

Optimization of growth rate and feeding efficiency of four economically important fish species in the bioflocs system



AGUSSYARIF HANAFIE¹, AKHMAD MURJANI¹, EL REDHA¹

¹Aquaculture Program Study, Lambung Mangkurat University, Indonesia

*Corresponding Author:
agus.shanafie@ulm.ac.id

Received: 09 September 2024
Revised: 10 March 2025
Accepted: 26 March 2025

Abstract. Research and development of biofloc technology (BFT) uses microbes to manage nutrient levels in production systems. until now only in the range of 14-15 species conducted. There are 4 species of fish that are feasible to be developed, especially freshwater fish groups in wetlands, such as fish (climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Opronomus gourami*) and Pangas (*Pangasius hypophthalmus*). This research has been using a complete randomised complete block design with four treatments with four replicates. Stocking density of 1000 fish 2500 L-1 using 2 m diameter round pond with biofloc media; feeding twice a day and the amount of feed given was 2.5% of total weight, for 158 days. Research parameters included; daily growth rate, feed efficiency, FCR, weight gain (gr) and length gain (cm). The results showed that the results of the anova test showed a significance value (Sig.) of 0.000 < 0.05, so there was a significant difference between treatments of the daily growth rate and weight gain parameters. Anova test results show that the feed conversion of fish research significance and survival rate value 0.000 < 0.05 means that the four types of fish studied, significantly different from those reared in the biofloc system.

Key Words: bioflocs, growth, feeding, efficiency, wetland

INTRODUCTION.

In the last 24 years, the application of biofloc technology (BFT) has expanded to include a wide range of aquaculture fish species. These species include white shrimp (*Litopenaeus vannamei*) [1,2] tilapia (*Oreochromis niloticus*) [3] channel catfish (*Ictalurus punctatus*) [4], giant freshwater prawn (*Macrobrachium rosenbergii*) [5], pink shrimp (*Farfantepenaeus duorarum*) [6,7], red shrimp (*F. paulensis*) [6], banana shrimp (*F. merguensis*) [8], tiger prawn (*Penaeus monodon*) [9], golden crucian (*Carassius auratus*) [10], bocachico (*Prochilodus magdalenae*) [11] and african cichlid (*Pseudotropheus saulosi*) [12]. Shrimp and tilapia are very suitable for rearing using biofloc technology because they can consume biofloc efficiently as a source of protein and high adaptability to biofloc systems [6,10]. Until this year, acceptance of BFT was limited due to the belief that clear water is preferable for fish rearing compared to highly turbid water containing bioflocs [1]. A severe epidemic of shrimp viral diseases prompted the widespread application of biofloc technology [13] including various systems such as activated sludge or suspended bacteria-based systems, microbial floc systems,

single-cell protein production systems, suspended growth systems, and zero-exchange autotrophic-heterotrophic systems [14].

BFT aquaculture research is dominated by studies using tilapia (*Oreochromis niloticus*) and white shrimp (*Penaeus merguensis*) as the initial benchmarks in BFT [15,16]. However, this technology can be applied to other species, particularly species that are tolerant of biofloc conditions and less carnivorous. However, the successful application of biofloc systems has also been observed in other species such as african catfish, *Clarias gariepinus* [17] and mullet [18] freshwater prawn (*Macrobrachium rosenbergii*) [19] black tiger prawn (*Penaeus monodon*) [20] banana shrimp (*Penaeus merguensis*) [21], giant gourami (*Osphronemus gouramy*) [22], carp (*Cyprinus carpio*) [23], rohu (*Labeo rohita*) [24], and bluegill (*Lepomis macrochirus*) [25]. In addition to these individual specimens, integrated approaches such as polyculture, combining species such as catfish and tilapia [26] (aquaponics or FLOCponics [27] and integrated multitrophic aquaculture (IMTA) [28], butter catfish (*Ompok bimaculatus*) [29]. Research on climbing perch (*Anabas testudienus* Bloch) biofloc system



This is an open access article under the terms of the Creative Commons Attribution (CC-BY) License, which permits use and distribution in any medium, provided the original work is properly cited. © 2025 The Authors. Jurnal Natural published by Faculty of Mathematics and Natural Science (FMIPA), Universitas Syiah Kuala.



Figure 1. Research Facilities in the Wet Laboratory Area of the Faculty of Fisheries and Marine Science, Lambung Mangkurat University, Banjarbaru, Indonesia

Table 1. Type, Number and Usefulness of Research Tools

Name of Tools	Number	Uses
Biofloc ponds two metres in diameter	16 pieces	Fish testing containers
Aeration stone blower and hose	1 set	Aerating the Test Media
Imhoff funnel	2 pieces	Measuring floc content
Scoop net	16 pieces	Catching test fish
Digital scales	1 piece	Measuring materials and test fish
Spectrophotometer Hach	1 unit	Measuring dissolved ammonia levels
Do meter	1 unit	Measure dissolved oxygen levels
PH meter	1 unit	Measuring the pH level of water
Digital ruler	4 pieces	Measure the length of the test fish
Basin	16 pieces	Fish sampling container
Stationery	1 set	Recording research data
Clear plastic bag	1 pack	Test fish feed container

Table 2. Type, Amount and Use of Research Materials

Name of Material	quantity	use
Climbing Perch ±5- 6 cm	4000 fish	Test fish
Snakehead ±5- 6 cm	4000 fish	Test fish
Giant Gourami ±5- 6 cm	4000 fish	Test fish
Pangas ±5- 6 cm	4000 fish	Test fish
PF 1000 feed (protein min 39%)		As required Test fish feed
LP1 feed (min protein 34%)		As required Test fish feed
LP2feed (protein min 31 – 33%)		As required Test fish feed
Potassium Permanganate, 40 mL/m3		As required Purify container
Salt 10 kg/m3		As needed Biofloc media material
Dolomite lime 800 gram/m3		As needed Biofloc media material
Chlorine 120 gram/m3		As needed Biofloc media material
Molasses / sugar cane drop 800 grams / m3		As needed Biofloc media material
Pineapple 4 kg/m3		As needed Biofloc media material
Probiotic Wasaka 7.0, 40 mL/m3		As needed Biofloc media material

has also been conducted on stocking density [30,31] and other studies conducted by [32] – [34] have also shown promising results in recent developments.

BFT is still in a premature stage of development, much research is needed to optimise the system (in relation to operational parameters) for example in relation to nutrient recycling, MAMP (Multi Annual Management Plan) production and immunological effects. Research findings need to be communicated to aquaculturists as the

application of biofloc technology will require an upgrade of their skills [35]. The objectives of current biofloc research by applying to new species, utilisation of bioflocs, mechanisms of mode of action such as bioflocs (formation, microbial composition, etc., response of aquaculture organisms (growth, health, reproduction), solutions to problems in the field with research by controlling the quantity and function of bioflocs and whether the biofloc system can reduce feed protein requirements [36].

Table 3. Water quality parameters, units, types of equipment and their use

Parameters	Units	Type of tool	How to use
Water Temperature	°C	Thermometer	According to the measurement procedure
Dissolved oxygen	mg L ⁻¹	DO-meter	According to the measurement procedure
pH of water	-	pH-meter	According to the measurement procedure
Dissolved Amonia	mg L ⁻¹	Spectrophotometer	According to the measurement procedure

Growth and feed consumption are not correlated, but both are correlated with feed efficiency. Feed-efficient fish eat smaller portions while maintaining higher growth rates. Feed-efficient fish have a lower minimal routine metabolic rate [37]. By increasing FCR within a species, feed consumption can be reduced with the same amount of growth, thereby reducing feed costs and environmental impact. Differences in FCR within a species and what factors may be associated with FCR efficiency as potential triggers [37]. Instantaneous growth rate is logarithmic and difficult to interpret, however specific growth rate (SGR) expresses growth as a percentage change in size per unit of time which can be understood intuitively [38]. Growth of aquacultured fry is usually measured by two indices, specific growth rate or SGR, and thermal unit growth coefficient or TGC. SGR is a relative growth index based on the logarithm of body weight, and decreases with body weight. The classic TGC is based on the third power of body weight and the summation of temperature over time [39].

On this basis, it is important to research 4 (four) economically important wetland fish species such as Climbing Perch (*Anabas testudineus* Bloch), Snakehead (*Channa striata* Bloch), Giant Gourami (*Ospronomus gourami* Lac.) and Pangas (*Pangasius hypothalmus*) as a contribution to science in the diversification of *Species* and its development which will eventually become a technology that is socially, environmentally and economically applicable to the community in biofloc systems with a growth rate and feed efficiency approach.

METHODOLOGY

General description of the research location

This research was conducted for ± 8 months (June 2023 - February 2024) in the Wet Laboratory area of the Faculty of Fisheries and Marine Sciences, Lambung Mangkurat University in Banjarbaru, Indonesia. The research container can be seen in Figure 1.

Tools, Materials and Procedures. The tools used in this study can be seen in Table 1. While the materials used in this study can be seen in Table 2.

Research design

The study used a completely randomised design (CRD) with 4 treatments and 4 replicates, the treatment used was the type of fish;

Treatment 1 = Climbing Perch (*Anabas testudineus* Bloch)

Treatment 2 = Snakehead (*Channa striata* Bloch)

Treatment 3 = Giant Gourami (*Ospronomus gourami*)

Treatment 4 = Pangas fish (*Pangasius hypothalmus*).

