1 **Larval growth and survival in Indian Butter Catfish, *Ompok bimaculatus* (Bloch): effect**
2 **of light intensity and photoperiod**

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Abstract

Two sequential indoor rearing trials each of 21 days duration were conducted to investigate the effect of light intensity and photoperiod respectively on the growth and survival of *Ompok bimaculatus* larvae. In first trial, five different light intensities viz. 0, 300, 500, 900, 1200 lx were applied randomly to 800 larvae (0.003 g; 0.51 cm) stocked in triplicate following a completely randomized design into aquarium (30.0 x 15.0 x 15.0 cm) tanks. Sequentially, in second trial, five photoperiod cycles (light: dark, L: D) namely, 24L: 0D, 16L: 8D, 12L: 12D, 8L: 16D and 0L: 24D in combination with the best performing light intensity (300 lx) as observed from the first trial were employed in triplicates in similar set up. From the first trial, significantly higher survival was observed in 0 and 300 lx, whereas growth was highest in 900 lx ($P < 0.05$). In the second trial, survival was higher in continuous darkness (0L: 24D), whereas, maximum growth was recorded in 24L: 0D and 16L: 8D groups ($P < 0.05$). Performance index (PI) showed no significant difference ($P > 0.05$) among 0 and 300 lx light intensities, but were reduced at higher light intensities. The lowest PI was found in 12L: 12D and 8L: 16D condition but did not have any effect in other photoperiod cycles. Overall, from the present study it can be concluded that growth of the larvae is found to be higher in higher light intensity (900lx) and longer photoperiodic cycles (24L: 0D and 16L: 8D), however, better survival was recorded in total dark conditions suggesting that continuous dark condition is recommended for better hatchery performance of the larvae.

Keywords: *Ompok bimaculatus*, performance index, photoperiod, light intensity, growth, survival

57 Introduction

58 Indian Butter catfish (*Ompok bimaculatus*), a fish species under Siluridae family has a
 59 greater preference among populations in the north-eastern and eastern states of India. The
 60 species has good medicinal value, apart from its delicacy in these regions and therefore,
 61 considered a priced food fish species fetching market price of US\$ 10-12 per kg. The species
 62 has considerable reasons for its mass scale promotion in aquaculture. Firstly, the present
 63 focus on diversifying available species with those having superior market, particularly the
 64 indigenous fishes can benefit upon lucrative return of investment (Pradhan *et al.*, 2014) from
 65 its culture practices. Secondly, due to the subsequent decline of population in wild, the
 66 species has been listed under threatened category (CAMP, 2008). In the midst, successful
 67 induced spawning of the said fish is documented earlier (Bhowmick *et al.*, 2000; Rawat *et al.*,
 68 2018), however, high mortality due to cannibalism is one of the bottlenecks towards
 69 successful rearing of the larvae (Chakrabarti *et al.*, 2012). Invariably, there is an urgent need
 70 for optimise the larval rearing techniques to overcome production of quality seed through
 71 manipulated culture conditions.

72 Among the environmental factors, photoperiod is considered the most important bio-
 73 factor influencing the growth and survival of the fishes (Head and Malison, 2000; Downing
 74 and Litvak, 2001; Ruchin, 2004; Downing, 2002; Giri *et al.*, 2002). For instance,
 75 photoperiods longer than that of ambient conditions increased growth of larval rabbit fish,
 76 *Siganus guttatus* (Duray and Kohno, 1988), sea bass, *Dicentrarchus labrax* (Barahona-
 77 Fernandes, 1979; Ronzani Cerqueira *et al.*, 1991), barramundi, *Lates calcarifer* (Barlow *et al.*,
 78 1995), greenback flounder, *Rhombosolea tapirina* (Hart *et al.*, 1996), freshwater sheat-
 79 fish, *Wallago attu* (Giri *et al.*, 2002) and european sea bass, *Dicentrarchus labrax* (Villamizar
 80 *et al.*, 2009). Besides, shorter day lengths are even preferable for larvae [e.g., striped bass
 81 *Morone saxatilis* (Martin-Robichaud and Peterson, 1998). Although light helps to be the
 82 primary sense involved in foraging activity and feeding (Puvanendran and Brown, 2002), but
 83 also plays a key roles in internal synchronization for the rhythmic synthesis and release of
 84 time-keeping hormones (i.e. melatonin), whose signal affects rhythmic physiological
 85 functions in fish (Bromage *et al.*, 2001; Amano *et al.*, 2003; Falcon *et al.*, 2010; Migaud *et al.*,
 86 2010). However, the optimal photoperiod for larval growth and survival may differ, and
 87 also vary with larval ontogeny (Fielder *et al.*, 2002).

