Indian J. Fish., 69(1): 114-120, 2022
DOI: 10.21077/ijf.2022.69.1.104846-12

Effect of initial starvation on growth performance and length-weight relationship of striped murrel *Channa striata* (Bloch, 1793) larvae

ARJUNAN KARTHY, RAJESH KUMAR, UTKAL LAXMI MOHANTY, DEBASHREE DEBASMITA, KALIDOSS RADHAKRISHNAN AND BINDU R. PILLAI
ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751 002, Odisha, India
e-mail: rajeshfishco@yahoo.co.uk

ABSTRACT

The study evaluated the effect of delayed initial feeding on the growth performance and length-weight relationship of *Channa striata* (Bloch, 1793) larvae. *C. striata* larvae [3 days post-hatch (dph); mean length: 5.960±0.32 mm] were reared in experimental tanks (10 l) at the stocking density of 5 larvae l^{-1} for 28 days in five treatments. The five treatments in triplicates were, T_1 (3 dph, 0-day delay in initial feeding), T2 (4 dph - 1day delay in initial feeding), T3 (5 dph - 2 days delay in initial feeding), T4 (6 dph - 3 days delay in initial feeding) and T5 (7 dph - 4 days delay in initial feeding). One-way ANOVA results showed that delayed initial feed had a significant ($p<0.05$) effect on weight gain, daily weight gain, specific growth rate and survival rate. Weight gain was highest in 2 days delayed initial feeding (280.50 mg ±9.5) and lowest in 1 day delayed initial feeding (207.87 mg ±3.2). Similar pattern was also observed for the specific growth rate and survival. The length-weight relationship of larvae exhibited the lowest b value (2.006) in 3-days delayed feeding and the highest (2.627) in 1-day delayed feeding, which indicates negative allometric growth in the experimental groups. A better condition factor of 0.85 was noticed in 2 days of delayed initial feeding compared to all other treatment groups. The growth, survival and length-weight relationship data of the study suggested that 2 days of delay in first feeding yielded better growth and survival of *C. striata* larvae. Thus the information generated in this study might help in better management of the initial larval stages of *C. striata*.

Keywords: *Channa striata*, Growth and survival, Larval rearing, Length-weight relationship, Starvation, Striped murrel

Introduction

The striped murrel *Channa striata* (Bloch, 1793) is a freshwater air-breathing fish that belongs to the Channidae family and is distributed in most Asian countries including India (Talwar and Jhingran, 1991; Kumar *et al*., 2012). It has high market demand and fetches USD$ 5-8 per kg due to its nutritional quality, lesser intra-muscular bones, delicious taste and medicinal value (Sahu *et al*., 2012). Most of *C. striata* come from the wild and its wild population has decreased due to intervention of human activities like degradation of feeding and breeding habitats (Kumar *et al*., 2011; Sahu *et al*., 2012). *C. striata* farming is an alternative source to reduce the exploitation of the wild population. Its tolerance to deteriorated water quality and higher stocking density makes it suitable for climate-resilient aquaculture (Chandra and Banerjee, 2004; Kumar *et al*., 2011). Though captive breeding of *C. striata* was successful, there are still technical issues related to the poor survival of early larvae.

The successful transition of larvae from endogenous feeding (yolk sac stage) to exogenous feeding is the most crucial stage (Rønnestad *et al.,* 2013; Ranjan *et al.,* 2018; Kumar *et al.,* 2021) where the food availability, its size and density, time of first feeding of larvae and ability of the larvae to consume the feed is taken care to accomplish better survival (Busch, 1996). *C. striata* larvae feed on live prey *viz*. Artemia nauplii, cladocerans and copepods (Qin and Fast, 1997; Kumari *et. al.,* 2018) which they capture by sit and wait forage behaviour (James and Heck, 1994). Absence of adequate nutrition in the initial days of life is considered a major cause of high mortality. Less food consumed by larvae severely alters its digestive system (Piccinetti *et al.,* 2015), but it can salvage the weight when re-fed (Piccinetti *et al*., 2015; Delgadin *et al.,* 2018). However, when the starvation is prolonged, physical deterioration of larvae occurs which ultimately leads to mortality (Kumar *et al.,* 2021). Therefore, sufficient food and suitable feeding strategies are essential to ensure survival and growth of the larvae in captive conditions (Dou *et al.,* 2005). Most of the starved larvae will attain a phase of physical deterioration, as they are unable to initiate the first feeding (Blaxter and Hempel, 1963), which leads to increase in mortality. Thus, it is crucial to know how long larvae can bear food deprivation without affecting growth and survival.