Research procedure

After the round pond was sanitised, then filled with well water as high as ± 80 cm. The first day, given 15 grams m⁻³ chlorine and aerated 24 hours until day 3-4. Day 5; 2.5 kg m⁻³ of krosok salt was given and aerated for 24 hours. Day 6, dolomite lime was given as much as 100 gr m⁻³ by taking a dipper that was already filled with water, then stirring the lime in the dipper and putting the white essence of lime into the pond, then letting it sit for 2 days with aeration and measuring the pH of the pond water. Day 7, molasses as much as 100 g m⁻³ with the addition of pineapple that has been blended as much as 1 kg, then put into the test container along with molasses. Day 8, 10 mL m⁻³ of probiotic was added to the test fish container and after 5-6 days the test fish could be stocked. To keep the media good, once a week molasses is given as much as 50 mL m⁻³ according to the media maintenance SOP procedure. Seeds used in accordance with the treatment were ±5-6 cm in size, the seeds came from farmers in Mentaos and BPBAT Mandiangin in Pulang Pisau. Seeds were stocked in the morning and evening at 400 fish m⁻³ or 1000 fish/2500 L. Feeding twice a day (morning (7.00 am) and evening (4.00 pm), at 2.5% of the population weight. Sampling of fish fry was carried out every 14 days, sampling 20% of the total fish, namely 200 fishes, and measuring floc content and water quality.

Specific growth rate (SGR) was calculated using the formula from [40]:

$$SGR = \frac{\ln W_t - \ln W_o}{t} \times 100\%$$

Description:

SGR = specific growth rate, daily growth rate (% day⁻¹)

Wt = average weight of fish at the end of the study (g head⁻¹)

Wo = average weight of fish at the beginning of the study (g head⁻¹)

T = time (length of rearing)

The absolute growth formula refers to [41]:

$$L = Wt + D - Wo$$

Description:

L = Absolute growth (g)

Wo = Weight of fish at the beginning of the study (g)

Wt = Weight of fish at the end of the study (g)

D = Weight of dead fish (g)

Length Growth Formula:

$$L = Lo - Lt$$

Description:

L = Absolute length growth (cm)

Lt = Fish body length at the end of the study (cm)

Lo = Fish body length at the beginning of the study (cm) [42]

Feed efficiency formula was calculated referring to [42]:

$$\text{Feed Efficiency} = \frac{(Wt+D- Wo)}{F} \times 100\%$$

Wt = Fish weight at the end of the study (g)

Wo = Weight of fish at the beginning of the study (g)

D = Weight of dead fish (g)

F = Feed given (g)

Feed Conversion Ratio with the formula:

$$\text{FCR} = \frac{F}{(Wt + D - Wo)}$$

Description:

FCR = Feed conversion ratio

F = Weight of feed given (g)

Wt = Biomass of test animals at the end of rearing (g)

D = Weight of dead fish (g)

Wo = Biomass of test animals at the beginning of maintenance (g) referring to [43]

Referring to [43] : the formula for calculating survival rate (SR) is:

$$\text{SR} = \frac{Nr}{Nl} \times 100\%$$

Description:

SR = Survival rate (SR) %

Nr = Number of fish at the end of rearing

Nl = Number of fish at the time of initial stocking

Floc content and water quality. Floc abundance was taken using an Imhoff cone so that the floc could be filtered. Floc content is a representation of the density of floc particles in

the biofloc system rearing container [44]. The volume of floc that settles is recorded and then calculated using the formula:

$$\text{Floc Volume Density (mL/L)} = \frac{\text{Floc deposited (mL)}}{\text{Water sampling (L)}}$$

Table 3 details the observed water quality parameters.

Hypotheses. H0 = Growth rate and feed efficiency are not optimal for four economically important wetland fish species in biofloc systems and H1 = Growth rate and feed efficiency are not optimal for four economically important wetland fish species in biofloc systems.

Data analysis

Data analysed included: specific growth rate (%/day), feed efficiency (%), absolute weight growth (gr), standard length (cm), survival rate (%), feed conversion ratio, which before analysing the variance, was first tested for normality and homogeneity, as a requirement for a completely randomised design (CRD) test. Fisher (F) test with SPSS 24 programme to determine the difference between treatments (significance) and post hoc test. Data on environmental quality (water) and floc content (ml/L) obtained from sampling measurements were then descriptively analysed to determine their influence on the main parameters of the study.

RESULTS AND DISCUSSION

The results of research on optimisation of growth rate and feeding efficiency of four economically important of wetland fish in the bioflocs system can be described as follows:

Specific Growth Rate (%/day)

The results of daily specific growth rate (SGR) (g) of climbing perch (*Anabas testudineus* Bloch), snakehead (*Channa striata* Bloch), giant gouramy (*Ospronomus gouramy*) and pangas (*Pangasius hypophthalmus*) during 158 days of rearing in the biofloc system can be seen in Table 4 and Figure 2.

The results of the ANOVA test show a significant value (Sig.) of 0.000 < 0.05, so there was a significant difference between treatments of the daily growth rate (SGR) parameter, the results of the area test also showed differences between treatments. The highest daily growth rate was obtained in climbing perch, followed by pangas fish, giant gourami and snakehead fish. Average daily weight gain (3.18±1.576 g day⁻¹) [45]. The specific growth rate (SGR) ranged from 1.75-2.30% day⁻¹ [46]. It was stated that the SGR value of climbing perch reared in hapa ranged from 3.69-3.82% day⁻¹ [47,48] the SGR value of climbing perch reared in cages ranged from 2.24-2.52% day⁻¹. The results of the study [31] range of SGR between 4.08 - 4.09% day⁻¹. Therefore, climbing perch fish is one

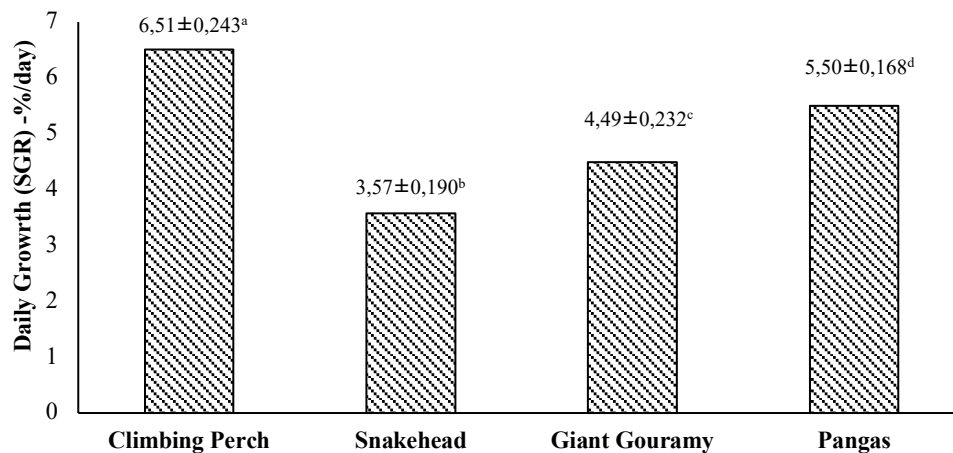


Figure 2. Average daily growth rate (SGR) (%/day) of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronemus gouramy*) and pangas (*Pangasius hypothalmus*) during 158 days of rearing in the biofloc system.

of the most suitable species to be cultured in biofloc system by adding rice flour or rice bran as a good carbon source alternative [31]. The use of feed with 34% feed protein is thought to be the trigger for daily growth with predominantly female climbing perch [34]. Snakehead final weight (g) was studied in the range of 138.30 - 506.39 and SGR 2.29% - 2.94% [49]. The average growth rate was observed to be faster during the rainy season compared to the dry season [50], specific growth rate (% day⁻¹) 6.73 [51]. SGR, were 3.34%, 3.37%, and 3.45% [52]. SGR = 100 x (ln final weight (g) - ln initial weight (g)) / time (days) SGR (%day⁻¹) 3.54 - 3.61 [53]. Best results for growth rate were found in the dose of 15 ml/kg feed) with an absolute growth rate of (23.12 % day⁻¹) and the lowest in P0 (without probiotics/control) with an absolute growth rate of (8.00 %/day) [54]. The results showed that the provision of probiotics with different doses in the feed showed significantly different results ($P < 0.05$) on the growth rate but had no significant effect on the survival rate of fish ($P > 0.05$). Reducing the feeding rate to 2.5% in carp rearing with a biofloc system can increase survival and feed efficiency, but provides the lowest growth rate compared to other treatments [55]. The SGR of Pangas fish fed with moringa was 23.5 g BW, 5.8 cm TL, and 4.3% SGR, respectively. While the control fish each weighed 13.0 g BW, TL 4.23 cm, and SGR 2.89% per day [56] (At the 9th week, fish in the 24d had a weight of 70.71 g BW with a TL of 19.27 cm (daily weight growth rate of 9.35%), while fish in the eighteenth had a weight of 69.41 g, a TL of 18.77 cm, and a daily growth rate of 9.29%. Fish grown under the normal photoperiod weighed about 61.95 g BW with a TL of 18.19 cm and a daily growth rate of 7.33% [57].

Weight gain (g)

The average weight gain (g) can be seen in Figure 3. Anova test showed a significance value as follows (Sig.) 0.000 < 0.05, so there was a real difference between treatments. The performance of growth and productivity of Thai climbing fish and Vietnamese climbing perch (*Anabas testudineus* Bloch) fed on a commercial diet of pellets (30% of crude protein). Indeed, after four months of culture, gross fish yields of 15,352 and 9,456 Kg/ha were recorded for the Vietnamese and Thai strains respectively [58]. These findings indicate that higher average growth and production were observed in the Vietnamese strain compared to the Thai climbing perch. [with fish with an average initial weight of 0.80 ± 0.02 g maintained in biofloc tanks for 13 weeks with three different stocking densities, 300 (T-300), 450 (T-450), and 600 (T-600) fish m³ in three replicates and the fish were fed with a commercial diet of 3%, indicating that the optimum stocking density of Climbing Perch fish in the biofloc system is 300–450 m³. [30]. Comparison of male to female fish from Bangladesh, Thailand and Vietnam with samples obtained by sex ratios respectively: 1.7; 1; 1.3; 1; and 2: 1. With a range of standard lengths for female origin Bangladesh 9.3 – 10.3 cm, Thailand 15.6–20.0 cm and Vietnam 11.7 – 14.6 cm with a range of lengths for male climbing perch fish from Bangladesh: 7.2 – 9.1 cm, Thailand 9.9 -14 cm and Vietnam 8 – 13.1 cm [59]. The absolute weight growth and daily growth rate of female climbing perch were 1.48 times and 1.17 times that of male climbing perch [60]. Snakehead fish weight gain (g) ranges from 3.89 - 6.29 [49]. Absolute weight growth rate (g day⁻¹) 0.13 - 0.14 [61]. The average weight gain at T1, T2, and T3 was 128.7, 140.7, and 162.3 g, [52]. The average weight gain at T1, T2, and T3 was 128.7, 140.7, and 162.3 [51].