88 Further, in aquaculture, finding the correct environmental lighting for most of teleost
 89 larvae is complex. For example, it is established that most fish larvae need a minimal

threshold of light intensity to survive. This threshold light intensity and periodicity acts a major role in regulating fish larval activity (e.g. feeding), prey selection and localization by fish (Nwosu and Holzlohner, 2000). Light intensity can also influence the fish to stress (Strand *et al.*, 2007; Rotllant *et al.*, 2003; Papoutsoglou *et al.*, 2005), which may affect their behaviour by altering swimming performance, activity levels and habitat consumption (Mesa and Schreck, 1989; Schreck *et al.*, 1997). For example, African catfish (*Clarias gariepinus*) juveniles showed the higher activity in 150 lux, compared to 15 lux, was considered a stress reaction (Almazán-Rueda *et al.*, 2004). The lighting regime has been documented in many cultured species by fish farmers to get benefits in terms of survival and growth under controlled rearing conditions (Tandler and Helps, 1985; Batty, 1987; Downing and Litvak, 1999). In contrast, standard lighting systems usually used in hatcheries create bright point light sources that are neither environment-specific nor species-specific and can potentially compromise fish welfare (Villamizar *et al.*, 2009). Moreover, light intensity and photoperiod can both control the ability for larvae to inflate their swim bladders in terms associated with larval survival (Battaglione, 1995; Fielder *et al.*, 2002).

Considering the lack of research available regarding the application of optimal light intensity and photoperiod manipulation in *O. bimaculatus* larviculture, the present work was taken up to delineate its effect on growth performance and survival of the species under controlled environmental conditions. The present study will be helpful in establishing an optimal environmental photo-periodic and light intensity regime for *O. bimaculatus* larviculture as already established in other catfishes of commercial importance.

Results

Water quality

The mean values of the physiochemical parameters of water in both the experiments show variations among the treatments, however; not significantly different ($P > 0.05$). Mean temperature ranged from 25.90 to 28.80 °C; dissolved oxygen levels was above 6 mg L⁻¹; pH ranged between 7.2 to 7.8; total alkalinity ranged between 53.9-61.2 mg CaCO₃ L⁻¹; total hardness ranged between 35.1–42.6 mg CaCO₃ L⁻¹; ammonia nitrogen (NH₃⁺-N), nitrate nitrogen (NO₃⁻-N) and nitrite nitrogen (NO₂⁻-N) ranged between 0.01–0.12 mg L⁻¹, 0.05–0.21 mg L⁻¹ and 0.01–0.05 mg L⁻¹ respectively. The above recorded water quality parameter values during the experimental groups fell within the standard optimal range for fish culture (Boyd, 1982).

Trial 1: light intensities effect on growth and survival

The growth performance of the larvae were significantly affected ($P < 0.05$) by the experimental light intensities provided (**Table 1**). The final weight (g), weight gain (%) and specific growth rate (SGR; % day⁻¹) was found significantly higher ($P < 0.05$) in 900 lx group compared to others, whereas, significantly lower value was found in 0 lx light intensity groups ($P < 0.05$). Final length and length increment (cm) was significantly lower in 0 lx groups while, no significant changes was observed among other groups. Other yield parameters such as survival (%), total biomass (g) and performance index (PI) during the length of the study were depicted in **Table 2**. The highest ($P < 0.05$) survival and performance index were found in 0 lx and 300 lx light intensities, however, no significant difference was observed among 500lx, 900lx and 1200 lx treatments. Significantly higher biomass (g) was recorded in lower intensities treatments (i.e. 0 lx to 500 lx) and relatively lower value was found in the higher light intensities ($P < 0.05$).