Morphometric characteristics are extensively used to examine the effect of delayed initial feeding in fish species (Ehrlich *et al.,* 1976; Yufera *et al.,* 1993; Pena and Dumas, 2005). Of the morphometric characteristics, the length and weight relationship was predominantly applied to establish the relationship between delayed initial feed and their growth. The delayed initial feeding adversely affect the growth of fish larvae and it is imperative to comprehend an appropriate time to initiate first feeding. Many studies attempted to address the effect of delayed initial feeding for *e.g.* in *Labeo rohita* and *Heteropneustes fossilis* (Mookerji and Rao, 1999), *Macquaria ambigua* (Rowland, 1996), *Oncorhynchus nerka* (Bilton and Robins, 1973), *Rhamdia voulezi* (de Lima *et al.,* 2017) and *Misgurnus anguillicaudatus* (Wang *et al.,* 2010). However, no studies so far established the relationship between growth and delayed initial feeding. The present study aimed to establish the length-weight relationship of *C. striata* exposed to delayed initial feeding.

Materials and methods

Experimental animals

The brood fish of *C. striata* were raised in cement cisterns (5 x 3 x 1 m) at the Air-Breathing Fish Unit of ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA), Bhubaneswar, India. The male and female were distinguished during spawning season through secondary sexual characters and induced bred following the standard protocol (Kumar *et al*., 2014; 2021). The fertilised eggs were stocked in an egg incubation chamber and hatching took place 18-24 h after fertilisation at 28-30°C. Healthy newly hatched 1-day old post-hatchlings (DPH) of *C. striata* were collected from the hatching tanks and transferred to the experimental glass tanks (20 l capacity) and acclimatised for two days before the start of the experiment. Mouth opens 50-55 h post-hatch at 28-30°C and complete yolk absorption takes place on 4th day. *C. striata* larvae carries good amount of oil globules which provides nutrient, after yolksac absorption. Therefore, this experiment was conducted to know the effect of delay in the initial feeding on the growth and survival of *C. strata* larvae. The experiment was performed following the ethical standards set by ICAR-CIFA, Bhubaneswar, India.

Experimental design

The experiment was started with 3 DPH *C. striata* larvae, following a completely randomised block design with five treatments and three replications. The five treatments were: T_1 (3 DPH, 0-day delay in initial feeding), T2 (4 DPH - 1day delay in initial feeding), T3 (5 DPH - 2 days delay in initial feeding), T4 (6 DPH - 3 days delay in initial feeding) and T5 (7 DPH - 4 days delay in initial feeding) and the experimental design setup is illustrated in Fig. 1. The experiment was conducted in indoor condition in square glass tanks of 20 l capacity containing 10 l good quality freshwater. The stocking density followed was five nos. l^{-1} and the experimental duration was 28 days.

Zooplankton, which was used as live feed, was collected from a well-maintained pond (1000 m^2) where fertilisation was carried out following Jena *et al*. (2020). The zooplankton was collected using 68 µm mesh size net in the morning (08 00 - 09 00 h), and sieved to the desired size (<300 µm) and fed to the larvae twice daily (09:00-10:00 hrs and 16:00-17:00 hrs). Live feed was supplied *ad libitum* during the entire study period. The zooplankton predominantly consisted of rotifers and cladocerans. Before feeding, all experimental tanks were siphoned to remove the faecal debris of the previous feeding and 100% water exchange was practiced daily.

Sampling

Sampling of larvae was done at the beginning and end of the experimental period. Total length (TL) was measured using a 30 cm ruler scale with an accuracy of 0.1 mm. Bodyweight (BW) was recorded using a digital electronic weighing balance, which had a precision of 0.0001 g.

Growth and survival

The growth performance of *C. striata* larvae for each treatment was calculated using the formula:

Weight gain (mg) = Final weight - Initial weight

Daily weight gain (mg) = Final weight - Initial weight/ Duration of the experiment

Specific growth rate (%/day) = log Final weight - log Initial weight/ Duration of the experiment ∗ 100

Fulton's condition factor = Weight/Length^3∗100

Survival rate (%) = No. of larvae harvested/No. of larvae stocked ∗ 100

Mortality rate = No. of dead larvae/No. of larvae stocked ∗ 100

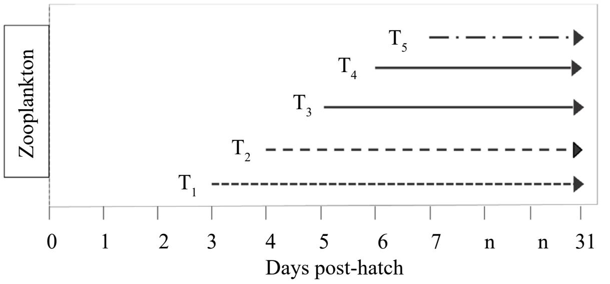

Fig. 1. Summary of the experimental design of delayed initial diet. T_1 (3 dph, 0-day delay in initial feeding), T2 (4 dph - 1day delay in initial feeding), T3 (5 dph - 2 days delay in initial feeding), T4 (6 dph - 3 days delay in initial feeding) and T5 (7 dph - 4 days delay in initial feeding)

