



Compensatory growth response of *Catla catla* (Hamilton, 1822) juveniles, stunted with varied stocking density and photoperiod, in subsequent grow-out phase

P. R. SAHOO, P. C. DAS, S. NANDA, B. SAHU AND L. MUDULI

ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar - 751 002, Odisha, India

*College of Fisheries, Odisha University of Agriculture and Technology, Rangailunda, Berhampur - 760 007, Odisha, India

e-mail: sahoo_prs@yahoo.com

ABSTRACT

Stunted juveniles of *Catla catla* (Hamilton, 1822) were produced through 150 days of stunting with five combinations of density and photoperiod. These stunted juveniles were subsequently polycultured in grow-out ponds for eight months along with rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). In grow-out trial, the five treatments with different combinations of stocking density and photoperiod comprised, control (20 m⁻³, 12L/12D), T-1 (30 m⁻³, 12L/12D), T-2 (40 m⁻³, 12L/12D), T-3 (20 m⁻³, 6L/18D) and T-4 (20 m⁻³, 0L/24D). After eight months of culture, growth curves of stunted catla in all treatments were non-convergent and inferior to control, indicating no compensatory growth response. Although survival (70-73%), average body weight, (ABW; 667-755 g) and weight gain (648-729 g) in grow-out phase were statistically similar in the groups with different stocking density (Control, T-1 and T-2) ($p>0.05$), the grow-out survival was relatively higher in T-2 (73.3%), indicating its positive correlation with higher stunting density. In contrast, juveniles stunted with reduced photoperiod (T-3 and T-4) showed significantly lower ABW and weight gain ($p<0.05$). The poor survival in T-3 and T-4 (40-43%) indicated significant effect of stunting with reduced photoperiod on subsequent grow-out survival and yield performance. Based on the results, the study recommend the use of rearing density up to 40 m⁻³ for juvenile stunting in catla.

Keywords: Catla, Compensatory growth, Fish culture, Mixed fish farming, Stunted fish

Introduction

Growth retardation has been reported in many fishes during early life stage owing to various factors such as overcrowding (Wedemeyer, 1997), diet restrictions or low food availability (Abdel-Hakim *et al.*, 2009) and photoperiod manipulation (Bolla and Holmefjord, 1988). Compensatory growth (CG) response of stunted juveniles in subsequent grow-out culture phase has been reported in many species including salmonids (Refstie and Kittelsen, 1976), channel catfish, *Ictalurus punctatus* (Gaylord and Gatlin, 2000) and cyprinids (Wieser *et al.*, 1992). Ali *et al.* (2003) reported full, partial and no CG responses in cyprinids. The degree of compensation in re-alimentation phase was found to depend on the growth retardation factors like density and duration (Hossain *et al.*, 2003; Little *et al.*, 2003; Das *et al.*, 2016), severity of food restriction imposed (Ali *et al.*, 2003; Abdel-Hakim *et al.*, 2009) and photoperiod manipulation (Bolla and Holmefjord, 1988) during the stunting phase. Although stunted juveniles of Indian major carps (IMCs viz., catla, rohu, mrigal) are widely used in culture systems in India and other south-east Asian countries (Nandeesh, 2007), little is known on the species specific CG response of these species with regard to the stunting protocol in culture

system. Only very few studies on stunting of seed and subsequent CG performance have been reported in rohu *Labeo rohita* (Prabhakar *et al.*, 2008; Das *et al.*, 2016), mrigal *Cirrhinus mrigala* (Singh and Balange, 2005) and catla *Catla catla* (Ramaswamy *et al.*, 2013; Mishra *et al.*, 2015). Das *et al.* (2016) in their study on growth performance of rohu juveniles stunted for 2-12 months at two densities in subsequent one year grow-out culture, reported non-existence of CG activity in the species. They also reported a lesser yield and economic loss to farmers with total compensation when feeding stopped for two months after two months of initial feeding followed by re-feeding for six months in pond culture of IMCs in fertilised ponds. Several studies on stunting by high density rearing and occurrence of CG in those stunted juveniles in the subsequent grow-out phase have also been reported in Atlantic salmon *Salmo salar* (Refstie and Kittelsen, 1976) and mono-sex tilapia *Oreochromis niloticus* (Little *et al.*, 2003). Hossain *et al.* (2003) reported CG response in 5 and 12 months stunted juveniles of rohu and mrigal in polyculture with Nile tilapia in fertilised ponds.