Trial 2: photoperiod effect on growth and survival

The growth and yield parameters of larvae under different treatments are shown in **Table 3 and 4** respectively. The growth performance of larvae was significantly affected ($P < 0.05$) by varied photoperiod cycles. The initial length and weight of *Ompok bimaculatus* larvae, stocked in all the treatments were the same ($P > 0.05$). The highest growth ($P < 0.05$) was observed in the treatment with 24L: 0D and 16L: 8D photoperiods and no significant difference ($P > 0.05$) was found among 12L: 12D, 8L: 16D and 0L: 24D treatments. The final mean length and length increment of larvae did not differ significantly ($P > 0.05$) among the groups. Moreover, the highest survival (%) was recorded in 0L: 24D and the lowest in 24L: 0D photoperiod cycles. The total biomass was found higher in 24L: 0D, 16L: 8D and 0L: 24D conditions but did not significantly differ among the groups. Significantly lower condition factor was reported in 0L: 24D photoperiods while, the performance index showed linearly higher in 24L: 0D, 16L: 8D and 0L: 24D photoperiod cycles.

Discussion

The present study showed that the growth performance of *Ompok bimaculatus* larvae was significantly affected by light intensities. The specific growth rate, body weight gain (%) and mean daily weight gain (%) was found significantly higher in 900 lux light intensities and lower in 0 lux groups whereas, no significance response was reported in other groups (Table 1). The better growth performance of the larvae at medium light intensities (i.e. 900 lux) was attributed by increased feed intake due the excitation of retinal pigments may permit for the contrast between prey and background (Downing and Litvak, 2001; Strand et al., 2007;

156 **Table 1. Growth parameters of *Ompok bimaculatus* larvae reared under different light intensities**

Parameter	Light intensities (lx)					P-values		
	0lx	300lx	500lx	900lx	1200lx	Overall	Linear	Quadratic
Initial length(cm)	0.52±0.05	0.49±0.03	0.53±0.01	0.53±0.04	0.54±0.01	0.832	0.388	0.757
Initial weight(g)	0.0032±0.0001	0.0032±0.00002	0.0031±0.00003	0.0031±0.00002	0.0032±0.00008	0.357	0.405	0.073
Final length(cm)	2.27±0.04 ^a	2.50±0.05 ^b	2.53±0.02 ^b	2.52±0.05 ^b	2.53±0.05 ^b	0.006	0.002	0.012
Final weight(g)	0.067±0.002 ^a	0.08±0.003 ^b	0.08±0.003 ^b	0.09±0.004 ^c	0.08±0.002 ^b	0.001	0.000	0.006
Body weight gain (%)	1955.76±28.15 ^a	2356.58 ±101.34 ^b	2540.83 ±107.05 ^b	2856.18±118.86 ^c	2476.10 ±72.26 ^b	0.001	0.000	0.002
Length increment (cm)	1.75±0.04 ^a	2.01±0.04 ^b	2.00 ±0.01 ^b	1.99±0.05 ^b	1.99±0.04 ^b	0.003	0.003	0.004
Specific growth rate (% d⁻¹)	3.02±0.01 ^a	3.20 ±0.04 ^b	3.27 ±0.04 ^b	3.38±0.05 ^c	3.25 ±0.03 ^b	0.000	0.000	0.001
Mean daily weight gain (%)	0.42±0.01 ^a	0.41±0.02 ^a	0.44±0.01 ^a	0.50±0.02 ^b	0.44±0.01 ^a	0.030	0.045	0.313

157 *Overall mean value (± SE, n = 3) having different superscript in the same row shows significance difference (P < 0.05); a, b and c denotes
158 significance differences between different treatments.

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Table 2. Yield parameters of *Ompok bimaculatus* larvae reared under different light intensities

Parameters	Light intensities (lx)					P-values		
	0lx	300lx	500lx	900lx	1200lx	Overall	Linear	Quadratic
Survival (%)	35.05±2.39 ^b	33.87±6.69 ^b	20.42±1.80 ^a	16.17 ±3.49 ^a	17.75±1.38 ^a	0.009	0.001	0.310
Total biomass (g)	18.70±1.56 ^{ab}	21.26±4.58 ^b	13.34 ±1.27 ^{ab}	11.96 ±2.70 ^a	11.61 ±0.67 ^a	0.079	0.016	0.942
Condition factor (K)	0.57±0.04	0.50 ±0.01	0.51±0.03	0.58±0.03	0.51±0.03	0.202	0.609	0.459
Performance index	0.001±0.0001 ^b	0.001±0.0003 ^b	0.0007±0.0001 ^a	0.0006±0.0002 ^a	0.0006±0.00003 ^a	0.006	0.002	0.978

*Mean values (±SE) in a row having the same superscripts are not significantly different (P < 0.05).