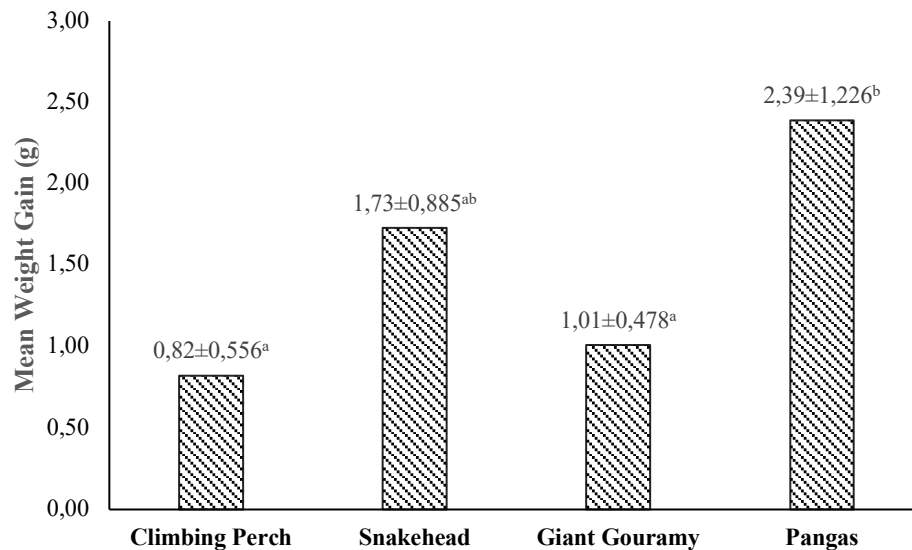


Figure 3. Mean weight gain (g) and specific growth rate (%/day) of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronomus gouramy*) and pangas (*Pangasius hypophthalmus*) during 158 days of rearing in the biofloc system.

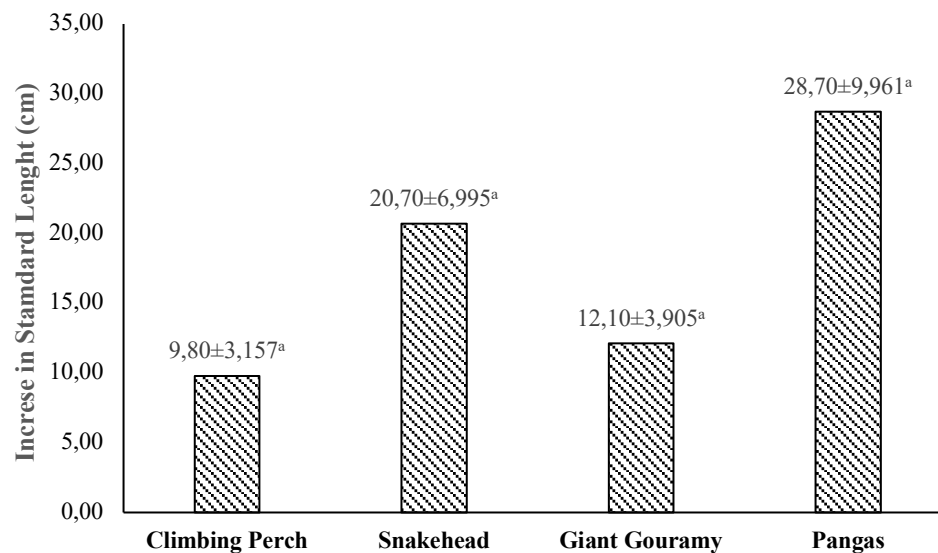


Figure 4. Standard average length gain (cm) of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronomus gouramy*) and pangas (*Pangasius hypophthalmus*) during 158 days of rearing in the biofloc system.

WG% = [(final weight (g)-initial weight (g)) / initial weight (g)] × 100 WG (%) 83.2, 87.0, 99.0, 89.3. ADG = weight final (g)-initial weight (g) / time (day) 4 ADG (g fish day⁻¹) 1.43, 1.50, 1.70, 1.54. FI = dry weight of feed / time (day) / number of fish in each tank FI (g fish⁻¹) 100.00, 95.4, 112.8, 106.8. PER = wet weight gain (g) / protein intake (g); PER 2.18, 2.24, 2.19, 2.12, CF 0.76, 0.77, 0.80, 0.79 =

(weight body (g) / Body length³ (cm)) × 100 %; 76%, 77%, 80%, and 79% [53]. These patterns indicate that *C. striata* larvae/juveniles are best reared to fry between 18 dph [62]. Several steps in the effort to implement a nursery strategy for snakehead fish seeds as a measure to anticipate population decline through biofloc technology are: (1) Development of an integrated snakehead fish cultivation center or center supported by regional potential; (2) Creating role models for snakehead fish cultivation using

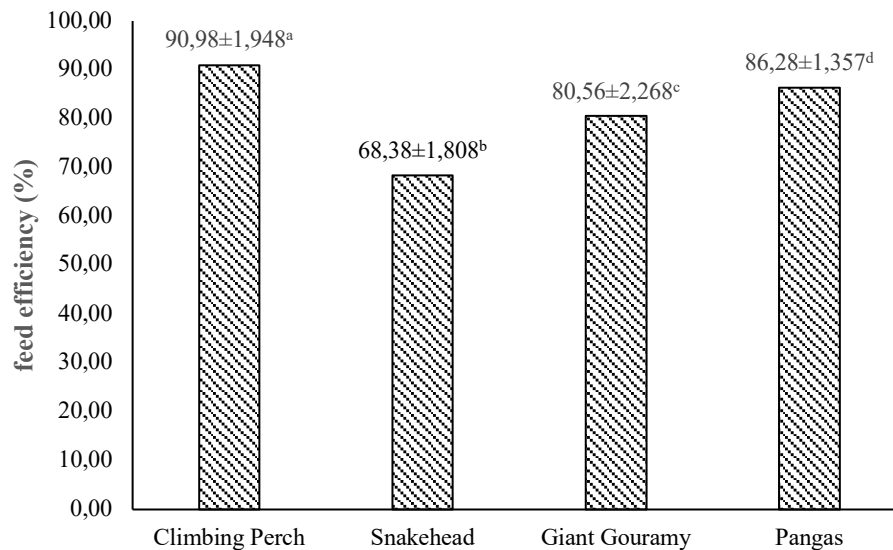


Figure 5. The average feed efficiency of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronomus gouramy*) and pangas (*Pangasius hypothalmus*) during 158 days of rearing in the biofloc system.

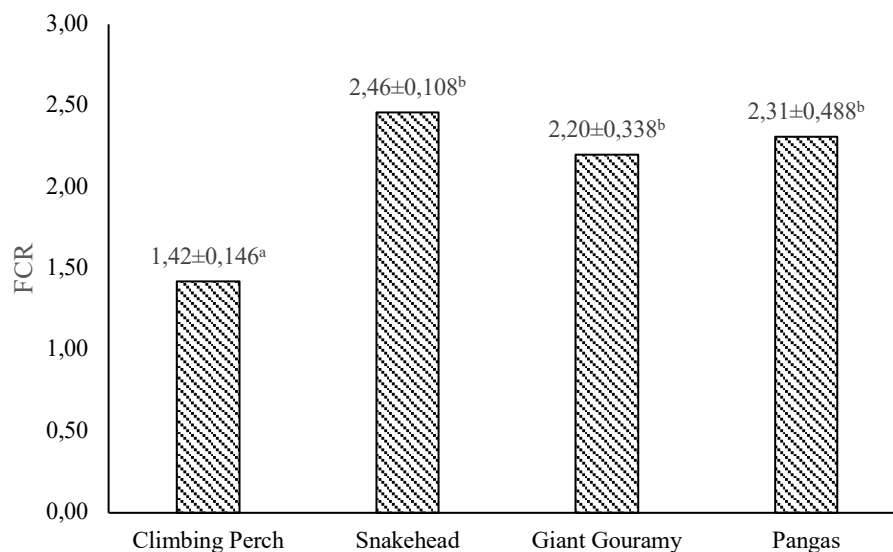


Figure 6. The conversion of average food of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronomus gouramy*) and pangas (*Pangasius hypothalmus*) during 158 days of rearing in the biofloc system.

the biofloc system, especially in the hatchery business segment; (3) Increasing the dissemination of biofloc technology in snakehead fish hatcheries; (4) Stimulation of snakehead fish cultivation businesses, especially in the hatchery segment, through assistance with seeds, prospective parents, technical guidance, and biofloc system cultivation facilities [64]. The adding of papain enzyme 2.0% significantly produces the best absolute growth of giant gourami, which is 3.06 ± 0.62 g [65]. The

provision of probiotics 7 with different doses consisted of the four treatments and three replications, treatment A (0 ml kg^{-1}), B (5 ml kg^{-1}), C (10 ml kg^{-1}) D (15 ml kg^{-1}). The feed was given as much as 5% of the biomass with a frequency of 2 times a day. The best weight gain was found in the treatment C which was 2.20 g, then followed by treatment D which was 2.15 g and treated B which was 2.11 g, while the lowest weight gain was found in treatment A which was 2.09 g. The highest weight gain was found in