All the data are presented as mean±standard error. The normality and homogeneity of all data were checked by Kolmogorov-Smirnov and Levene's test respectively. One-way ANOVA was performed to determine the significant difference ($p<0.05$) in the growth parameters, survival and mortality among the different treatments, followed by Duncan's multiple range test.

Length and weight relationship

The length-weight relationship (LWR) of *C. striata* larvae for each treatment was established using the formula (Le Cren, 1951):

$W = aL^b$, expressed as, $\text{Log } W = \log a + b \log L$

where W is the body weight (mg) and L is the total length (mm) of larvae, 'a' coefficient of determination and 'b' the exponent. The model with the highest r^2 was used to predict the weight of larvae using total length. The analysis of covariance was performed to determine variation in 'b' values.

Results

Growth and survival

The final weight and length showed a significant ($p<0.05$) difference among the treatments. Delayed feeding had a significant effect on weight gain [$F(4,5) = 7.120$; $p=0.027$], which is higher in T3 than those in the other treatment groups (Table 1). A significantly higher daily weight gain [$F(4,5) = 7.120$; $p = 0.027$] was noticed in T3 (10.02 mg ±0.34 ^{b}) in comparison to other treatment groups. The specific growth rate was also significantly higher [$F(4,5) = 7.437$; $p=0.025$] in T3 (17.68±0.12) and lower in T2 (16.62±0.06). The yield also differed significantly ($p<0.05$) and was highest in T3 (1198 mg ±30.25 ^{b}) and lowest in T_1 (798 mg ±26.76 ^{a}). The number of survivors of *C. striata* larvae is portrayed in Fig. 2. Significantly high survival percentage was found in T3 (85±5), whereas it was lowest (66±2) in T5. The cumulative mortality of *C. striata* is depicted in Fig. 3. Greater mortality rate was recorded in the late and early feeding of *C. striata* larvae ($p<0.05$).

Length-weight relationship

A total of 30 larvae of *C. striata* from each treatment group were used in this study to establish the relationship between length and weight. The statistical summary with all obtained parameters from length and weight is presented in Table 2. The b value ranged from 2.006 to 2.627, representing negative allometric growth ($b<3$) in all the treatments. In addition, the condition factor was found to be less than 1 in all the treatment (above 0.8 for T1, T2, T3 and less than 0.8 for T4 and T5). The length and weight relationship of *C. striata* larvae in all the treatments had a statistical significance ($p<0.05$) and the coefficient of determination ranged from 0.551 (T4) to 0.653 (T3).

Discussion

Growth and survival

The morphometric characteristics were used widely as indices to estimate the degree of effect of delayed initial feeding/starvation (Mookerji and Rao, 1999; Yoseda *et al.*, 2006). The time of initial feeding had significant effect on the larval growth of *C. striata*. Two days of delayed initial feeding had significant effect on total length, specific growth rate and daily weight gain when compared to 0-day and 1-day delayed initial feeding. This was mainly due to the presence of nutritionally rich oil globules in the

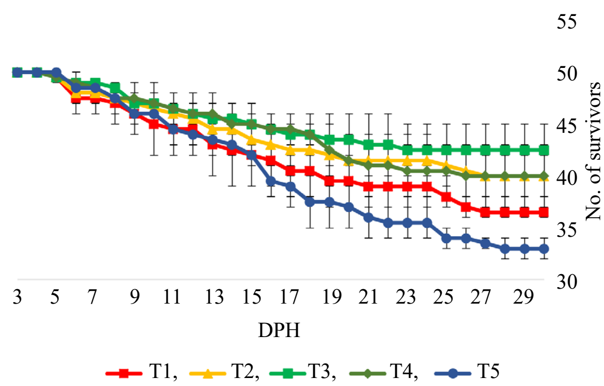

Fig. 2. Survivors of *C. striata* larvae at different ages. Data presented as mean and SE. T_1 (3 dph, 0-day delay in initial feeding), T2 (4 dph - 1day delay in initial feeding), T3 (5 dph - 2 days delay in initial feeding), T4 (6 dph - 3 days delay in initial feeding) and T5 (7 dph - 4 days delay in initial feeding)