165 **Table 3 Growth performance of *Ompok bimaculatus* larvae reared under different photoperiods.**

Parameters	Photoperiods					P-values		
	24L:0D	16L:8D	12L:12D	8L:16D	0L:24D	Overall	Linear	Quadratic
Initial length(cm)	0.4833±0.02	0.5033± 0.03	0.5133±0.03	0.5400±0.01	0.5160±0.05	0.731	0.290	0.524
Initial weight(g)	0.003 ± 0.0001	0.003 ±0.00005	0.003 ± 0.00007	0.003 ±0.00007	0.003 ± 0.00006	0.283	0.067	0.334
Final length(cm)	2.05 ± 0.07	2.27 ± 0.04	2.01 ± 0.21	1.96 ± 0.04	2.27 ± 0.03	0.177	0.712	0.374
Final weight(g)	0.091± 0.01 ^b	0.086± 0.01 ^b	0.061 ± 0.004 ^a	0.063±0.004 ^a	0.064± 0.001 ^a	0.005	0.001	0.078
Body weight gain (%)	2907.76± 179.93 ^b	2722.66 ± 251.71 ^b	1901.84± 146.07 ^a	1964.15± 193.48 ^a	1873.88± 56.03 ^a	0.004	0.001	0.137
Length increment (cm)	1.563 ±0.09	1.77 ± 0.05	1.50 ± 0.20	1.42 ± 0.03	1.751 ± 0.04	0.133	0.941	0.279
Specific growth rate (% d⁻¹)	3.40±0.06 ^b	3.33±0.09 ^b	2.99± 0.07 ^a	3.02± 0.10 ^a	2.98± 0.03 ^a	0.004	0.001	0.150
Mean daily weight gain (%)	0.58± 0.05 ^b	0.55± 0.04 ^b	0.39± 0.03 ^a	0.40±0.03 ^a	0.40± 0.01 ^a	0.005	0.001	0.080

166 *Mean values (± SE, n = 150; r=3) in a row having the same superscripts are not significantly different (p ≥0.05).

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170 **Table 4 Yield parameters of *Ompok bimaculatus* larvae reared under different photoperiods**

Parameters	Photoperiods					P values		
	24L:0D	16L:8D	12L:12D	8L:16D	0L:24D	Overall	Linear	Quadratic
Survival (%)	23.96 ± 2.29 ^a	28.63±2.49 ^{ab}	28.21±1.80 ^{ab}	27.96±1.55 ^{ab}	35.05 ± 2.39 ^c	0.050	0.010	0.545
Total biomass (g)	17.42± 2.38 ^{ab}	19.41 ± 0.31 ^b	13.67 ± 0.83 ^a	14.24 ± 1.76 ^a	17.94 ± 1.52 ^{ab}	0.102	0.417	0.123
Condition factor (K)	1.06±0.09 ^b	0.73±0.09 ^{ab}	0.81±0.19 ^{ab}	0.85±0.11 ^{ab}	0.55±0.03 ^a	0.097	0.030	0.981
Performance index	0.0010±0.0001 ^{ab}	0.0011±0.00001 ^b	0.0007±0.00004 ^a	0.0008±0.0001 ^a	0.0010±0.00008 ^{ab}	0.095	0.038	0.121

171 *Different superscripts in the same row signify statistical differences (p<0.05) (mean ± S.E.).

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Villamizar et al., 2011). Moreover, the higher light intensity may also influences the behavioural changes of both larvae and prey resulting in increased encounter rates (Downing and Litvak, 1999). Several other studies also reported that a threshold light intensities increased the growth in fishes such as spotted sand bass, *Paralabrax maculatofasciatus* (Downing and Litvak, 2001; Brown et al., 2003; Pena et al., 2004; Villamizar et al., 2011) which is relevant to the present study. However, in the present study the growth performance of the *Ompok bimaculatus* larvae had declined in elevated light intensity (i.e. 1200 lx). This finding may be influenced by the environmental stress at the elevated light intensities resulting in lower feeding rates (Delabbio et al., 2015). Similar findings were also reported in the Atlantic cod larvae *Gadus morhua* (Puvanendran and Brown, 1998) and European sea bass (Barahona-Fernandes, 1979) where light intensities beyond the threshold limit had a negative effect on the growth performance of the fish. The complete dark groups (0 lx) showed significantly lower final length and the length increment while, no significant response ($P>0.05$) was observed in others. This result was possibly due to lower growth rate in 0 lx groups (**Table 1**).