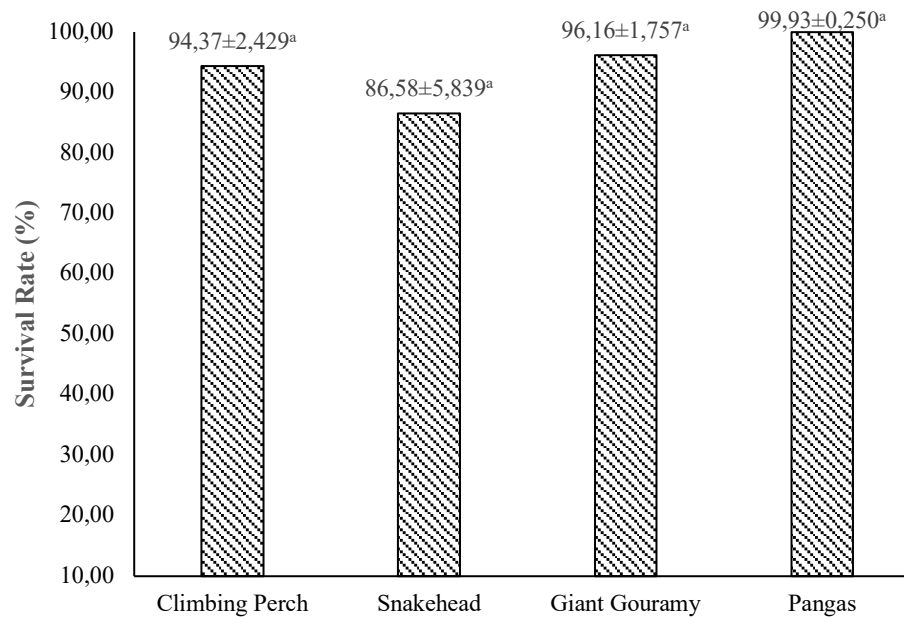


Figure 7. Mean survival rate of climbing perch (*Anabas testudineus*), snakehead (*Channa striata*), giant gourami (*Ospronemus gouramy*) and pangas (*Pangasius hypothalmus*) during 158 days of rearing in the biofloc system.

Table. 5. Water quality and floc content in maintenance media of Climbing Perch (*Anabas testudineus* Bloch), Snakehead (*Channa striata* Bloch), Giant Gouramy (*Ospronemus gouramy*) and Pangas (*Pangasius hypothalmus*) during 158 days of rearing in biofloc system

Parameters	Range				
	Unit	Climbing Perch	Snakehead	Giant Gouramy	Pangas
Content floc	ml L ⁻¹	23 - 90	10 - 200	15 - 75	14 - 60
Water temperature	°C	26,50 - 31,00	26,30 - 30,00	27,1 - 31,0	26,6 - 31,2
pH		6,91 - 7,12	6,96 - 7,19	6,99 - 7,23	6,99 - 7,27
dissolved oxygen	mg L ⁻¹	3,68 - 4,74	3,64 - 4,81	3,99 - 4,68	3,59 - 4,89
dissolved ammonia	mg L ⁻¹	0,05 - 0,47	0,05 - 0,49	0,05 - 0,36	0,05 - 0,44

treatment C which was 2.20 g, followed by treatment D which was 2.15 g and treatment B which was 2.11 gr [66]. Pangas fish weighed a difference of 99.78 g and control 71.62 g [56]. Absolute growth of Weight (g) 74.06 ± 12.29 72.75 ± 5.36 58.61 ± 11.66 [57]. The deployment of biofloc technology in the culture systems of several aquatic species can increase net yield productivity by 8-43%, compared to non-biofloc controlled (traditional water exchanged, freshwater systems, or recirculating Aquaculture systems) [67].

Standard length increase (cm)

Anova test results show a significance value (Sig.) of 0.052 > 0.005, so there was no real difference between treatments; The growth of each treatment shows

characteristics between species depending on the genes of the species.

The initial length ranges from 5.60 cm, while the ultimate length in the aquaponic system was 9.02 cm and 8.19 cm in the conventional system with an increase in length of 3.6 cm and 2.59 cm during the 42 days of rearing, respectively [68]. The ultimate average length gain (cm) of the Vietnamese variety climbing perch was in the ranges of 13.58 - 13.70 cm with an undisclosed initial length, only an averaged weight of 1.01 grams during 7 months of rearing [69]. The ending length was in the interval (cm) 11.15-12.50, with a different interval of 5.35-6.70 cm [70]. The absolute highest increase the longest was in the C treatment with a probiotic dose of 10 ml/kg of feed which produced a width of 4.27 cm, then B treatment = 4.23 cm, then D with 4.21 cm, and A with 3.99 cm [66] that with

24D0L lighting (22.48 cm) the length of the Pangas fish was 3.55 cm longer than the control (18.93 cm). Relative growth of fish length (cm) [56]; 17.73 - 19.28 [57].

Feed efficiency (%)

Figure 5 shows the average feed efficiency of climbing perch (*Anabas testudineus* Bloch), snakehead (*Channa striata* Bloch), giant gouramy (*Ospronomus gouramy*) and pangas (*Pangasius hypophthalmus*) during 158 days of rearing in the biofloc system. Anova test results show a significance value (Sig.) $0.000 < 0.05$, so there was a real difference between treatments in terms of feed efficiency.

Feed utilization efficiency of climbing perch $6.72 \pm 3.47 - 52.22 \pm 6.54$ [71], feeding efficiency of climbing perch was also higher in treated fishes (39.73-48.07%) compared to that of control (33.73%) [72]. There was no significant difference in. BSF larvae meal protein can be used to partially replace fish meal and improve growth performance and feed utilization, while increasing in HSI, VSI and crude lipid content may negatively impact climbing perch health [73]. Snakehead feed efficiency (78.22%), protein retention (41.91%), energy retention (30.81%) [51]. Giant gouramy feed efficiency was highest in treatment P3 (dose 15 ml kg^{-1} feed) with a value of (72.50 %) and lowest in treatment P0 with a value of (33.38 %) [54]. The feed consumption level is 93.63 ± 0.43 , the protein efficiency ratio is 6.39 [74]. Pangas that were fed pellets enriched with moringa showed the highest feed efficiency (90.42-97.46%) while fish that were not fed moringa feed showed the lowest FE 75.48% [67]. Improving the feed efficiency (FE) of aquacultured fish is essential to reducing the production cost and increasing the sustainable of the sector. Recognizing that the organism is a comprehensive system whose emergent hypothesis is the product of multiple interacting molecular processes, a systems-based approach is expected to provide new scientific insights into FE and growing capacity [75]. Increasing the feed efficiency (FE) is central to decreasing cost of the production in the aquaculture and reaching the sustainability for the aquaculture industries. The feed expense accounted for 30-70% of the overall costs of production in the aquaculture industry; many studies have been conducted on the nutritional and rearing aspects of improving FE, but few studies have been dedicated to the use of genetics, regardless of its potency[76].

Feed Conversion Ratio (FCR)

Figure 6 shows the average food conversion results of climbing perch (*Anabas testudineus* Bloch), snakehead (*Channa striata* Bloch), giant gouramy (*Ospronomus gouramy*) and pangas (*Pangasius hypophthalmus*) during 158 days of rearing in the biofloc system.

Feed conversion ratio (FCR) ranges from 1.55 - 1.57. The Anova test results show that the survival rate of the study fish has a significance score of $0.000. < 0.05$, meaning that the four types of fish studied are significantly different

from those kept in the biofloc system [31], while it ranges between 1.48, 1.85, and 1.56; 2.81 - 3.19, [45]; 2.65 - 2.93 [74]; 2.81-3.19 [78]; 3.31-3.99; [47]; 1.94 - 11.42 [71]. FCR values were 2.26, 2.05, and 1.79; while T3 showed the highest and seed growth of *Channa striata* Bloch compared with other commercial feeds [45]. The best feed conversion ratio for giant gouramy was in treatment P3 (1.38 ± 0.17 g) and the lowest was in P0 (3.05 ± 0.49 g) [54]. Feeding with a protein level of 17% + adding molasses with a C/N ratio of 12) the feed conversion ratio of feeding with a protein level of 30% without molasses is low, namely 1.6 [76]. The smallest feed conversion ratio is 1.00. The retention of the best protein is found in the B treatment, which is 13% [68] The smallest feed conversion ratio is 1.00 ± 0.25 . The best protein retention was in treatment B, namely 13% ; Lowest FCR ($1.03 - 1.11$ [74] FCR in the range 1.3 - 1.9.[79]. Feed Conversion Ratios (FCRs), which are utilized as a proxy for the growth as a function of feed intake, depend mainly on the feeding rate as well as the temperature. FCR is estimated simply; however, the potential practical applicability of this ratios is restricted to the cases where the fish are being fed in excess of the rearing rate [80].

Survival rate (%)

The average survival rate from this study can be seen in Figure 7.