Saunders *et al.* (1985) reported that under continuous light regime, the growth and survival of Atlantic salmon *Salmo salar* was better than the natural photoperiod

regime in subsequent rearing in sea cages. Studies on combination of photoperiod (continuous light) and high temperature in completion of the Parr-smolt transformation and subsequent growth performance in seawater of Atlantic salmon *Salmo salar* have been reported by many researchers (Stefansson *et al.*, 1991; Solbakken *et al.*, 1994). Gunnarsson *et al.* (2012) reported an increase in the biomass and growth rate in Arctic charr (*Salvelinus alpinus*) when winter photoperiod was used as a tool during the juvenile phase. It was demonstrated that using a continuous (24L:0D) or extended light (18L:6D) photoperiods in seawater can stimulate the growth performance and feed utilisation of rainbow trout (Turker and Yildirim, 2011).

Similar information on stunting and its subsequent compensatory growth response in grow-out pond system is lacking for *C. catla*, the fastest growing IMC. The present study aimed to evaluate the grow-out performance and CG response of stunted catla juveniles, variedly stunted with manipulation of rearing density and photoperiod.

Materials and methods

Stunted juvenile production

The study was conducted at the seed rearing complex of ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA) (20°11'06; 85°50'52"E). In a separate study, fry of catla (0.84 g, 3.88 cm, same batch) were stunted for 150 days in 15 outdoor FRP tanks (1000 l) with five different combinations of rearing density and photoperiod to produce stunted juveniles. These combinations (treatments) included control (20 m⁻³, 12L/12D), T-1 (30 m⁻³, 12L/12D), T-2 (40 m⁻³, 12L/12D), T-3 (20 m⁻³, 6L/18D) and T-4 (20 m⁻³, 0L/24D) with three replications for each. The stunted juveniles produced were tagged and used for the grow-out study and the same nomenclature of treatments, *i.e.* control, T-1, T-2, T-3 and T-4, were retained. The tagged juveniles were polycultured in grow-out ponds along with rohu and mrigal for a period of eight months.

Tagging of stunted juveniles

Thirty juveniles from each of the control and treatment groups were collected and released separately in well aerated FRP tanks. The next day, juveniles were anaesthetised in 50 mg l⁻¹ MS222 solution (tricaine methanesulfonate, Sigma-Aldrich; Jhingran and Pullin, 1985). On ceasing of gill movement, one electronic transponder (radio frequency identification tag, Model TX1400L) was inserted into the ventral side of body cavity above the anal opening (Das *et al.*, 2016). Subsequent protocols for recovery and handling of the tagged juveniles were followed as per

Mahapatra *et al.* (2001) and Das *et al.* (2016). Tagged fishes were maintained in FRP tank containing clean and aerated water for three days with supplementary feeding. Tags of juveniles were read using a Mini Portable Reader (MPR Model HS 5900L F, Destron Technologies, www.biomark.com) and individual tag number, length and weight were recorded prior to stocking in grow-out pond.

Experimental set up for grow-out culture

Three earthen ponds (0.04 ha each; designated P-1, P-2 and P-3) were used for the grow-out study. Almost similar sized juveniles of catla, rohu and mrigal, sourced from ICAR-CIFA farm, were stocked at equal species ratio and at combined density of 8000 juvenile ha⁻¹ in these ponds. The catla component (107 juveniles) of seed in each pond comprised of 50 tagged juveniles (10 each from control and four treatments) and the rest similar sized normal juveniles (20.5±3.4 g, 11.9±1.2 cm) brought from the farm. In this way, three replications of each treatment and the control were ensured with three ponds. Besides, the community rearing of the treatments in the same pond minimised the pond effect on growth of the variedly stunted juveniles. The initial stocking size recorded for the stunted and tagged catla juveniles in the control, T-1, T-2, T-3 and T-4 were 27.8±1.3 g, 13.3±0.3 cm; 22.1±1.3 g, 12.4±0.2 cm; 18.5±2.0 g, 12.0±0.4 cm; 19.1±2.2 g, 11.0±0.3 cm and 14.7±0.8 g, 10.5±0.1 cm; respectively.

