survival rate.

The zooplankton density observed in the present study was higher than those observed in Lokpoho River (1217 ind. L^{-1}) and Bandama (463 ind. L^{-1})/ according to Soro *et al*. (2019). The high abundance of zooplankton could be explained by the fact that the ponds are rich in minerals (N. P. C) resulting from the decomposition of leftover and faeces from fish. However, the density of zooplankton in the ponds of the inland fisheries and aquaculture research station observed in this study (1327 ind. L^{-1}) was lower than that observed by Kouassi *et al*. (2009) in the same ponds (1800 ind. L^{-1}). This low abundance could be explained by the fact that the ponds have been fertilized before sampling. Water quality parameters were within suitable ranges for *Oreochromis niloticus* rearing. Specifically, temperature fell within the recommended range of 20 - 35 °C, dissolved oxygen levels remained above 3 mg L^{-1} and pH values were within the acceptable interval of 6.1-8.3 (Makori *et al*., 2017). Diet type had a significant effect on larval survival. The inert diet group recorded the lowest survival rate (52.5 ± 4.5 %), significantly lower than the live prey (71.0 ± 3.5 %) and combined (72.5 ± 4.45 %) groups. These findings are supported by a study of Oyoo-Okoth *et al*. (2011). Those authors reported survival rates exceeding 90 % in *Clarias gariepinus* larvae co-fed with 50 % Artemia and 50 % dry diet, compared to significantly lower survival rates when larvae were abruptly weaned to 100 % dry diet. The authors linked this difference to the inability of early larvae to fully digest and absorb the nutrients from inert diets, resulting in nutritional deficiencies and increased mortality. Yousefi *et al*. (2025) made similar observations in Beluga sturgeon (Huso huso) larvae. The comparable survival rates between the live prey (71.0 %) and combined (72.5 %) diet groups in the present study further highlighted the critical importance of live organisms for larval survival.

The combined diet yielded the highest growth performance in *H. longifilis* larvae. Final mean weight (1081 ± 76.7 mg) and mean weight gain (1077.66 ± 75.1 mg) were significantly greater than those recorded for the inert and Live zooplankton groups (Table 1). The superior growth observed in the combined diet group can also be explained by nutritional complementarity. Live prey organisms supply essential long-chain polyunsaturated fatty acids (LC-PUFAs), free amino acids, exogenous digestive enzymes, and bioactive growth factors not yet fully replicable in formulated feeds (Teye-Gaga *et al*., 2025). The SGR also followed the same trend, with the combined diet producing the highest value (19.79 ± 0.21 % day^{-1}). Karakatsouli *et al*. (2021) demonstrated a similar pattern in red seabream (*Sparus aurata*) larvae, where early introduction of dry feed alongside live prey promoted superior larval growth without compromising survival. In contrast, the inert diet alone produced the lowest growth values. This result likely reflects the immaturity of the digestive system of early *H. longifilis* larvae. At the onset of exogenous feeding, larval fish have limited secretion of key digestive enzymes such as trypsin, amylase, and lipase. Their ability to digest particulate formulated diets is consequently reduced (Teye-Gaga *et al*., 2025).

No significant differences in FCR were detected among the three dietary treatments (4.38 to 4.47). Despite clear differences in absolute growth, all diets were converted with similar metabolic efficiency. This pattern has been reported in comparable studies on clariid catfish larvae, suggesting that diet type influences the magnitude of

growth but not the ratio of feed used to generate unit body mass (Oyoo-Okoth *et al*., 2011). The uniformity of FCR values across treatments may reflect the fact that larval metabolic pathways for nutrient processing operate at a similar efficiency once minimum dietary requirements are met. It should also be noted that high FCR values in larval fish are generally expected. During early ontogeny, a substantial proportion of energy is directed toward organogenesis, locomotion, and thermoregulation rather than somatic growth (Halpati *et al*., 2026). This systemic metabolic cost reduces the apparent efficiency of dietary conversion, irrespective of diet type. Similar FCR ranges have been reported for *Clarias gariepinus* larvae under various feeding protocols (Oyoo-Okoth *et al*., 2011). Cannibalism rates were low and statistically similar across all dietary groups (4.80 to 5.56 %). The absence of significant differences among treatments suggests that diet type was not a determining factor of inter-individual predation in this study. Rather, cannibalism is primarily driven by size heterogeneity within cohorts, feeding frequency, and the satiation level of individuals (Yousefi *et al*., 2025). Adequate and regular feeding, regardless of diet composition, appears sufficient to suppress the nutritional motivation for cannibalism in *H. longifilis* larvae. This observation is consistent with studies on other catfish species. Similarly, high feeding frequency has been documented as a key factor in reducing size-based aggression and cannibalism in Amazonian catfishes (Halpati *et al.*, 2026). The slightly lower CR in the combined diet group (4.80 %) may reflect the better nutritional status and satiety of larvae receiving a more complete diet.

The Coefficient of Variation (CV) for individual weight was similar across all groups (5.66 to 6.48 %) since no significant differences were observed among dietary treatments ($p > 0.05$). This indicates comparable within-group growth homogeneity across all three diets. All treatments supported relatively uniform individual growth. No pronounced size disparities were generated among larvae. This limited intraspecific competition and reduced the risk of cannibalism. These results are consistent with the low cannibalism rates recorded across all groups. They suggest that the experimental feeding conditions were adequate to prevent marked individual growth variability.

CONCLUSION

This study demonstrated that the combined diet (live prey + inert feed) produced the best growth performance and survival in *Heterobranchus longifilis* (Bandama strain) larvae. The Live zooplankton supported high survival rates, comparable to those of the combined diet. However, it resulted in significantly lower growth performance. The inert diet alone yielded the lowest survival and growth rate. These results suggest that combining zooplankton and formulated feed is the most effective strategy for early rearing of *H. longifilis* larvae. Future research should assess the economic profitability of this combined feeding approach at a larger production scale.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on Request.

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