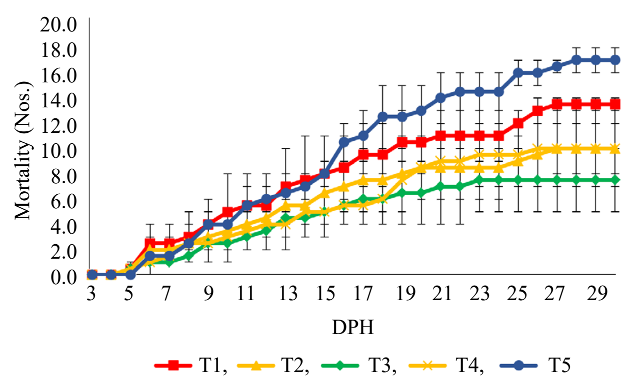

Fig. 3. Cumulative mortality rates of *C. striata* larvae at different ages. Data presented as mean and SE. T_1 (3 dph, 0-day delay in initial feeding), T2 (4 dph - 1day delay in initial feeding), T3 (5 dph - 2 days delay in initial feeding), T4 (6 dph - 3 days delay in initial feeding) and T5 (7 dph - 4 days delay in initial feeding)

Table 1. Summary of results on growth performance of *C. striata*

Parameters	T1 (0-day delay)	T2 (1-day delay)	T3 (2-days delay)	T4 (3-days delay)	T5 (4-days delay)
Final length (mm)	29.8 ± 0.73 [a]	29.3 ± 0.17 [a]	32.1 ± 0.77 [b]	30.24 ± 0.64 [ab]	31.54 ± 0.47 [ab]
Final weight (mg)	218.74 ± 4.33 [a]	209.87 ± 3.2 [a]	282.5 ± 9.5 [b]	213.24 ± 2.16 [a]	249.13 ± 23.4 [ab]
Weight gain (mg)	216.74 ± 4.33 [a]	207.87 ± 3.2 [a]	280.5 ± 9.5 [b]	211.24 ± 2.16 [a]	247.13 ± 23.4 [ab]
Daily weight gain (mg)	7.75 ± 0.16 [a]	7.43 ± 0.11 [a]	10.02 ± 0.34 [b]	7.55 ± 0.08 [a]	8.83 ± 0.83 [ab]
Weight gain (%)	10836.75 ± 216.75 [a]	10393.5 ± 160 [a]	14025 ± 475 [b]	10561.75 ± 108.25 [a]	12356.5 ± 1170 [ab]
Instantaneous growth rate (mg day^{-1})	0.168 ± 0 [a]	0.166 ± 0 [a]	0.177 ± 0 [b]	0.167 ± 0 [a]	0.172 ± 0 [ab]
Specific growth rate (% day^{-1})	16.77 ± 0.07 [a]	16.62 ± 0.06 [a]	17.68 ± 0.12 [b]	16.68 ± 0.04 [a]	17.22 ± 0.33 [ab]
Condition factor	0.83 ± 0.04 [a]	0.83 ± 0 [a]	0.855 ± 0.03 [a]	0.77 ± 0.06 [a]	0.79 ± 0.04 [a]
CV for length (%)	8.59 ± 0.3 [b]	5.35 ± 0.74 [a]	5.405 ± 0.78 [a]	4.92 ± 1.94 [a]	7.11 ± 0.74 [b]
CV for the weight (%)	23.87 ± 0.92 [b]	18.34 ± 0.91 [a]	16.695 ± 0.7 [a]	15.17 ± 4.31 [a]	18.62 ± 3.16 [a]
Yield (mg l^{-1})	798.6 ± 26.76 [a]	838.84 ± 29.17 [a]	1198.65 ± 30.25 [b]	853.59 ± 72.63 [a]	819.79 ± 52.31 [a]
Survival rate (%)	72.67 ± 0.67 [ab]	80.00 ± 3.46 [ab]	84.67 ± 4.06 [b]	80.00 ± 4.62 [ab]	66.00 ± 2.00 [a]
No of larval output	36.33 ± 0.33 [ab]	40.00 ± 1.73 [ab]	42.33 ± 2.03 [b]	40.00± 2.31 [ab]	33.00 ± 1.00[a]

The initial value of length and weight was 5.00 mm and 2.0 mg respectively. Data presented as mean and SE. Different superscript lower-case letters in the same row indicate significant difference ($p<0.05$) among different treatments (Duncan's multiple range tests).