Grow-out pond management and feed management

The pre-stocking pond preparation included sun drying of ponds, application of lime (CaCO₃) at 200 kg ha⁻¹ followed by basal fertilisation (3 t of cow dung mixed with 30 kg of single super phosphate, SSP per ha). Post-stocking management included fortnightly application of cow dung at 500 kg ha⁻¹ and inorganic fertilisers (10 kg urea and 15 kg SSP ha⁻¹), applied in alternate week, to maintain pond fertility (Jena *et al.*, 2009). Interim liming at 200 kg ha⁻¹ was also followed at 3 months intervals (Das *et al.*, 2016). Ponds were covered with net to avoid predation by birds and other animals. Seepage and evaporation loss in pond was topped up periodically to maintain the water depth.

Supplementary feeding was done with floating pellets (26% crude protein, 5% crude fat, 6% fibre and 11% moisture; ABIS, Indian Solvent Industry, Rajnandgaon, Chattisgarh, India) once during morning hours (09 00 and 09 30 hrs). Fishes were fed *ad libitum* and the actual daily feed amount of each pond was adjusted based on the consumption pattern of previous meal and prevailing weather conditions of the day (Das *et al.*, 2016).

Data collection and analysis

Water sampling in ponds was carried out during morning hours (07 00 and 08 00 hrs) from 15 cm

below the water surface and at fortnightly intervals to monitor the important physico-chemical parameters. Water temperature and pH were measured at the pond site. Estimation of dissolved oxygen (DO) (Winkler's method), total alkalinity, total hardness and inorganic nutrients *viz.*, ammonia, nitrite, nitrate and phosphate were measured following standard methods (APHA, 2005) in the laboratory.

Fish sampling was carried out at monthly intervals and capture of maximum number of tagged fish was ensured through repeated netting. Total weight and length of individual tagged catla along with non-tagged ones of all the three species were recorded. Due to mortality of a few fish and non-capture of all tagged fish during sampling, it was not possible to take the readings of all tagged individuals in each sampling. However, after completion of 8 months of grow-out phase, ponds were completely drained and all surviving tagged individuals

were captured to record their growth. Specific growth rate (SGR) was calculated using the formula:

$$\text{SGR (\%)} = \frac{(\ln \text{ final weight} - \ln \text{ initial weight})}{\text{No. of days of culture}} \times 100$$

Data on individual fish growth (weight, length, net weight gain), survival and net biomass production of each pond were collected and analysed statistically using the PC-SAS program for Windows, release v6.12 (SAS Institute, Cary, NC, USA) and Duncan's multiple range test was performed to compare the growth.

Results

Water temperature in the ponds gradually decreased from 28.2°C in August to 19.8°C in November and then further increased till end of the study (Fig. 1). Mean dissolved oxygen (DO) concentrations varied between 1.6-4.4 mg l⁻¹. Both DO and pH increased gradually during