This study also revealed that fish reared under 0 lx ($35.05\pm2.39\%$) and 300 lx ($33.87\pm6.69\%$) light intensities showed significantly highest ($P<0.05$) survival (%), whereas no significant difference ($P > 0.05$) was recorded in other groups (**Table 2**). Similar observation was reported in Atlantic cod larvae *Gadus morhua* (Puvanendran and Brown, 2002), Atlantic halibut *Hippoglossus hippoglossus* (Bolla and Holmefjord, 1988), African catfish *Clarias geripineus* (Britz and Pienaar, 1992) and Orange-Spotted Grouper *Epinephelus coioides* (Takeshita and Soyano, 2008) where low light intensities (0 and 300 lx) had lower mortality rates when compared to larvae reared at higher light intensities. This result may be due to the fact that an elevation of light intensity acts as environmental stressor that induces swim bladder hypertrophy which possibly leads to high mortality (Johnson and Katavic, 1984; Strand et al., 2007; Villamizar et al., 2011). Moreover, the light intensity known to persuade the secretion of retina and pineal gland (light receptor) in fish (Bromage et al., 2001; Amano et al., 2003; Falcon et al., 2010). As a result melatonin release increased with the dark and decreased with the light conditions in the rainbow trout and goldfish (Iigo and Aida, 1995) which reported to inhibit the cannibalism of *Aequidens pulcher* (Munro, 1986). This finding may be possibly the reason behind the decreased cannibalism of Pabda larvae reared under lower light intensities (i.e. 0 and 300 lx). The present study was inconformity with the observation in African catfish *Clarias geripineus* (Britz and Pienaar,

1992), yellowtail (Sakakura and Tsukamoto, 1997) and Orange-Spotted Grouper *Epinephelus coioides* (Takeshita and Soyano, 2008) where higher light intensity showed increasing incidence of territorial aggression leads to mortality. The result of the study also showed that total biomass and performance index was significantly higher ($P < 0.05$) in lower light intensity groups followed by other groups, whereas, lower value was recorded in higher intensity groups (i.e. 900 and 1200 lx). This may be due to more survivability in case of lower light intensity groups which indicate the optimum light intensity for the *O. bimaculatus* larvae.

It has been reported that freshwater fish species are more responsive to photoperiod than marine and diadromous species (El-Sayed *et al.*, 2004). Moreover, the effect of marine species to photoperiods has been well documented, while little information is available on freshwater species. The results of the present study indicated that the *Ompok bimaculatus* larvae were clearly affected by the different rearing conditions of photoperiod displaying better growth (wet weight), specific growth rate, weight gain (%) and daily mean weight gain (%) in long light cycles compared to those exposed to intermediate or short light periods. A similar results was also observed with several fish larvae such as obscure puffer *Takifugu obscurus* larvae (Shi *et al.*, 2010), freshwater cat fish *Wallgo attu* (Giri *et al.*, 2002), *Clarias gariepinus* (Ataguba *et al.*, 2015) and rabbitfish *Siganus guttatus* (Duray and Kohno, 1988), where the better growth rate was achieved with increasing light periods. This outcome may be due to the fact that continuous light offered an increased chance for the larvae to come across food organisms (Shi *et al.*, 2010), and the darkness reduced the growth, possibly by hindering the intake of an adequate amount of food (Giri *et al.*, 2002; Hart *et al.*, 1996) which is relevant to the present study. It also reported that in shorter light periods may require more energy to synchronizing an endogenous rhythm to the external environment (Biswas and Takeuchi, 2002; Biswas *et al.*, 2002; El-Sayed *et al.*, 2004) and more standard metabolic rate (Biswas *et al.*, 2002), which leads to decline in somatic growth in fish. Hence, it is concluded that *Ompok bimaculatus* conserve energy when reared under different photoperiod cycles with longer light phases. The survival of *Ompok bimaculatus* larvae was significantly influenced by photoperiods. In the present study, Pabda larvae rearing under continuous dark condition showed maximum survival rates with reduced cannibalism. Similarly, Parameswaran *et al.* (1970) and Chakrabarti (2012) also reported that the dark condition is preferred for better survival of *O. bimaculatus* larvae during in-door rearing as their cannibalistic habit profound in light conditions. The lower survival (%) in continuous light

(24L: 0D) photoperiod was possibly due to carnivorous and cannibalistic mode of life of *O. bimaculatus* during early stages and also attributed by the visual clues during the rearing under continuous light (24L: 0D) cycles. This was probably due to the absence of stress and aggressiveness, as well as the suppression of locomotory activities in the dark. The study also showed that total biomass and performance index did not vary with the treatments because of differential growth and survival. Condition factor was significantly higher ($P < 0.05$) in continuous light (24L: 00D) conditions may be due to more chances of cannibalistic encounter among larvae due to light.