Table 2. Summary of the descriptive statistics and length-weight relationship of *C. striata* (n=30)

Treatments	TL (mm)		TW (mg)		Intercept	Slope value	
	Min	Max	Min	Max	a	b	r^2
T_1 (0-day delay)	25	35	132	331	0.150	2.142	0.646
T_2 (1-day delay)	26	32	136	297	0.029	2.627	0.600
T_3 (2-days delay)	30	36	192	376	0.109	2.264	0.653
T_4 (3-days delay)	25	32	147	292	0.227	2.006	0.551
T_5 (4-days delay)	27	35	166	352	0.120	2.209	0.560

TL (Min-Max): Total length (minimum-maximum); WT (Min-Max): Total weight (minimum-maximum); a and b: Parameters of relationship among TL and WT; r2, Pearson r^2 squared for log-log regression (all relationships significant at $p<0.05$). T_1 (3 DPH, 0-day delay in initial feeding), T2 (4 DPH-1 day delay in initial feeding), T3 (5 DPH-2 days delay in initial feeding), T4 (6 DPH-3 days delay in initial feeding) and T5 (7 DPH-4 days delay in initial feeding).

eggs which met the energy requirement for the initial days in *C. striata.* The larvae obtain energy from oil globules after exhaustion of the yolk sack which is a good way of survival when food availability is inadequate in the natural environment. Similarly, Wang (2010) observed that the nutritionally rich oil globule remains for 2-3 days after yolk sac exhaustion in *M. anguillicaudatus.* The egg and yolk sizes decide the tolerance of larvae against delayed initial feeding and higher nutritional reserve in bigger-sized eggs serve as a food source for an extended duration (Blaxter and Hempel, 1963). However, the energy requirements for the fish larvae are met by a combination of both exogenous and endogenous feeding during the initial days (Kamler, 1992; Kailasam *et al.,* 2007; Kumar *et al.,* 2021). Larval capacity to tolerate food deprivation for a specific period is critical to larval growth and survival (Chen *et al.,* 2007). Successful initial feeding establish earlier at higher water temperature as compared to lower water temperature as reported in larvae of Japanese flounder *Paralichthys olivaceus* (Dou *et al.,* 2005), Atlantic herring *Clupea harengus* (Yin and Blaxter, 1987) and Malabar grouper *Epinephelus malabaricus* (Yoseda *et al.,* 2006).

The survival rate of the larvae depends on biotic and abiotic factors but the time of the initial feeding depends on the fish species which is based on the egg size and water temperature (Shan *et al*., 2008). The survival rate is normally affected when feed is given too early or too late, therefore an appropriate initial feeding time is important to achieve better larval production. In the present study, the egg yolk sac intake was completed on 3 dph at 26^0C. The highest (85%) survival rate was observed in the 2 days delayed first feeding and the lowest (66.25%) in 4 days delayed initial feeding. Delayed initial feeding up to 2 days had not affected larvae adversely and survival percentage was not significantly different from the 0 and 1 day delayed initial feeding but it had adversely affected the survival of larvae when initial feeding was delayed for 4 days. This indicated that prolonged starvation badly affected the fish's digestive physiology and thereby significantly reduced its survival. Similarly, *Salvelinus alpinus* showed correlation between larval survival and delayed first feeding (Wallace and Aasjord, 1984). But when the initial feed was delayed for tilapia, no significant variation in survival rate was observed (Nakaghi *et al.,* 2011). High mortality of 34% was found in 4 days delayed first feeding followed by 27% in 0 days delayed first feeding, 20% in 1 day delayed first feeding and 2 days delayed first feeding showed the least mortality of 15%. Generally during larval rearing, greater mortality is associated with change from endogenous feed to exogenous feed. This depends on the development of an internal organ (digestive tract), size of feed and mouth size and swimming ability of the fish. Greater mortality was also observed in this study in less initial delayed feeding days (0 and 1 day), this could be due to the accumulation of food material in the culture environment when oil globules exist for use.

Length and weight relationship

The length and weight relationship vary between the fish species owing to inherited body shape and size. It also varies within a species according to culture conditions, robustness of fish and food availability. Fish growth is described by b value, the positive allometric growth when the b value is greater than 3; negative allometric growth if it is less than 3 and isometric growth if the b value is equal to 3. In this study, negative allometric growth was observed in all the treatment groups; thus, the highest b value of 2.626 was found in 1 day delayed first feeding and the lowest of 2.005 in 0 days delayed first feeding which is depicted in Fig. 4. *Channa marulius* and *C. striata* had negative allometric growth when reared in different culture environments (Kumar *et al.,* 2013). Similarly, another study also found negative allometric growth for *Channa* species for all culture systems (Pauly, 1984) influenced by food availability, life stages and different sex proportions in the sample (Kleanthidis *et al.,* 1999). The condition factor (K) delivers the evidence on the particular situation under which the larvae were reared (Araneda *et al.,* 2008). The condition factor of a fish also reflects the physical and biological conditions and therefore an indicator of the general fish condition. It reflects the physical and biological events and interaction with delayed initial first feed and water quality parameters (Le Cren, 1951). The K value observed in the present study ranged between 0.77 (3 days delayed first feeding) to 0.855 (2 days delayed first feeding), indicating that *C. striata* were reared in an ideal culture environment. The condition factor of 0.74 and 0.71 for *C. striata* and *C. marulius* respectively, showed that the fishes were in good condition, indicating suitability of these species for culture (Kumar *et al.,* 2013).