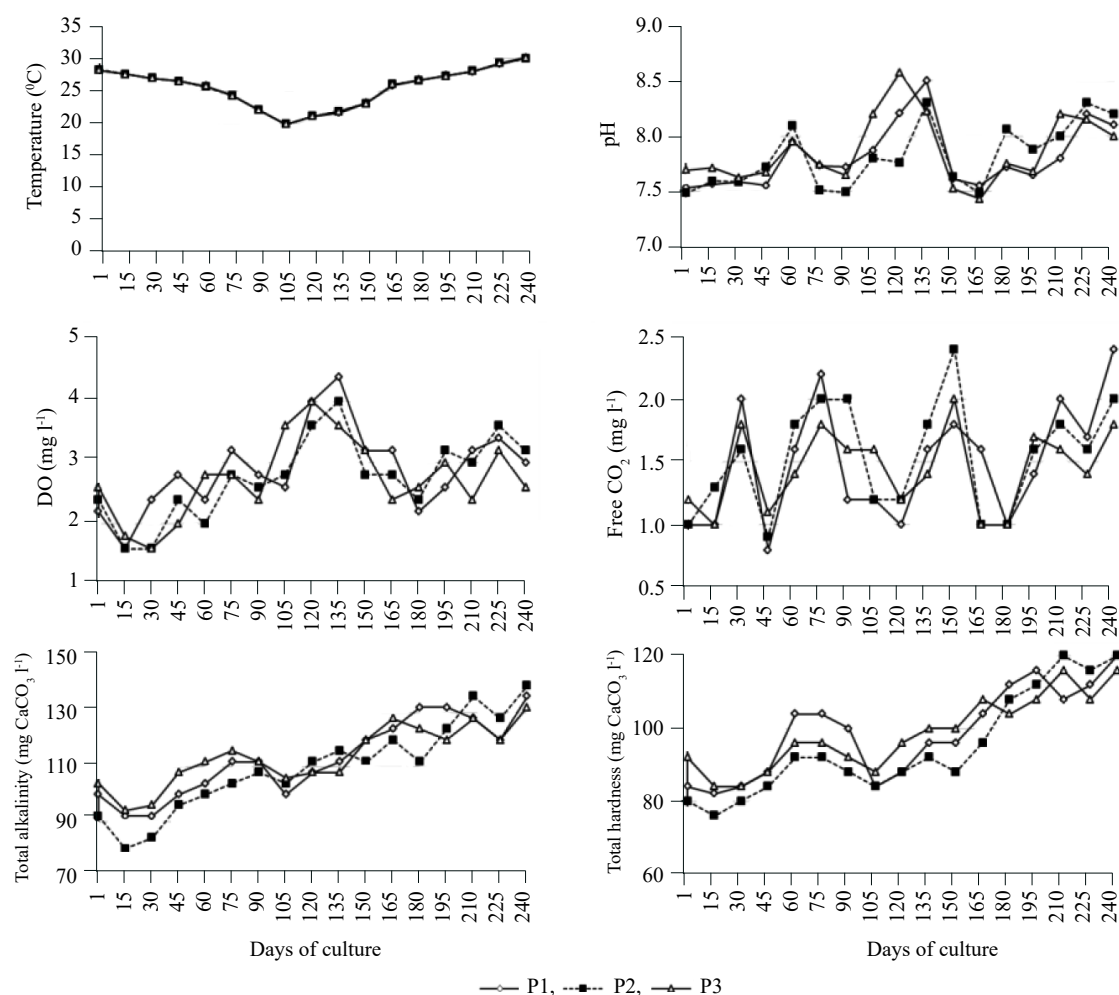


Fig. 1. Water quality parameters in pond water during the grow-out culture

the initial four months, reduced in the 5th month and again increased subsequently till end of the study. But, the trend of changes was similar in all the three ponds and without any marked variation. Total alkalinity and total hardness gradually increased in water with progress of culture, but without any marked variation among the three ponds.

The inorganic nutrients in water (Fig. 2) such as total ammonia nitrogen (TAN) and nitrite ($\text{NO}_2\text{-N}$) though fluctuated, showed a gradual rise. Nitrate ($\text{NO}_3\text{-N}$) and phosphorous ($\text{PO}_4\text{-P}$) content in water fluctuated during the study, but remained at lower level and without any definite trend. Variation in concentration of all these nutrients among the three ponds was minimal.

The growth curves in terms of weight and length of the tagged catla individuals of both density (T-1 and T-2) and photoperiod (T-3 and T-4) groups with progress of culture are depicted in Fig. 3. As seen in the figure, curves of all the treatments showed identical and non-converging growth trajectories as that of control and remained inferior to the control trajectory in the order T-1, T-2, T-3 and T-4.

At the end of 8 months grow-out culture, fish survival, average total length and body weight (Table 1) remained same in control, T-1 and T-2 ($p>0.05$). But all these attributes in the two photoperiod groups T-3 and T-4 remained similar, but significantly lower ($p<0.05$) compared to those of the control. Similarly, the net weight gain of the stunted catla in the two density groups remained similar with control but those of the photoperiod

group (T-3 and T-4) were lower ($p<0.05$). Specific growth rate (SGR) value increased in all the four treatment groups than the control, but the difference was significantly higher only in T-2 and T-4 ($p<0.05$).

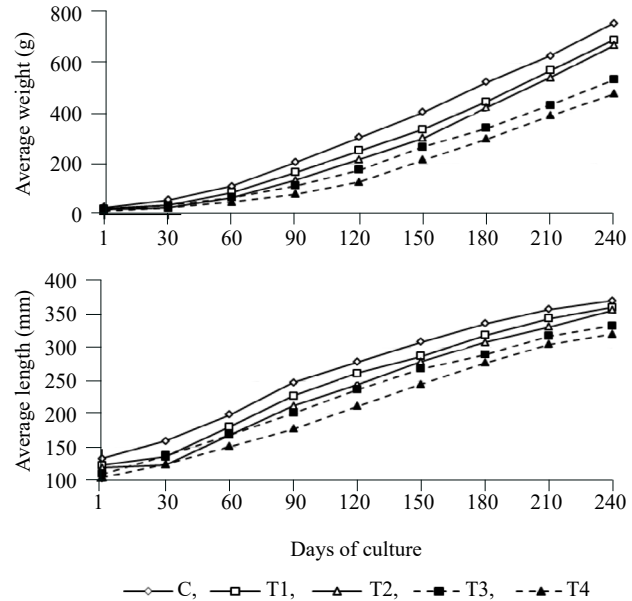


Fig. 3. Growth curves of stunted catla fingerlings (subjected to stunting process using varied stocking density and photoperiod exposure) during subsequent grow-out culture ($n=3$)