In the present study, although, the growth performance of the Pabda larvae was found significantly higher in higher light intensity (i.e. 900lx) and longer light cycles (i.e. 24L: 0D and 16L: 8D), but the performance of a hatchery generally judged based on the survivor rather than the growth. The better survival was recorded in total dark conditions suggesting that the larval rearing in continuous dark condition is recommended for better hatchery performance.

Materials and methods

Sources of larvae

The fish attained maturity at the end of the first year. Fully ripe females and males (40g or above) were taken from the pond of College of Fisheries, Lembucherra, Tripura, India and used for induced breeding. Females can be distinguished by a rounder, fuller abdomen, reddish vent colour and rounded genital papilla. Males have an extended and pointed genital papilla. The induce breeding was carried out by administrating a single injection of inducing agent Ovatide® @ 1–1.5 ml kg⁻¹ body weight for females and 0.5-1.0ml kg⁻¹ body weight for males (Chakrabarti *et al.*, 2012). Females were stripped for spawning after 8 – 10 hours of hormone injection and the eggs were collected in a tray. Milt was attained from males by surgically removing the testes, which were macerated to get a suspension to be mixed with the eggs for fertilisation. Then the fertilized eggs were washed carefully with clean water and transferred to a fibreglass tank for hatching, with constant aeration. Hatching takes place within 22-24 hours of fertilization. Subsequently newly hatched larvae (2 days old) were taken for the study.

Experimental set up

The study was carried out for 21 days at the wet laboratory of College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India to find out the effect of light

intensity and photoperiod on growth performance, survival and production of *O. bimaculatus* larvae. The larvae were reared in glass aquarium (30.0 x 15.0 x 15.0 cm) filled with 25-L of chlorine-free bore well water with continuous aeration. Aquariums were properly cleaned, sterilised and dried before introducing the larvae. Larvae were fed with chopped fresh tubifex upto satiation thrice everyday at 06:00, 14:00 and 22:00 h. Dead larvae, faeces, and other debris were siphoned out, and the number of dead larvae was recorded every day. Fifty percent of the water in each aquarium was replaced with fresh water daily. The water quality parameters viz. temperature, pH, dissolved oxygen (DO), free carbon dioxide (CO₂), carbonate hardness, ammonia-N and nitrate-N were analysed every weekly interval following the standard procedure (APHA, 2005) in both the experiments. Sampling of fish was done at 5-days intervals and completely randomized design (CRD) was followed throughout the study.

Trial 1: Effect of light intensity on growth and survival of larvae

Five light intensity namely 0, 300, 500, 900 and 1200 lx were employed in triplicates. Required was obtained by placing incandescent white light (300 lx to 1200 lx; Soft White bulb) 30 cm over head the water surface constantly. Each aquaria were enclosed within a box made from black plastic PVC sheeting to avoid the escape of light to the surrounding tanks. Light intensity was measured at the aquaria water surface using a lux meter (model ZU 104766, AEG, Frankfurt, Germany). Larvae (2-DPH; mean weight 0.003±0.00 g; mean total length 0.52±0.03 cm) were randomly assigned to 15 aquaria ((30.0 x 15.0 x 15.0 cm, 25-L) with 800 nos. of larvae per aquarium filled with chlorine-free bore well water with continuous aeration.

Trial 2: Effect of photoperiod on growth and survival of larvae

Larvae were reared in five different photoperiods cycles (light: dark, L: D) at 300lx namely 24 h continuous light (24L: 0D), 16 h light-08 h darkness (16L: 8D), 12 h light-12 h darkness (12L: 12D), 08 h light-16 h darkness (8L: 16D) and 24 h continuous darkness (0L: 24D), using incandescent white bulbs. Light intensity was kept constant at 300 lx throughout the study which was placed at 30 cm vertically from the water surface as described by Daniels et al. (1996). The complete darkness was obtained by covering the aquariums with black plastic PVC sheets with the provision for administering of feed to the larvae. Photoperiods were maintained by using a 24-h timer (Multi 9, Merlingerin, Germany). Triplicate groups of 800

nos. of 2-day post hatchling (2-DPH; mean weight 0.003 ± 0.0001 g; mean total length 0.51 ± 0.02 cm). The larvae were stocked into 25-L rearing aquariums for photoperiod study.