Results from the present study suggest that delayed initial feeding up to two days improved the growth and

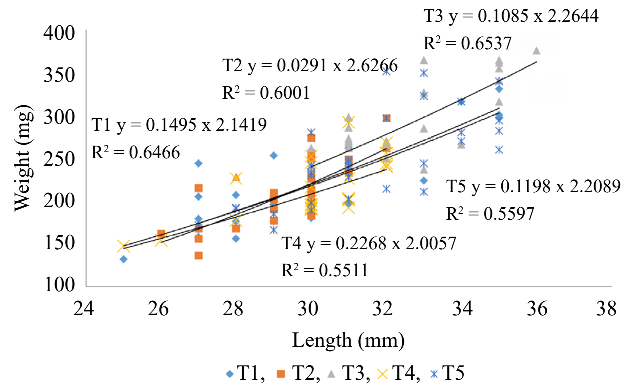

Fig. 4. Length-weight relationship of *C. striata* in different treatments. T_1 (3 DPH, 0-day delay in initial feeding), T2 (4 DPH - 1day delay in initial feeding), T3 (5 DPH - 2 days delay in initial feeding), T4 (6 DPH - 3 days delay in initial feeding) and T5 (7 DPH - 4 days delay in initial feeding)

survival of striped murrel. Better condition factor was observed (0.855) with a b value of 2.264 when initial feeding was delayed for 2 days. The growth and length-weight relationship data suggest that delay up to 2 days in initial feeding may have beneficial effect on larval production of *C. striata.*

Acknowledgements

Authors would like to thank the Director, ICAR- CIFA, Bhubaneswar, India for providing all the facilities during the study period. The study was financially supported by the National Fisheries Development Board (NFDB), Hyderabad, India (Grant No: NFDB/TUP/CIFA/Murrel/ 2015-16).

References

Araneda, M., Perez, E. P. and Gasca-Leyva, E. 2008. White shrimp *Penaeus vannamei* culture in freshwater at three densities: Condition state based on length and weight. *Aquaculture*, 283(1): 13-18. https://doi.org/10.1016/j.aquaculture.2008.06.030.

Bilton, H. T. and Robins, G. L. 1973 The effects of starvation and subsequent feeding on survival and growth of Fulton Channel sockeye salmon fry (*Oncorhynchus nerka*). *J. Fish. Res. Board Can.,* 30(1): 1-5. https://doi.org/10.1139/f73-001.

Blaxter, J. H. S. and Hempel, G. 1963. The influence of egg size on herring larvae (*Clupea harengus l.*). *ICES J. Mar. Sci.,* 28: 211-240. https://doi.org/10.1093/icesjms/28.2.211.

Busch, A. 1996. The transition from endogenous to exogenous nutrition: Larval size parameters determining the start of external feeding and size of prey ingested by Ruegen spring herring *Clupea harengus*. *Mar. Ecol. Prog. Ser.,* 130: 39-46. https://doi.org/10.3354/meps130039.

Chandra, S. and Banerjee, T. K. 2004. Histopathological analysis of the respiratory organs of *Channa striata* subjected to air exposure. *Veterinarski Arhiv*., 74(1): 37-52.

Chen, B. N., Qin, J. G., Carragher, J. F., Clarke, S. M., Kumar, M. S. and Hutchinson, W. G. 2007. Deleterious effects of food restrictions in yellowtail kingfish *Seriola lalandi* during early development. *Aquaculture*, 271(1-4): 326-335. https://doi.org/10.1016/j.aquaculture.2007.04.016.

de Lima, A. F., Makrakis, M. C., Andrade, F. F., Kashiwaqui, E. A. L., Gimenes, M. de F. and Makrakis, S. 2017. Feeding selectivity in early life stages of *Rhamdia voulezi* under experimental conditions. *Aquac. Res.,* 48(4): 1618-1628. https://doi.org/10.1111/are.12996.