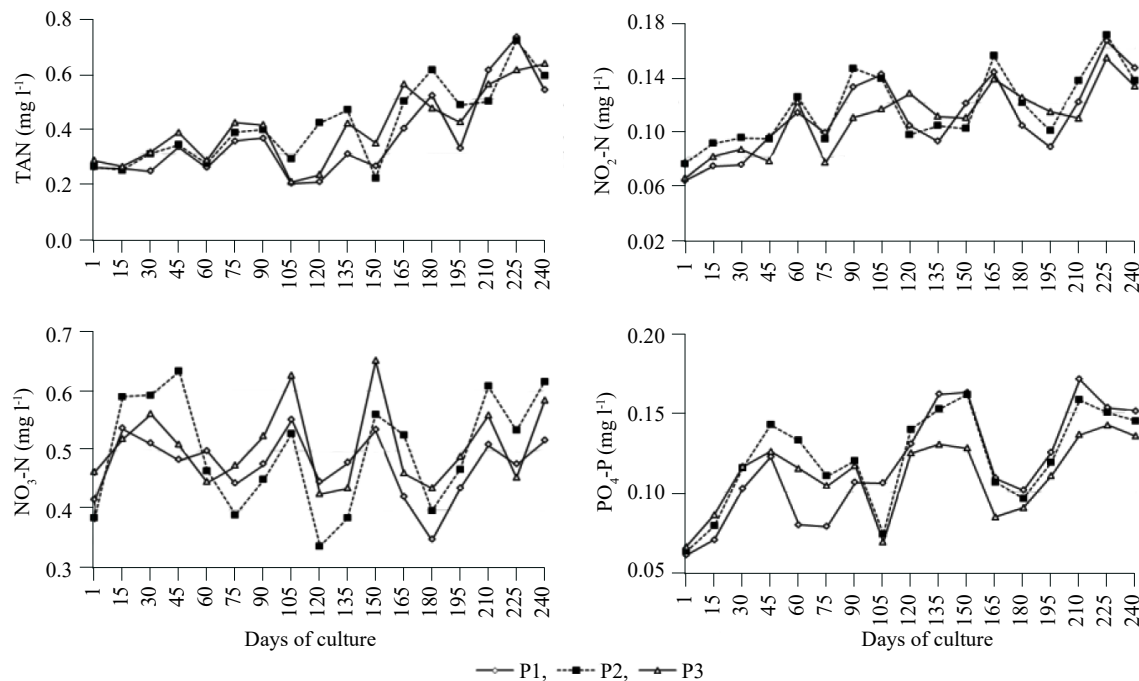


Fig. 2. Nutrient levels in pond water during the grow-out culture

Table 1. Yield attributes and compensatory growth of stunted catla fingerlings during grow-out phase (n=3)

Treatment*	Control (20m ² , 12L/12D)	T-1 (30 m ⁻³ , 12L/12D)	T-2 (40 m ⁻³ , 12L/12D)	T-3 (6L/18D; 20 m ⁻² ,)	T-4 (0 L-24D; 20 m ⁻² ,)
ABW (g)	755.19±47.53 ^a	689.53±88.14 ^a	667.36±49.65 ^a	531.73±57.11 ^b	475.67±7.02 ^b
ABL (cm)	369.52±6.80 ^a	359.58±13.50 ^a	355.33±7.29 ^a	332.29±12.32 ^b	319.67±1.53 ^b
Survival (%)	70.00±0.00 ^a	70.00±10.00 ^a	73.33±5.77 ^a	43.33±11.55 ^b	40.00±10.00 ^b
SGR	1.38±1.52 ^c	1.43±0.06 ^{bc}	1.50±0.02 ^a	1.39±1.36 ^{bc}	1.45±0.91 ^{ab}
Net weight gain (g)	728.52±46.90 ^a	668.82±87.04 ^a	647.78±47.27 ^a	511.82±56.14 ^b	460.95±6.43 ^b

*Control, T-1 and T-2 comprises the varied density group and control, T-3 and T-4 comprises the varied photoperiod group.