The Anova test results show that the survival rate of the study fish has a significance value of $0.000 < 0.05$, which implies that four types of fish studied were significantly different from those kept in the biofloc system. The best median score for survival was for pangas fish (99.92%) in subset 3, while climbing perch (94.46%) and giant gouramy (96.23%) were the same (subset 2) and snakehead with 86.62%, the lowest (subset 1). The biofloc system's survival range is 86.62-99.67%. Survival rate of climbing perch ranges between 92.50 - 95.12 % [69]; 92.75% - 98.5%, [45] and reported in the range of 96.57 % - 96.00% [83], which also showed the same result, while the vietnamese climbing perch variety has a life expectancy range of 93.25 - 95.14% [76] and the magur variety 64.00 - 72.00 % [67]; [54],the highest (93.60%) and lowest (83.06%) survival rates in climbing perch Thailand (T4) and climbing perch locally (T3); $95.15 - 96.06\%$ [81]; 72.00%-96.00%; [82]; in biofloc system is 94.89 - 99.67% and of the traditional system is 82.00 - 94.26%. [32] and 99.48 - 99.66% [33]. Snakehead Survival Rate ranges from 59.11 - 86.67 [48]. Survival rate (%) $92.5 - 94.58$ [59]; 92% [61]. The average survivability rates in T1, T2, and T3 were 45.5%, 71.8%, and 82.67%, respectively, while the FCR rates were 2.26, 2.05, and 1.79. T1 had the poorest survival and the lowest FCR [52]. $\text{SR} = 100 \times (\text{Final fish number}/\text{initial fish number})$ $95.9 - 96.3\%$; FCR 1.14 - 1.20 [52]. Provision of artificial feed with a protein level of 17% + addition of molasses with a C/N ratio of 12 provided better survival, but the feed conversion ratio was poor. The

average survival rate with a protein level of 17% + addition of molasses with the highest C/N 12 giant gouramy ratio is 89% [76]. Survival values for control treatments, 2.0% and 2.5% classified as good and ranges from 70.00-76.67%. However, the survival value in the treatment with the addition of 1.5% papain enzyme was classified as moderate, namely 33.33 % [65]. The best survivability was found in treatment C (probiotic dosage of 10 ml) with a percentage of 80%, followed by treatment D (probiotic dosage of 15 ml) with a presentation percentage of 80%, followed by treatment D (probiotic dosage of 15 ml) with a percentage of 77%, followed by treatment B (5 ml probiotic dosage) with a percent of 67% and the least was treated A (0 ml dosing) or controlled with a percent of 60% [66]. The fish survival rate in all treatments was 93.3 - 98.89% [67]. The first experiment showed that larvae fed in the first 30 hours showed Significantly greater survival (24%) than larvae that were fed at the first 36, 42 and 48 hours (19%, 16% and 16%, respectfully). The 2nd attempt showed that larvae fed at densities of 8 and 11 ind/mL exhibited significantly higher survival rates (32% and 32%) than larvae fed at densities of 3 and 5 ind/mL (13% and 23%). The 3rd attempt showed that the higher survival level (66%) was observed when larvae were fed 6 feedings per day [86]. Biofloc technology can support the provision of good quality seeds by improving the reproductive performance of aquaculture fish and increasing fish immunity and resilience [83, 86 – 87].

Water quality and floc contents

The results of measuring floc content and water quality in rearing media of Climbing Perch (*Anabas testudineus* Bloch), Snakehead (*Channa striata* Bloch), Giant Gouramy (*Ospronomus gouramy*) and Pangas fish (*Pangasius hypophthalmus*) during 158 days of maintenance in the bioflocs system can be seen in the Table. 5.

The floc contains

The floc content during the study of the 4 types of fish studied was in the 10-200 ml/L range. Climbing Perch floc content in biofloc and traditional fish rearing systems ranged from 15.50-43.06 ml L⁻¹ [88]. The climbing perch floc content in the range of 170- 190 mg L⁻¹. The floc volume density is 60-80 ml L⁻¹, [31], more suitable for cultivating catfish in a biofloc system [78]. The range of floc content is 4.75 - 9.40 ml L⁻¹ [32]; 5.35 –8.16 ml L⁻¹ [33] and 9,583-10,524 ml L⁻¹ [34] The floc content during the study was in the low - high category in accordance with the opinion of [89] that the amount of floc in the ranges of 1-10 ml L⁻¹ is relatively low and the amount between 10-20 ml L⁻¹ is moderate. The optimal floc amount in a biofloc system for shrimp is in the 5-15 ml L⁻¹ range, tilapia fry in the 5-20 ml L⁻¹ range, juvenile to adult size (“consumable size”) in the 20-50 ml L⁻¹ range [87].

Water temperature

The temperature range in research water temperature (°C) research ranges from 26.50 – 31.00, 26.30 – 30.00 26.10 – 31.0, 26.60 - 31.20. this is in the acceptable limit for aquaculture, and these outcomes are in line with the findings [46,48, 90, 91]. Water quality for the climbing perch biofloc systems with a wide range of water temperature levels 26.80 - 30.67°C. [78]. Water temperature range 26.5 – 27.4°C [32]; 28.54 - 28.71°C [33] and 26.89-27.62 °C [34]. Snakehead water temperature ranging from 25.0-30.55°C [49]; 29–30 [61]; Pangas fish water temperature range 27.6–27.9°C [92]; Pangas 28.67 - 29.67[57]; the water quality range for pangas is 31.50 - 32.03 [79]; giant gourami water temperature (°C) 26.93 – 27.39 [65]; giant gouramy 23.6-30.0°C [76] have also noted that the water temperatures between 26.06-31.97°C are acceptable for fish farming, while based on[87], the biofloc method is in the 28-30°C range [31].

Degree of acidity (pH)

The range of acidity in all treatment was in the interval of 6.91-7.27. The climbing perch biofloc systems were in the 7.6 - 7.8 range [88] and 6.87-7.04 [33] and 6.87-7.04 [34]; 7.85 - 8.14 [31]. Snakehead water pH ranges from 6.725-9.075 [49] and pH 5.36–5.57.25 [61]. Ranges water pH for gourami 7.4 – 9.1; [93]; 7.69 -7.99 [65]; 5.0 [57] and 6.3-8.8 [76]. Range water pH for pangas, pH 6.50 - 6.87[92]. Good acidity degrees for biofloc systems are in the range 6.8–8.0 [87]. pH is important parameter that should be continuously monitored in BFT.To ensure the successful development and maintenance of the BFT production cycle, it is essential to understand the parameters of water quality and their interactions.

Dissolved oxygen

The range of dissolved oxygen levels in this research is in the following range of 3.59 – 4.89 mg L⁻¹). Dissolved oxygen ranges for climbing perch fish 5.1 - 7.8 mg L⁻¹[33], and 5.1-7.8 mg L⁻¹ [34]. The dissolved oxygen concentration ranges are within the acceptable range for climbing perch fish farming and are in accordance with the observations [48], [90, 91]. Ranges for snakehead fish 2.91-5.14 mg L⁻¹ [49];3.62–6.14 mg L⁻¹ [61]. Ranges for gourami 6.4-8.8 mg L⁻¹ [76]; 6.5 – 9.3 mg L⁻¹, [93]. Ranges for pangas fish 3.75 – 4.05 mg L⁻¹ [93] ;5.34 – 5.41 ml/L [80] and 4.50 – 5.9 mg L⁻¹ [57]. For optimal growth of fish, dissolved oxygen level should be more than 5 mg L⁻¹ for tropical aquatic fish specifically [95]. Nevertheless, fish can tolerate a concentration of 0.50 mg L⁻¹, but the most acceptable range of dissolved oxygen for aquaculture is recommended to be between 5.0-8.0 mg L⁻¹ [96], recommend that the dissolved oxygen concentration in biofloc systems be higher than 4 mg L⁻¹ [87].

Dissolved ammonia

The average range of Ammonia concentration was in the ranging of 0.05 - 0.49 mg L⁻¹. In the climbing perch biofloc system, the limit of ammonia value is 0.24 - 0.78 mg L⁻¹ [88], Ammonia-nitrogen 0.05-0.85 0.06-0.92 mg L⁻¹ [58]. Water quality for climbing perch in biofloc system with the range of dissolved ammonia is 0.019 - 0.021 mg L⁻¹ [31], in Snakehead ammonia range 0.016 – 0.027 mg L⁻¹ [51] (at the fish tank), ammonia 0.10 – 1.40 mg L⁻¹ [48]. Giant gouramy dissolved ammonia 0.16 – 0.21 mg L⁻¹ [92] and 0.093 – 0.098 mg L⁻¹ [93]. Pangas, ammonia 2.60 – 6.06 mg L⁻¹ [57]. Soluble ammonia concentration should be below 1 mg/L of soluble ammonia [87]. Thus, water quality with 4 main parameters is able to support growth and development of the 4 economically important types of fish studied.

CONCLUSION

The results showed that the results of the anova test showed a significance value (Sig.) of 0.000 < 0.05, so there was a significant difference between treatments of the daily growth rate (SGR) parameter, the results of the area test also showed differences between treatments. The highest daily growth rate was obtained in climbing perch, followed by pangas, giant gourami and Snakehead. The results of the anova test for weight gain showed a significance value (Sig.) of 0.000 < 0.05, so there was a significant difference between treatments. The anova test results showed a significance value (Sig.) of 0.052 > 0.005, so there was no significant difference between treatments; the growth of each treatment showed peculiarities between species depending on genes. Anova test results show that the feed conversion of fish research significance value 0.000 < 0.05 means that the four types of fish studied, significantly different from those reared in the biofloc system Survival rate of fish research significance value 0.000 < 0.05 means that the four types of fish studied, significantly different from those reared in the biofloc system. Water quality with 4 main parameters is able to support the growth and development of the 4 economically important fish species studied.

ACKNOWLEDGMENT

We thank: Hamidtahul Hasanah, Arya Mahatama, M. Fudaeli, Sandi Syahdana Rangkuti, M. Nizar, Aldam Dandi Prayoga, Yusuf Cahyo Susilo, Dhiya Ulhaq Falih Pandi, Kusumawardhani, Ardi Hatim Fannani for their participation and assistance starting to prepare equipment, materials, sampling, data processing for this research.