Larval growth study

All fish in the aquaria were sampled at 5-day intervals. A sub-group of 150 randomly selected fish from both experiment collectively weighted using a digital electronic balance with provision for ± 0.1 mg accuracy. Besides, lengths of a sub-group of 20 randomly selected larvae from each treatment were measured. Fish that disappeared were supposed to be victims of cannibalism. At the end of the experiment, fishes from each tank were weighed (mg) and counted. Growth parameters were calculated based on the following formulae:

Length increment (cm) = Final length – initial length

Body Weight gain (BWG) % = $100 [(final\ weight - initial\ weight) / initial\ weight]$

Specific growth rate (SGR) % = $100 [\{ \ln (final\ weight) - \ln (initial\ weight) \} / experimental\ period]$

Mean daily Weight gain (%) = $100 [(total\ final\ weight - total\ initial\ weight) / days\ of\ experiment]$

Fulton's condition factor (K) = $(final\ weight / final\ length^3)$

Survival percentage (%) = $100 [Total\ number\ of\ harvested\ fish / Total\ number\ of\ initial\ stock]$

Total biomass (g) = final number of fish x mean final weight

Performance index (PI) = Survival rate (%) $[(Final\ mean\ body\ weight - Initial\ mean\ body\ weight) / days\ of\ experiment]$

Survival Percentage

Survival (%) was calculated at the end of the study by counting the number of fish in each treatment and is calculated as follows:

Survival (%) = $Number\ of\ surviving\ fish / Total\ number\ of\ larvae\ stocked \times 100$

Statistical analysis

The experimental data were statistically analyzed through linear and quadratic orthogonal polynomial contrasts using SPSS version 16.0 (IBM, Chicago, USA) statistical software. A 5% level of probability ($P < 0.05$) was chosen to determine the statistically significant

difference among the treatments means. Results were presented as mean $\pm$ SE (standard error).

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Competing interests

The authors declare no competing or financial interests.

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Reference

- Almazán-Rueda P, Schram JW, Verreth JAJ (2004) Behavioural responses under different feeding methods and light regimes of the African catfish (*Clarias gariepinus*) juveniles. Aquaculture 231: 347–359.
- Amano M, Iigo M, Ikuta K, Kitamura S, Yamamori K (2003) Characterization and maturational differences of melatonin binding sites in the masu salmon brain. Gen Comp Endocrinol 131: 338–344
- APHA (2005) Standard Methods for Examination of Water and Wastewater, 20th edn. American Public Health Association, Washington, DC
- Ataguba GA, Okomoda VT, Azave VT (2015) effect of photoperiod on hatching success of eggs and early fry performance of *clarias gariepinus* (siluriformes, burchell 1822). Trakia Journal of Sciences 2:171-174
- Barahona-Fernandes MH (1979) Some effects of light intensity and photoperiod on the sea bass larvae (*Dicentrarchus labrax*) reared at the Centre Oceanologique de Bretagne. Aquaculture 17: 311–321
- Barlow CG, Pearce MG, Rodgers LJ, P Clayton (1995) Effects of photoperiod on growth, survival, and feeding periodicity of larval and juvenile barramundi, *Lates calcarifer* (Bloch). Aquaculture 138: 159-168
- Battaglione SC (1995) Induced ovulation and larval rearing of Australian marine fish. PhD Thesis, University of Tasmania, Launceston, Tasmania.