Discussion

The present study was aimed at finding the growth performance of stunted catla fingerlings, subjected to varied stocking density and photoperiod, during the post-stunting grow-out culture in earthen ponds. The reduction in water pH and DO during the 1st month in ponds could be attributed to the decomposition of the organic manure applied during pre-stocking pond preparation (Boyd, 1995). Availability of good water volume in pond during the initial 3-4 months (rainy season) would have helped in dilution of the released nutrient from mineralisation process, keeping their levels lower (Fig. 1 and 2) and within tolerable ranges as prescribed for carp culture (Jena *et al.*, 2002; Das *et al.*, 2005). But with further culture progress, there was reduction in DO and pH and rise in the inorganic nutrients, obviously due to increase in the input use and absence of dilution effect of rain. However, all the parameters remained within the range suitable for carps, attributed to the periodic application of lime and fertilisation as part of the standard management protocol. Total alkalinity and total hardness gradually increased with the progress of culture period due to increased use of feed and other inputs (Avnimelech, 1999; Das *et al.*, 2005), while similar variations among the three ponds was attributed to use of same levels of inputs.

At the end of eight months grow-out culture, fish survival (Table 1) in T-1 and T-2 (density group) were similar to control, but those in the photoperiod group reduced significantly. Survival of the fingerlings largely depends on the inter-specific interaction in the system and only the fittest one survive and can better adopt to a new environment. Das *et al.* (2016) have reported higher survival of stunted rohu juveniles in grow-out phase with longer stunting duration and attributed it to gradual elimination of poor quality juveniles during stunting. In the present study, the higher survival in two treatments of the density group could probably be attributed to the exposure to crowding stress during stunting at higher density (Wedemeyer, 1997). Further, relative increase in survival from control to T-2 indicated positive correlation between stunting density and subsequent survival in culture phase. In the absence of such exposure to crowding stress during stunting, fingerlings of T-3 and T-4 (photoperiod group

stunted at 20 m⁻²) were expected to show better survival during culture phase. In contrast, survival in these two treatments were significantly lower than control and within the group, it reduced from control through T-3 to T-4 indicating a positive correlation between photoperiod during stunting process and survival in subsequent culture phase.

Das *et al.* (2016) in their study on stunted rohu juveniles revealed longer stunting duration though resulted in higher length and weight gain in the grow-out phase, impact of the stunting stress was enough to cause failure in the fingerlings to converge their growth with control. Kim and Lovell (1995) in channel catfish *Ictalurus punctatus* found that three weeks restricted feeding group compensated better than six and nine weeks restricted feeding group when re-fed for 18 weeks. Results of the above studies indicated that growth performance of the stunted individuals during culture phase, to be dependent on the stress levels it was being exposed during stunting or restricted feeding. Similarly, varied influence of seed stunting was also observed in the current study as there was increased reduction in growth (both length and weight) at the end of culture phase in T-1 through T-4.

Although the grow-out SGR increased in the order T-2>T-1>C in the density group and T-4>T-3>C in the reduced photoperiod group, there was no convergence of growth curve of any treatments with that of control (Fig. 2), indicating no marked compensatory growth (CG) exhibited by any treatment. Rather the growth curves become inferior from T-1 to T-4 compared to control. Such results indicated probably a higher stunting stress in the juveniles owing to reduced photoperiod compared to that with increasing density. Carps are basically planktivorous in nature (Jhingran, 1991) and probably their body physiology is intrinsically related to the photoperiod which is the basis for plankton productivity in culture pond. Insufficient photoperiod in larval stage of fish has been reported to influence the normal body development (Bolla and Holmefjord, 1988). In the current study, lower growth in T-4 compared to T-3 and control indicated such phenomenon which might have originated from the reduced photoperiod during stunting process.

The present study revealed increasing rearing density during stunting to result in increased survival during culture

phase, which was attributed to their exposure to increased crowding levels during stunting. However, reduction in the photoperiod exposure probably caused greater stress in the stunted juveniles, leading to poor survival and growth in grow-out phase. Growth curves of the stunted juveniles in both density and photoperiod groups were non-convergent and inferior to that of control from T-1 to T-4 which indicated absence of growth compensation in culture phase. Since there was no variation in SGR among the treatments and control and survival was higher with increased stunting density, the study recommends use of higher rearing density as an effective tool for juvenile stunting in catla.