REFERENCE

- [1] Ahmad, A. F.; Nasr, M.; Guldhe, A.; Kumar, G. S.; Rawat, I.; Bux, F. 2020. Techno-economic feasibility of algal aquaculture via fish and biodiesel production pathways: A commercial-scale application. *Sci. Total Environ.* **704** 135259. DOI: 10.1016/j.scitotenv.2019.135259.
- [2] Anjalee, D. C.; Madhusoodana, K. B. 2015. Biofloc technology: An overview and its application in animal food industry. *Int. J. Fish Aquac. Sci.* **5** 1–20. irphouse.com/ijfas/ijfasv5n1_01.pdf.
- [3] Sousa, A. A.; Pinho, S.M.; Artur, N. R.; Giovanni, L. M.; Emerenciano, M. G. C. 2019. Pizzeria by-product: A complementary feed source for Nile tilapia (*Oreochromis niloticus*) raised in biofloc technology. *Aquaculture* **501** 359–367. DOI:10.1016/j.aquaculture.2018.11.055.
- [4] Bartholomew, W. G.; Kevin, K. S.; Steven, D. R.; Carl, D. W.; Matthew, E. M. 2020. Comparison of unused water and year-old used water for production of channel catfish in the biofloc technology system. *Aquaculture* **519** 734739. DOI:10.1016/j.aquaculture.2019.734739.
- [5] Ekasari, J.; Nugroho, U.A.; Fatimah, N. 2021. Improvement of biofloc quality and growth of *Macrobrachium rosenbergii* in biofloc systems by Chlorella addition. *Aquacult. Int.* **29** 2305–2317 (2021). DOI:10.1007/s10499-021-00750-1
- [6] Emerenciano, M. G. C.; Ballester, E. L. C.; Cavalli, R. O.; Wasielesky, W. 2011. Effect of biofloc technology (BFT) on the early post larval stage of pink shrimp *Farfantepenaeus paulensis*: Growth performance, floc composition and salinity stress tolerance. *Aquac. Int.* **19** 891–901. DOI: 10.1007/s10499-010-9408-6.
- [7] Emerenciano, M.; Cuzon, G.; Ballester, E. L.; Cavalli, R. O.; Wasielesky, W. 2012. Biofloc technology application as a food source in a limited water exchange nursery system for pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817). *Lat. Am. J. Aquat. Res.* **43** 447–457. DOI: 10.1111/J.1365-2109.2011.02848.X.
- [8] Walker, D. A. U.; Morales, S. M. C.; Emerenciano M.; Cuzon, G. 2020. Biofloc technology: principles focused on potential hypothalmusecies and the case study of Chilean river shrimp *Cryphiops caementarius*, *Rev. Aquacult.* **12** 1759–1782. DOI: 10.1111/raq.12408.
- [9] Emerenciano, M. G. C.; Artur, N. R.; Felipe, D. N.; Vieira, M. A.; Martins, G.J.C.; Truong, H.H.; Tansyn, H.N.; Cedric J.S. 2022. Review Intensification of Penaeid Shrimp Culture: An Applied Review of Advances in Production Systems, Nutrition and Breeding. *Animals* **12** 236. DOI: 10.3390/ani12030236.
- [10] Yu, Z.; Li, L.; Zhu, R.; Li, M.; Duan, J.; Wang, J. Y.; Liu, Y. H.; Wu, L. F. 2020. Monitoring of growth, digestive enzyme activity, immune response and water quality parameters of golden crucian carp (*Carassius auratus*) in zero-water exchange tanks of

- biofloc systems. *Aquacult. Rep.* **16** 100283. <http://dx.doi.org/10.1016/j.aqrep.2020.100283>.
- [11] Julia, A. G.; Vicente, P. B.; César, J. V.; Víctor, A. G.; Martha P. G. 2018. Describing the planktonic and bacterial communities associated with bocachico *Prochilodus magdalenae* fish culture with biofloc technology. *J. MVZ Cordoba* **24** 7209-7217.
- [12] Waite, R.; Beveridge, M.; Brummett, R.; Castine, S.; Chaiyawannakarn, N.; Kaushik, S.; Mungkung, R.; Nawapakpilai, S.; and Phillips, M. 2014. Installment 5 of “creating a sustainable food future: Improving productivity and environmental performance of aquaculture: creating a sustainable food future installment five, 2014, World Resources Institute, Washington, DC. 60 pp. <http://www.wri.org/publication/improving-aquaculture>
- [13] Crab, R.; Defoirdt, T.; Bossier, P.; Verstraete, W. 2012. Biofloc technology in aquaculture: beneficial effects and future challenges. *Aquaculture* **356-357** 351-356. DOI: 10.1016/j.aquaculture.2012.04.046
- [14] Hargreaves, J.A. 2006. Photosynthetic suspended-growth systems in aquaculture. *Aquac. Eng.* **34** 344–363.
- [15] Hargreaves, J. A. 2013. Biofloc production systems for aquaculture. Southern Regional Aquaculture Center 450: 1–12. https://aquaculture.ca.uky.edu/sites/aquaculture.ca.uky.edu/files/srac_4503_biofloc_production_systems_for_aquaculture.pdf
- [16] Khanjani, M. H.; Mozanadeh, M. T.; Sharifinia, M.; Emerenciano, M. 2023a. Broodstock and seed production in biofloc technology (BFT): An updated review focused on fish and penaeid shrimp. *Aquaculture* 579.
- [17] Diatin, I.; Shafruddin, D.; Hude N.; Sholihah, M.; Mutsmir, I. 2021. Production performance and financial feasibility analysis of farming catfish (*Clarias gariepinus*) utilizing water exchange system, aquaponic, and biofloc technology. *J. Saudi Soc. Agric. Sci.* **20** 344–351. DOI: 10.1016/j.jssas.2021.04.001
- [18] Garcés, S.; Gabriele, L. 2023. Applying biofloc technology in the culture of *Mugil cephalus* in subtropical conditions: effects on water quality and growth parameters. *Fishes* **8** 1-11. <http://dx.doi.org/10.3390/fishes8080420>.
- [19] Pérez, R. C. I.; Pérez, F. J. A.; Hernández, V. M. P. 2014. Biofloc, a technical alternative for culturing malaysian prawn *Macrobrachium rosenbergii*. *InTech* **57501**: 87-104. <http://dx.doi.org/10.5772/57501>.
- [20] Promthale, P.; Pongtippatee, P.; Withyachumnarnkul, B.; Wongprasert, K. 2019. Bioflocs substituted fishmeal feed stimulates immune response and protects shrimp from *Vibrio parahaemolyticus* infection. *Fish Shellfish Immunol.* **93** 1067-1075. <http://dx.doi.org/10.1016/j.fsi.2019.07.084>.
- [21] Khanjani, M. H.; Sharifinia, M. 2022a. Biofloc as a food source for banana shrimp *Fenneropenaeus merguensis* postlarvae. *N. Am. J. Aquacult.* **84** 469–479. DOI: 10.1002/naaq.10261.
- [22] Amriawati, E. T.; Budiardi, M.; Setiawati, D.; Rohmana.; Ekasari, J. 2021. Digestive system and growth performance of giant gouramy (*Ospronomus goramy* Lacepede) juveniles in biofloc systems fed with different feed types. *Aquacult. Res.* **52** 4661–4669. DOI: 10.1111/are.15300
- [23] Khanjani, M. H.; Sharifinia, M.; Hajirezaee, S. 2023b. Biofloc: A sustainable alternative for improving the production of farmed cyprinid species. *Aquacult. Rep.* **33** 101748. <http://dx.doi.org/10.1016/j.aqrep.2023.101748>
- [24] Ahmad, I.; Leya, T.; Saharan, N. 2019. Carbon sources affect water quality and haemato-biochemical responses of *Labeo rohita* in zero-water exchange biofloc system. *Aquac. Res.* **50** 2879–2887. DOI: 10.1111/are.14241
- [25] Fischer, H.; Romano, N.; Renukdas, N.; Egnew, N.; Sinha, A. K.; Ray, A. J. 2020. The potential of rearing juveniles of bluegill, *Lepomis macrochirus*, in a biofloc system. *Aquacult. Rep.* **17** 100398. DOI: 10.1016/j.aqrep.2020.100398
- [26] Sudirman, A.; Rahardjo, S.; Rukmon, D. 2020. Economical analysis of polyculture of catfish and tilapia fish in biofloc system. *Int. J. Eng. Sci.* **9** 1–7.
- [27] Pinho, S.; Valladão, F.; Roberto, D.; Luiz, Q. K.; Emerenciano, M. G. C.; Portella, M. 2022. Economic comparison between conventional aquaponics and floponics systems. *Aquaculture* **552** 737987. <http://dx.doi.org/10.1016/j.aquaculture.2022.737987>
- [28] Khanjani, M. H.; Zahedi, S.; Mohammadi, A. 2022b. Integrated multitrophic aquaculture (IMTA) as an environmentally friendly system for sustainable aquaculture: functionality and application of biofloc technology (BFT). *Environ. Sci. Pollut. Res.* **29** 67513–67531. DOI: 10.1007/s11356-022-22371-8.
- [29] Majhi, S. S.; Singh, S. K.; Biswas, P.; Debbarma, R.; Parhi, J.; Ngasotter, S.; Waikhom, G.; Meena, D. K.; Devi, A. G.; Mahanand, S. S. 2023. Effect of stocking density on growth, water quality changes and cost efficiency of butter catfish (*Ompok bimaculatus*) during seed rearing in a biofloc system. *Fishes* **8** 1-15. DOI: 10.3390/fishes8020061.
- [30] Debnath, S.; Ahmed, M. U.; Parvez, M.S.; Karmokar, A. K.; Ahsan, M. N. 2021. Effect of stocking density on growth performance and body composition of climbing perch (*Anabas testudineus*) in biofloc system. *Aquacult. Int.* **30** 1089 - 1100. DOI: 10.1007/s10499-021-00812-4.
- [31] Arnuparp, W.; Tongsiri, S.; Chaibu, P. 2020. Growth performance of climbing perch (*Anabas testudineus*)