Delgadin, T. H., Simo, I., Perez Sirkin, D. I., Di Yorio, M. P., Arranz, S. E. and Vissio, P. G. 2018. *Cichlasoma dimerus* responds to refeeding with a partial compensatory growth associated with an increment of the feed conversion efficiency and a rapid recovery of GH/IGFs axis. *Aquac. Nutr.,* 24(4): 1234-1243. https://doi.org/10.1111/anu.12661.

Dou, S. Z., Masuda, R., Tanaka, M. and Tsukamoto, K. 2005. Effects of temperature and delayed initial feeding on the survival and growth of Japanese flounder larvae. *J. Fish Biol.,* 66: 362-377. https://doi.org/10.1111/j.0022-1112.2005.00601.x.

Ehrlich., K. F., Blaxter., J. H. S. and Pemberton, R. 1976 Morphological and histological changes during the growth and starvation of herring and plaice larvae. *Mar. Biol.,* 35(2): 105-118.

James, P. and Heck, K. 1994. The effects of habitat complexity and light intensity on ambush predation within a simulated seagrass habitat. *J. Exp. Mar. Biol. Ecol.,* 176(2): 187-200. https://doi.org/10.1016/0022-0981(94)90184-8.

Jena, J., Mitra, G., Patro, B., Mohanta, D., Mishra, B. and Das, P. C. 2020. Role of fertilisation, supplementary feeding and aeration in water quality changes and fry growth in intensive outdoor nursing of fringed lipped carp *Labeo fimbriatus* (Bloch). *Aquac. Res.,* 51(12): 5241-5250.

Kailasam, M., Thirunavukkarasu, A. R., Selvaraj, S. and Stalin, P. 2007. Effect of delayed initial feeding on growth and survival of Asian seabass *Lates calcarifer* (Bloch) larvae. *Aquaculture*, 271(1-4): 298-306. https://doi.org/10.1016/j.aquaculture.2007.05.005.

Kamler, E. 1992. *Early life history of fish*. Chapman and Hall, London, UK.

Kleanthidis, P. K., Sinis, A. I. and Stergio, K. I. 1999. Length-weight realtionships of freshwater fishes in Greece. *Naga, The ICLARM Q.*, 22: 37-41.

Kumar, K., Eknath A. E., Sahu, A. K., Mohanty, U. L., Kumar, R., Sahoo, M. and Jahan, N. 2011. Snake heads: Challenging fish for diversification of fish farming. *Fishing Chimes,* 31(1): 110-113.

Kumar, K., Kumar, R., Saurabh, S., Sahoo, M., Mohanty, A. K., Lalrinsanga, P., Mohanty, U. L., Sahu, A. K. and Jayasankar, P. 2012. *Snakehead fishes: Fact sheets.* ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, India, p. 1-38.

Kumar, K., Lalrinsanga, P. L., Sahoo, M., Mohanty, U. L., Kumar, R. and Sahu, A. K. 2013. Length-weight relationship and condition factor of *Anabas testudineus* and *Channa* species under different culture systems. *World J. Fish Mar. Sci.,* 5(1): 74-78. https://doi.org/10.5829/idosi.wjfms.2013.05.01.64201.

Kumar, P., Kailasam, M., Biswas, G., Christina, L. and Ghoshal, T. K. 2021. Effect of different inducing hormones, sex ratio and oocyte diameter on breeding performance of brackishwater catfish, *Mystus gulio*. *Aquaculture*, 530: 735821.

Kumar, R., Mohanty, U. L. and Jayasankar. P. 2014. Induced breeding of striped snakehead *Channa striatus* in hatchery condition. *Book of Abstracts,10th Indian Fisheries and Aquaculture Forum,* ICAR-National Bureau of Fish Genetic Resources, Lucknow, India, p. 121.

Kumar, R., Mohanty, U. L. and Pillai, B. R. 2021. Effect of hormonal stimulation on captive broodstock maturation, induced breeding and spawning performance of striped snakehead, *Channa striata* (Bloch, 1793). *Anim. Reprod. Sci.,* 224: 106650.

Kumari, S., Tiwari, V. K., Rani, A. B., Rajesh, K. and Satya, P. 2018. Effect of feeding rate on growth, survival and cannibalism in striped snakehead, *Channa striata* (Bloch, 1793) fingerlings. *J. Exp. Zool.,, India*, 21(1): 205-210.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.,* 20(2): 201-219. https://doi.org/10.2307/1540.

Mookerji, N. and Rao, T. R. 1999. Rates of yolk utilisation and effects of delayed initial feeding in the larvae of the freshwater fishes rohu and singhi. *Aquac. Int.*, 7(1): 45-56. https://doi.org/10.1023/A:1009244819835.