Acknowledgments

The authors are thankful to the Director, ICAR-CIFA, Bhubaneswar, India, for providing the facilities to conduct the experiment.

References

- Abdel-Hakim, N. F., Stat, H. A. A., Al-Azab, A. A. and El-Kholy, K. F. 2009. Effect of feeding regimes on growth performance of juvenile hybrid tilapia (*Oreochromis niloticus* x *Oreochromis aureus*). *World J. Agric. Sci.*, 5: 49-54.
- Ali, M., Nicieza, A. and Wootton, R. J. 2003. Compensatory growth in fishes: A response to growth depression. *Fish Fish.*, 4: 147-190. <https://doi.org/10.1046/j.1467-2979.2003.00120.x>.
- APHA 2005. *Standard methods for the examination of water and wastewater*. 21st edn. American Public Health Association, Washington, DC, USA.
- Avnimelech, Y. 1999. Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture*, 176: 227-235. [https://doi.org/10.1016/S0044-8486\(99\)00085-X](https://doi.org/10.1016/S0044-8486(99)00085-X).
- Bolla, S. and Holmefjord, I. 1988. Effect of temperature and light on development of Atlantic halibut larvae. *Aquaculture*, 74: 355-358.
- Boyd, C. E. 1995. *Bottom soils, sediment and pond aquaculture*. Chapman and Hall, New York, USA, 348 pp.
- Das, P. C., Ayyappan, S. and Jena, J. K. 2005. Comparative changes in water quality and role of pond soil after application of different levels of organic and inorganic inputs. *Aquac. Res.*, 36: 785-798. <https://doi.org/10.1111/j.1365-2109.2005.01288.x>.
- Das, P. C., Mishra, S. S., Mishra, B. and Jayasankar, P. 2016. Influence of juvenile stunting on grow-out performance of rohu, *Labeo rohita* (Hamilton, 1822). *J. Appl. Ichthyol.*, 32(5): 807-999.
- Gaylord, I. G. and Gatlin III, D. M. 2000. Assessment of compensatory growth in channel catfish *Ictalurus punctatus* R. and associated changes in body condition indices. *J. World Aquac. Soc.*, 31: 326-336. <https://doi.org/10.1111/j.1749-7345.2000.tb00884.x>.
- Gunnarsson, S., Imsland, A. K., Siikavuopio, S. I., Arnason, J., Gustavsson, A. and Helgi Thorarensen, H. 2012. Enhanced growth of farmed Arctic charr (*Salvelinus alpinus*) following a short-day photoperiod. *Aquaculture*, 350-353: 75-81.
- Hossain, M., Little, D. C. and Bhujel, R. 2003. Nursing duration and pond fertilisation level affect polycultures of Indian major carp (rohu *Labeo rohita* and mrigal *Cirrhinus mrigala*) with monosex Nile tilapia *Oreochromis niloticus*. *Aquac. Res.*, 34: 765-775. <https://doi.org/10.1046/j.1365-2109.2003.00883.x>.
- Jena, J. K., Ayyappan, S. and Aravindakshan, P. K. 2002. Comparative evaluation of production performance in varied cropping patterns of carp polyculture systems. *Aquaculture*, 207: 49-64. [https://doi.org/10.1016/S0044-8486\(01\)00800-6](https://doi.org/10.1016/S0044-8486(01)00800-6).
- Jena, J. K., Das, P. C., Das, B. K., Mohapatra, B. C., Sarangi, N., Modayil, M. J. and Ayyappan, S. 2009. *Aquaculture technologies for farmers*. Indian Council of Agricultural Research, Krishi Bhawan, New Delhi, India, 126 pp.
- Jhingran, V. G. 1991. *Fish and fisheries of India*, 3rd edn. Hindustan Publishing Corporation (India), New Delhi, India, 727 pp.
- Jhingran, V. G. and Pullin, R. S. V. 1985. *A hatchery manual for the common, Chinese and Indian major carps*. ICLARM Studies and Reviews 11. Asian Development Bank, Manila, Philippines and International Centre for Living Aquatic Resource Management, Manila, Philippines, 191 pp.
- Kim, M. K. and Richard, T. and Lovell, R. T. 1995. Effect of restricted feeding regimens on compensatory weight gain and body tissue changes in channel catfish *Ictalurus punctatus* in ponds. *Aquaculture*, 135: 285-293. [https://doi.org/10.1016/0044-8486\(95\)01027-0](https://doi.org/10.1016/0044-8486(95)01027-0).
- Little, D. C., Bhujel, R. C. and Pham, T. A. 2003. Advanced nursing of mixed sex and monosex tilapia (*Oreochromis niloticus*) fry and its impact on subsequent growth in fertilised ponds. *Aquaculture*, 221: 265-276. DOI: 10.1016/S0044-8486(03)00008-5.
- Mahapatra, K. D., Gjerde, B., Reddy, P. V. G. K., Sahoo, M., Jana, R. K., Saha, J. N. and Rye, M. 2001. Tagging: On the use of passive integrated transponder (PIT) tags for the identification of fish. *Aquac. Res.*, 32: 47-50.
- Mishra, S. S., Misra, S. K., Nanda, S. and Satapathy, D. 2015. Compensatory growth in *Catla catla* fingerlings following cyclical feed deprivation and refeeding. *J. Appl. Zool. Res.*, 26(2): 209-214.
- Nandeesh, M. C. 2007. Asian experience on farmer's innovation in freshwater fish seed production and nursing and the role of women. In: Bondad-Reantaso, M. G. (Ed.), *Assessment of freshwater fish seed resources for sustainable aquaculture*. FAO Fisheries Technical Paper, No. 501. Food and Agriculture Organisation of the United Nations, Rome, Italy, p. 581-602.