- in biofloc culture system using different sources of organic carbon. *Burapha Sci. J.* **25** 1015-1025.
- [32] Hanafie, A. 2020. Growth rate of papuyu fish (*Anabas testudineus* Bloch) biofloc system with different probiotic sources. In Prosiding Seminar Nasional Lingkungan Lahan Basah **5** 104-112. [in Indonesian].
- [33] Hanafie, A., Biyatmoko, D.; Fatmawati; Fauzana N. A. 2023a Growth performance and survival of climbing perch (*Anabas testudineus* Bloch) raised in conventional and bioflocs system. *Asian J. Fish. Aquat. Res.* **21** 14-37. DOI: 10.9734/ajfar/2023/v21i2530.
- [34] Hanafie, A.; Biyatmoko, D., Fatmawati; Fauzana, N. A. 2023b. Study of growth and survival of climbing perch (*Anabas testudineus* Bloch) with different sex ratio in biofloc system. *RJOAS* **2** 185-201. <http://10.18551/rjoas.2023-02.22>.
- [35] Bossier, P.; Ekasari, J. 2017. Biofloc technology application in aquaculture to support sustainable development goals. *Microb. Biotechnol.* **10** 1012–1016. DOI: 10.1111/1751-7915.12836.
- [36] Ekasari J. 2020 Research for solutions to biofloc technology problems (pp-pdf). presented at the sukabumi freshwater aquaculture fisheries center webinar. Directorate General of Aquaculture Fisheries, KKP. 21 pp. [in Indonesian].
- [37] Jordan, E. E.; Jane, E. S.; Zoë, H.; Seumas, P. W.; Louis, A. T.; Paula, C.; Neill, A. H. 2022. The relationship of feed intake, growth, nutrient retention, and oxygen consumption to feed conversion ratio of farmed saltwater Chinook salmon (*Oncorhynchus tshawytscha*). *Aquaculture* **554** 738184. DOI: 10.1016/j.aquaculture.2022.738184.
- [38] Crane, D. P.; Ogle, D. H.; ; Shoup, D. E. 2020. Use and misuse of a common growth metric: guidance for appropriately calculating and reporting specific growth rate. *Rev Aquacult.* **12** 1542-1547. DOI: 10.1111/raq.12396.
- [39] Márquez, L.; Almansa, E.; Ruiz, D. N. E.; Díaz, M.; Moyano, F. J. 2024. Relationships between the specific growth rate and the thermal-unit growth coefficient applied to cultured juvenile fish. *Front. Mar. Sci.* **11** 1332912. DOI: 10.3389/fmars.2024.1332912.
- [40] Johnston, D.; Roy, M. S.; Blair, H. 2007. Survival and growth of western rock lobster *Panulirus cygnus* (George) fed formulated diets with and without fresh mussel supplement. *Aquaculture* **273** 108-117. DOI: 10.1016/j.aquaculture.2007.09.02.0
- [41] Rodde, C.; Béatrice, C.; Marc, V.; Trong, Q. T.; John, A.H.; Benzie H. V. 2020. Can individual feed conversion ratio at commercial size be predicted from juvenile performance in individually reared Nile tilapia *Oreochromis niloticus*. *Aquacult. Rep.* **17** 100349. DOI: 10.1016/j.aqrep.2020.100349.
- [42] Zonneveld, N.; Huisman, E. A.; Boon, J. H. 1991 Principles of fish farming. Gramedia Pustaka Utama, Jakarta. 318 pp. https://perpustakaan.kkp.go.id/union/index.php?p=s&how_detail&id=5283.
- [43] Krebs, C. J. 2014 Ecological Methodology. Menlo Park: Benjamin Cummings 1st edition. 624 pp. urn:lcp:ecologicalmethod00char:lcpdf:3cdc6332-04d4-47f7-bc29-4132790a28ec.
- [44] Avnimelech, Y. 2012 Biofloc Technology – A practical guide book. Publisher the world aquaculture society. Baton Rouge. Edition 2nd.
- [45] Waseeh, M.; Rahman, A. A.; Najmus, S. K. 2020. Effects of artificial food additives in vietnam koi, *Anabas testudineus* (Bloch, 1792) Pond culture system. *Int. J. Fish. Aquat. Res.* **5** 50-54.
- [46] Uddin, K. B.; Bashar, A. M.; Saiful, I. A. K. M. 2021. Nursing of Thai climbing perch, *Anabas testudineus* in Kaptai lake cages. *AACL Bioflux* **14** 3645-3653.
- [47] Hasan, M.; Ahmad, A. K. S.; Khan, M. M. R. 2010. A preliminary investigation into the production of Thai koi (*Anabas testudineus*) reared in nylon hapas in Bangladesh. *Bangladesh Res. Publ. J.* **4** 15-23.
- [48] Uddin, K. B.; Basak, S.; Moniruzzaman, M.; Islam, A. K. M. S.; Mahmud, Y. 2015. Impact of brush shelter - a fish aggregating device (FAD) on the production potentiality of Kaptai lake in Bangladesh. *World J. Fish Mar. Sci.* **7** 288-294.
- [49] Puspaningsih, D.; Lies, S.; Eri S.; Imam, T. 2021. Effect of different stocking density of snakehead fish (*Channa striata* Bloch) cultured in recirculation aquaculture system. *E3S Web Conf.* **322** 02005 DOI: 10.1051/e3sconf/202132202005.
- [50] Djumanto; Setyobudi, E.; Simanjuntak, C. P. H.; Rahardjo, M. F. 2020. Estimating the spawning and growth of striped snakehead *Channa striata* Bloch, 1793 in lake Rawa Pening Indonesia. *Sci. Rep.* **10**(1) 19830. www.nature.com/scientificreports DOI: 10.1038/s41598-020-76825-5.
- [51] Purnamawati; Djokosetiyanto, D.; Nirmala, K.; Surawidjaja, E. H.; Affandi R. 2017. Survival and growth of stiped snakehead fish (*Channa striata* Bloch.) juvenile reared in acid sulfate water and rainwater medium. *AACL Bioflux* **10** 265-272. <http://www.bioflux.com.ro/aacl>. <http://www.bioflux.com.ro/docs/2017.265-273.pdf>.
- [52] Awal, M. R.; Islam, M. S.; Khanom, M.; Bhadra, A.; Mahmud, Y. 2023. Domestication performance of the striped snakehead *Channa striata* fry in pond conditions using different diets. *Arch. Agric. Environ. Sci.* **8** 364-369. DOI: 10.26832/24566632.2023.080301.
- [53] Suratip, N.; Siripavee, C.; Rungkan, K.; Mikael, H.; Bundit, Y. 2023. An investigation into the effects of using protein hydrolysate in low fish meal diets on growth performance, feed utilization and health status

- of snakehead fish (*Channa striata* Bloch) fingerling. *Aquacult. Rep.* **30** 101623 DOI: 10.19027/jai.7.151-157.
- [54] Herimaweti, M.; Amri. 2023. The Effect of giving probiotics at different doses on the growth and survival of gourami fish (*Ospronemus gouramy*). *Ejurnal bunghatta* **2** 2. [in Indonesian]. (<https://www.sciencedirect.com/science/article/pii/S2352513420301459>).
- [55] Ningsih, L. S.; Ekasari, J.; Fauzi, I. A. 2019. Growth performance of *Ospronemus gouramy* gourami fish seeds in a biofloc system with different feeding levels. <http://repository.ipb.ac.id/handle/123456789/101948>. [in Indonesian].
- [56] Kohinoor, A. H. M.; Islam, M. S.; Jahan, D. A.; Khan, M. M.; Hussain, M. G. 2012. Growth and production performances of crossbred climbing perch koi, *Anabas testudineus* in Bangladesh. *Int. J. Agril. Res. Innov. Technol.* **2** 19-25.
- [57] Windarti, W.; Bintal, A.; Simarmata, H. A. 2021. Growth and health status of *Pangasianodon hypophthalmus* reared under manipulated photoperiod conditions. *F1000Research* **10** 154. DOI: 10.12688/f1000research.28259.2.
- [58] Parvez, I.; Mahajebin, T.; Clarke, M. L.; Chhanda, M. S.; Shirin, S. 2020. Genetic variation of native and introduced climbing perch *Anabas testudineus* (Bloch, 1792) derived from mitochondrial DNA analyses. *Ecol. Genet. Genomics* **17** 100067. DOI: 10.1016/j.egg.2020.100067.
- [59] Sihombing, C.; Fauzi, M.; Windarti, W. 2021. Survival and growth of *Pangasianodon hypophthalmus* cultured under controlled photoperiod. *Depik* **10** 98-102. [in Indonesian]. DOI: 10.13170/depik.10.2.20053.
- [60] Adang, S.; Tatag, B.; Reza, S.; Naufal, D. R. 2018. Growth performance and survival of Snakehead *Channa striata* Bloch juvenile with different stocking density reared in recirculation system. *J. Akuakultur Indonesia* **17** 104–112. [in Indonesian]. DOI: 10.19027/jai.17.2.104-112.
- [61] Hidayat, R.; Carman, O.; Alimuddin. 2016. Sexual dimorphism related to growth in climbing perch *Anabas testudineus*. *J. Akuakultur Indonesia* **15** 8–14. [in Indonesian]. DOI: 10.19027/jai.15.8-14.
- [62] Windarti, W.; Siregar, S.; Simarmata, H. A.; Samiaji, J. 2023. Survival and growth of *Pangasianodon hypophthalmus* fed with *Moringa oleifera* enriched pellets and reared in tank with aquaponic system and dark condition. *J. Natur Indonesia* **21** 1-6. [in Indonesian].
- [63] Rakhi, K.; Srivastava, P. P.; Kedar, N.; Mohanta, P. D.; Rajesh, K.; Lakshman, S.; Prakash, S.; Gopal, K.; Anirban, P.; Siddaiah, G. M. 2024. Optimization of weaning age for striped murrel (*Channa striata* Bloch) based on expression and activity of proteases, *Aquaculture* **579** 740277. DOI: 10.1016/j.aquaculture.2023.740277.
- [64] Sihananto, B.; Supriyono, E.; Diki, D.; Supriani. 2023. Snakehead fish seed nursery strategy as a step to anticipate population decline using biofloc technology. *Policy Brief Agric. Mar. Trop. Biosci.* **5**(4):790-795. DOI: 10.29244/agro-maritim.0504.790-795.
- [65] Sofiyandi, D.; Anandita, E.; Dewi, N.; Dewi, W.; Emyliana, L. 2022. Growth and survival rate of gourami (*Ospronemus gouramy* Lac.) with supplementation of papain enzyme in feed. *J. Maiyah* **1** 14-23. [in Indonesian]. DOI: 10.20884/1.maiyah.2022.1.1.6626.
- [66] Monoarfa, E.; Hasim, H.; Tuiyo, R. 2023. The effect of probiotic probio 7 with different doses in feed on the growth and survival of gourami fish seeds (*Ospronemus gouramy*). *J. Fish. Agribusiness* **1** 85-93. [in Indonesian]. DOI: 10.56190/jfa.v1i2.18.
- [67] Ekasari, J. 2014 Biofloc Technology as an Integral Approach to Enhance Production and Ecological Performance of Aquaculture, (Dissertation) Ghent University. 207 pp.
- [68] Anantharaja, K.; Mohapatra, B. C.; Pillai, B. R.; Kumar, R.; Devaraj, C.; Majhi, D. 2017. Growth and survival of climbing perch, *Anabas testudineus* in nutrient film technique (NFT) aquaponics system. *Int. J. Fish. Aquat. Stud.* **5** 24-29.
- [69] Haque, M.; Mozamme, L. M.; Hosen, H.; Rahman, M. M. 2017. Growth performance of Vietnamese koi (*Anabas testudineus*). *Int. J. Curr. Res. Bio. Med.* **2**: 1-7. DOI: 10.22192/ijcrbm.2017.02.03.001.
- [70] Uddin, K. B.; Moniruzzaman, M.; Bashar, A. M.; Sanjib, B.; Saiful, I. A. K. M.; Yahia, M.; Seunghan, L.; Sungchul, C. B. 2016. Culture potential of Thai climbing perch (*Anabas testudineus*) in experimental cages at different stocking densities in Kaptai Lake, Bangladesh. *AACL Bioflux* **9**: 564-573.
- [71] Fauzana, N. A.; Akbar, J.; Komariah, S. N. 2024. Effects of feed in fasting time difference on growth rate and survival of climbing perch (*Anabas testudineus* Bloch) UDC 639. *Biotika* **1** 1- 10. DOI: 10.18551/biotika.
- [72] Sunarto; Suriansyah; Sabariah. 2008 Effect of dietary vitamin C ascorbic acid on the growth performance and immune response of betok *Anabas testudineus* Bloch. *J. Akuakultur Indonesia* **7** 151–157. [in Indonesian]. DOI: 10.19027/jai.7.151-157.
- [73] Mapanao, R.; Jiwyam, W.; Nithikulworawong, N.; Weeplian, T. 2021. Effects of black soldier fly (*Hermetia illucens*) larvae as a fish meal replacement on growth performance, feed utilisation, morphological characters and carcass composition of Thai climbing perch (*Anabas testudineus*). *J. Appl.*