Pauly, D. 1984. *Fish population dynamics in tropical waters: A manual for use with programmable calculators*. ICLARM, Philippines, 325 pp. https://doi.org/10.1016/0165-7836(86)90044-5.

Piccinetti, C. C., Donati, M., Radaelli, G., Caporale, G., Mosconi, G., Palermo, F., Cossignani, L., Salvatori, R., Lopez, R. P. and Olivotto, I. 2015. The effects of starving and feeding on Dover sole (*Solea solea*, Soleidae, Linnaeus, 1758) stress response and early larval development. *Aquac. Res.,* 46(10): 2512-2526. https://doi.org/10.1111/are.12410.

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

Ranjan, R., Megarajan, S., Xavier, B., Ghosh, S., Santhosh, B. and Gopalakrishnan, A. 2018. Broodstock development, induced breeding and larval rearing of Indian pompano, *Trachinotus mookalee* (Cuvier, 1832) A new candidate species for aquaculture. *Aquaculture*, 495: 550-557.

Ronnestad, I., Yufera, M., Ueberschar, B., Ribeiro, L., Saele, O. and Boglione, C. 2013. Feeding behaviour and digestive physiology in larval fish: Current knowledge and gaps and bottlenecks in research. *Rev. Aquac.,*5(1): S59-S98. https://doi.org/10.1111/raq.12010.

Rowland, S. J. 1996. Development of techniques for the large-scale rearing of the larvae of the Australian freshwater fish golden perch, *Macquaria ambigua* (Richardson, 1845). *Mar. Freshw. Res.,* 47(2): 233-242. https://doi.org/10.1071/MF9960233.

Sahu, B. B., Kumar, K., Sahu, A. K., Kumar, R., Mohanty, U. L., Maji, U. J., Jahan, N., Sahoo, M., Samal, R. and Jayasankar, P. 2012. Quality and storage stability of low acid murrel (*Channa striatus*) fish pickle at room temperature. *Int. Food Res. J.,* 19(4):1629.

Sahu, B. B., Kumar, K., Sahoo, A. K., Kumar, R., Mohanty, U. L., Sahoo, N. J. M. and Eknath, A. E. 2012. Carcass characteristics of marketable size striped murrel, *Channa striatus* (Bloch, 1793). *J. Appl. Ichthyol.,* 28(2): 258-260. https://doi.org/10.1111/j.1439-0426.2011.01917.x.

Shan, X., Quan, H. and Dou, S. 2008. Effects of delayed first feeding on growth and survival of rock bream *Oplegnathus fasciatus* larvae. *Aquaculture*, 277(1-2): 14-23. https://doi.org/10.1016/j.aquaculture.2008.01.044.

Talwar, P. K. and Jhingran, A. 1991. *Inland fishes of India and adjacent countries, vol. 1&2.* Oxford and IBH Publishing Co., New Delhi, India, 1077 pp. https://doi.org/10.1016/j.aquaculture.2019.01.028.

Wallace, J. C. and Aasjord, D. 1984. The initial feeding of Arctic charr (*Salvelinus alpinus*) alevins at different temperatures and under different feeding regimes. *Aquaculture*, 38(1): 19-33. https://doi.org/10.1016/0044-8486(84)90134-0.

Wang, Y., Hu, M., Wang, W., Cheung, S. G., Shin, P. K. S. and Cao, L. 2010. Effects of the timing of initial feeding on growth and survival of loach (*Misgurnus anguillicaudatus*) larvae. *Aquac. Int.,* 18(2): 135-148. https://doi.org/10.1007/s10499-008-9231-5.

Yin, M. C. and Blaxter, J. H. S. 1987. Escape speeds of marine fish larvae during early development and starvation. *Mar. Biol.,* 96(4): 459-468. https://doi.org/10.1007/BF00397963.

Yoseda, K., Dan, S., Sugaya, T., Yokogi, K., Tanaka, M. and Tawada, S. 2006. Effects of temperature and delayed initial feeding on the growth of Malabar grouper (*Epinephelus malabaricus*) larvae. *Aquaculture*, 256(1-4): 192-200. https://doi.org/10.1016/j.aquaculture.2006.01.031.

Yufera, M., Pascual, E., Polo, A. and Sarasquete, M. C. 1993. Effect of starvation on the feeding ability of gilthead seabream (*Spams aurata* L.) larvae at first feeding. *J. Exp. Mar. Biol. Ecol.,* 169(2): 259-272.

Date of Receipt : 15.09.2020
Date of Acceptance : 20.12.2021