- Prabhakar, S. K., Sardar, P. and Das, R. C. 2008. Effect of starvation with subsequent realimentation with respect to compensatory growth of Indian major carp, rohu (*Labeo rohita* H.). *Anim. Nutr. Feed Technol.*, 8: 89-96.
- Ramaswamy, B., Naveen Kumar, B. T., Doddamani, P. L., Panda, K. and Ramesh, K. S. 2013. Dietary protein requirement of stunted fingerlings of the Indian major carp, *Catla catla* (Hamilton) during grow-out phase. *Indian J. Fish.*, 60(4): 87-91.
- Refstie, T. and Kittelsen, A. 1976. Effect of density on growth and survival of artificially reared Atlantic salmon. *Aquaculture*, 8: 319-326. [https://doi.org/10.1016/0044-8486\(76\)90114-9](https://doi.org/10.1016/0044-8486(76)90114-9).
- Saunders, R. L., Henderson, E. B. and Harmon, P. R. 1985. Effects of photoperiod on juvenile growth and smolting of Atlantic salmon and subsequent survival and growth in sea cages. *Aquaculture*, 4: 55-66. [https://doi.org/10.1016/0044-8486\(85\)90257-1](https://doi.org/10.1016/0044-8486(85)90257-1).
- Singh, R. K. and Balange, A. 2005. Effect of restricted feeding regimes on compensatory weight gain and body tissue in fry of the Indian major carp *Cirrhinus mrigala* (Hamilton, 1822). *Isr. J. Aquac. Bamidgeh*, 57: 250-254.
- Solbakken, V. A., Hansen, T. and Stefansson, S. O. 1994. Effects of photoperiod and temperature on growth and Parr-smolt transformation in Atlantic salmon (*Salmo salar* L.) and subsequent performance in seawater. *Aquaculture*, 121: 13-27.
- Stefansson, S. O., Björnsson, B. T., Hansen, T., Haux, C., Taranger, G. L. and Saunders, R. L. 1991. Growth, parr-smolt transformation and changes in growth hormone of Atlantic salmon (*Salmo salar*) reared under different photoperiods. *Can. J. Fish. Aquat. Sci.*, 48: 2100-2108.
- Turker, A. and Yildirim, O. 2011. Interrelationship of photoperiod with growth performance and feeding of seawater farmed rainbow trout (*Oncorhynchus mykiss*). *Turkish J. Fish. Aquat. Sci.*, 11: 393-397.
- Wedemeyer, G. A. 1997. Effects of rearing conditions on the health and physiological quality of fish in intensive culture. In: Iwama, G. K., Pickering, A. D., Sumpter, J. P. and Schreck, C. B. (Eds.), *Fish stress and health in aquaculture*. Cambridge University Press, Cambridge, UK, p. 35-71.
- Wieser, W., Krumschnabel, G. and Ojwang-Okwor, J. P. 1992. The energetics of starvation and growth after refeeding in juveniles of three cyprinid species. *Environ. Biol. Fishes*, 33: 63-71.