- Aquacult.* **351**–15. DOI: 10.1080/10454438.2021.1923609.
- [74] Afriyanti, E. A.; Hasan, O. D. S.; Djunaidah, I. S.; 2020. Growth performance of giant gourami (*Osphronemus gouramy*) fed with combination of fish meal and azolla flour (*Azolla microphylla*). *J. Iktiologi Indonesia* **20** 133-141. [in Indonesian]. DOI: 10.32491/jii.v20i2.520.
- [75] Young, T.; Olivier, L.; Seumas, P.; Walker, M.; Miller, R.; Paula, C.; Konstanze, S.; Noah, E.; Ruixiang, Z.; John, P.; Bowman, R.; Wilson, A.; Bridle, C. G.; Carter, B. F.; Nowak, A.; Alfaro, C.; Jane E. 2023. Symonds prediction of feed efficiency and performance-based traits in fish via integration of multiple omics and clinical covariates. *Biology* **12** 1135. DOI: 10.3390/biology12081135.
- [76] Wijayanti, R.; Muarif.; Lesmana D. 2019. Survival rate and feed conversion ratio in cultivated gourami fish (*Ospronemus goramy* LAC.) Using the biofloc system and feeding with different protein levels]. *Mina Sci. J.* **5** 42-49. [in Indonesian]. DOI: 10.30997/jms.v5i1.1772.
- [77] Hugues, V.; Hans, K.; Edwige, Q.; Béatrice, C.; François, A.; John A. H. B.; Marc, V. 2018. Improving feed efficiency in fish using selective breeding: a review. *Rev. Aquacult.* **10** 833-851. DOI: 10.1111/raq.12202.
- [78] Moniruzzaman, M.; Uddin, K. B.; Basak, S.; Mahmud, Y.; Zaher, M.; Bai S. C. 2015. Effects of stocking density on growth, body composition, yield and economic returns of monosex tilapia (*Oreochromis niloticus* L.) under cage culture system in Kaptai Lake of Bangladesh. *J. Aquacult. Res. Dev.* **6** 357. DOI: 10.4172/2155-9546.1000357.
- [79] Perveen, S.; Khan, N.; Yin F. 2023. Development of *Pangasius hypophthalmus* polyculture production in Pakistan when cultured with freshwater and Chinese carps. *Aquacult Int.* **31** 2727–2741. DOI: 10.1007/s10499-023-01102-x
- [80] Bethke, E.; Bernreuther, M.; Tallman, R. F. 2013. Feed efficiency versus feed conversion ratio -- demonstrated on feeding experiments with juvenile cod (*Gadus Morhua*). *Food Industry eJournal. SRRN* **2313137** 1-19. DOI: 10.2139/ssrn.2313137.
- [81] Jannat, K. M.; Rahman, M. M.; Bashar, A. M.; Hasan, N. M.; Ferdous, A.; Hossain, Y. M. 2012. Effects of stocking density on survival, growth and production of Thai climbing perch (*Anabas testudineus*) under fed ponds. *Sci. Malaysiana* **41** 1205-1210.
- [82] Mondal, M. N.; Shahin, J.; Wahab, M. A.; Asaduzzaman, M.; Yang, Y. 2010. Comparison between cage and pond production of Thai climbing perch (*Anabas testudineus*) and tilapia (*Oreochromis niloticus*) under three management systems. *J. Bangladesh Agril. Univ.* **8** 313–322. DOI: 10.3329/JBAU.V8I2.7943
- [83] Ekasari, J.; Rivandi, D. R.; Firdausi, A. P.; Surawidjaja, E. H.; Zairin, Jr. M.; Bossier, P.; De Schryver P. 2015. Biofloc technology positively affects Nile tilapia *Oreochromis niloticus* larvae performance. *Aquaculture* **441** 72–77. DOI: 10.1016/j.aquaculture.2015.02.019.
- [84] Zafar, M. A.; Hasan, M. Z.; Ali, M. M.; Asif A. A. 2017. Growth and production performance of vietnamese koi (*Anabas testudineus*) with magur (*Clarias batrachus*) at different stocking densities. *Asian-Austr. J. Biosci. Biotech* **2** 226-237.
- [85] Ekasari, J.; Suprayudi, M. A.; Wiyoto, W.; Hazanah, R. F.; Lenggara, G. S.; Sulistiani, R. 2016. Biofloc technology application in African catfish fingerling production: the effects on the reproductive performance of broodstock and the quality of eggs and larvae. *Aquaculture* **464** 349–356.
- [86] Ngoc, U. V.; Truong, G. H. 2020. Optimized live feed regime significantly improves growth performance and survival rate for early life history stages of pangasius catfish (*Pangasianodon hypophthalmus*). *Fishes* **5** 20.
- [87] Sumitro.; Arfan, A.; Safia, W.O. 2022. Evaluation of flock volume levels on water quality and production performance of catfish (*Clarias gariepinus*) cultured using a micropore pipe as an aeration diffuser. *J. Aquacult. Fish Health* **11** 163-169. DOI: 10.20473/jafh.v11i2.25186.
- [88] Emerenciano, M.; Martinez, C.; Luis, R.; Martinez, P.; Porchas, M.; Miranda, B.; Anselmo. 2017. Biofloc Technology (BFT): A Tool for Water Quality Management in Aquaculture. In: *Water Quality*. IntechOpen, London. DOI: 10.5772/66416.
- [89] Kumar, R. 2017. Growth and survival of climbing perch, *Anabas testudineus* in Nutrient Film Technique (NFT) Aquaponics System. *Int. J. Fish. Aquat. Stud.* **5** 24-29.
- [90] Avnimelech, Y. 2009 Biofloc technology. A practical guide book. Publisher the world aquaculture society. Baton Rouge. Edition 1st.
- [91] Bashar, A. E.; Basak, S.; Uddin, K. B.; Islam, A. K. M. S.; Mahmud, Y. 2015a. Changing trends of physicochemical parameters in Kaptai lake of Bangladesh. *Res. Agric. Livest. Fish.* **2** 319-327.
- [92] Bashar, E. A.; Basak, S.; Uddin, K. B.; Islam, A. K. M. S.; Mahmud, Y., 2015b. Seasonal variation of zooplankton population with reference to water quality of Kaptai Lake, Bangladesh. *Bangladesh Res. Publ. J.* **11** 127-133.
- [93] Hasibuan, S.; Syafriadiman, S.; Netti, A.; Fadhli, M.; Hasibuan, M. 2023. The age and quality of pond bottom soil affect water quality and production of *Pangasius hypophthalmus* in the tropical environment. *Aquacult. Fish.* **8** 296-304. DOI: 10.1016/j.aaf.2021.11.006.
- [94] Suwarsito.; Susylowati, D. 2024. Performance of gourami (*Ospronemus gouramy*) fry fed maggot and

- silk worm diets]. *Agrokompleks* **24** 140-149. [in Indonesian]. DOI: 10.51978/japp.v24i1 .731.
- [95] Boyd, C. E. 1982 Water quality management for pond fish culture. Elsevier, Amsterdam, 318.
- [96] Department of Fisheries (DoF). 1996 Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh. 81.

How to cite this article:

Hanafie, A.; Murjani, A.; Redha, E. (2025). Optimization of growth rate and feeding efficiency of four economically important fish species in the bioflocs system. *Jurnal Natural*, 25(1), 48-63.