- 362 Batty R (1987) Effect of light intensity on activity and food-searching of larval herring,
363 *Clupea harengus*: a laboratory study. Marine Biology: 94 323-327.
- 364 Bhowmick ML, Mondal SC, Chakrabarty PP, Das NK, Saha RN, Ayyapan S (2000) Captive
365 breeding and rearing of Ompok pabda. In Sarkar AG (ed) Fish biodiversity of North
366 East India, NBFGR NATP Publication, India
- 367 Biswas AK, Endo M, Takeuchi T (2002) Effect of different photoperiod cycles on metabolic
368 rate and energy loss of both fed and unfed young tilapia *Oreochromis niloticus*: Part I.
369 Fish Sci 68: 465 – 477
- 370 Biswas AK, Takeuchi T (2002) Effect of different photoperiod cycles on metabolic rate and
371 energy loss of both fed and unfed adult tilapia *Oreochromis niloticus*: Part II. Fish Sci
372 68: 543– 553
- 373 Bolla S, Holmefjord I (1988) Effect of temperature and light on development of Atlantic
374 halibut larvae. Aquaculture 74:355–358
- 375 Boyd CE (1982) Water Quality Management for Pond Fish Culture. Elsevier, The
376 Netherlands
- 377 Britz PJ, Pienaar AG (1992) Laboratory experiments on the effect of light and cover on the
378 behaviour and growth of African catfish, *Clarias gariepinus* (Pisces: Clariidae). J
379 Zool (Lond) 227: 43–62
- 380 Bromage N, Porter M, Randall C (2001) The environmental regulation of maturation in
381 farmed finfish with special reference to the role of photoperiod and melatonin.
382 Aquaculture 197:63–98
- 383 Brown JA, Minkoff G, Puvanendran V (2003) Larviculture of Atlantic cod (*Gadus morhua*):
384 progress, protocols, and problems. Aquaculture 227: 357–372
- 385 CAMP (1998) Conservation assessment and management plan for freshwater fishes of India.
386 Workshop report. Zoo Outreach Organization, Coimbatore/CBSG and NBFGR,
387 Lucknow, India, pp. 1-158
- 388 Chakrabarti PP, Mandal SC, Chattopadhyaya DN, Mandal RN, Paul BN, Jayasankar P (2012)
389 Pabda-seed production & culture. Central Institute of Freshwater Aquaculture,
390 Bhubaneswar, India

391 Daniels HV, Berlinsky DL, Hodson RG, Sullivan CV (1996) Effects of stocking density,
392 salinity and light intensity on growth and survival of Southern flounder *Paralichthys*
393 *lethostigma* larvae. J. World Aquacult Soc 27: 153– 159

394 Delabbio J (2015). The importance of environmental light to the culture of marine fish larvae.
395 Director of research and development ONCE innovations Inc.

396 Downing G (2002) Impact of spectral composition on larval haddock, *Melanogrammus*
397 *aeglefinus* L., growth and survival. Aquac Res 33: 251–259

398 Downing G, Litvak MK (1999) The effect of photoperiod, tank colour and light intensity on
399 growth of larval haddock. Aquaculture International 7: 369-382

400 Downing G, Litvak MK (2001) The effect of light intensity and spectrum on the incidence of
401 first feeding by larval haddock. J Fish Biol 59: 1566–1578

402 Duray M, Kohno H (1988) Effects of continuous lighting on growth and survival of first-
403 feeding larval rabbitfish *Siganus guttatus*. Aquaculture 72: 73–79

404 El-Sayed AFM, Kawanna M (2004) Effects of photoperiod on the performance of farmed
405 Nile tilapia *Oreochromis niloticus*: I. Growth, feed utilization efficiency and survival
406 of fry and fingerlings. Aquaculture 231: 393-402

407 Falcon J, Migaud H, Munoz-Cueto JA, Carrillo M (2010) Current knowledge on the
408 melatonin system in teleost fish. Gen Comp Endocrinol 165: 469–482

409 Fielder DS, Bardsley WJ, Allan GL, Pankhurst PM (2002) Effect of photoperiod on growth
410 and survival of snapper *Pagrus auratus* larvae. Aquaculture 211: 135–150

411 Giri SS, Sahoo SK, Sahu BB, Sahu AK, Mohanty SN, Mukhopadhyay PK, Ayyappan S
412 (2002) Larval survival and growth in *Wallago attu* (Bloch and Schneider): effects of
413 light, photoperiod and feeding regimes. Aquaculture 213:151–161

414 Hart PR, Hutchinson WG, Purser GJ (1996) Effects of photoperiod, temperature and salinity
415 on hatchery-reared larvae of the greenback flounder (*Rhombosolea tapirina* Günther,
416 1862). *Aquaculture* 144: 303-311

417 Head AB, Malison JA (2000) Effects of lightning spectrum and disturbance level on the
418 growth and stress response of yellow perch *Perca flavescens*. J World Aquac Soc 31:
419 73–80

420 Iigo M, Aida K (1995) Effects of season, temperature, and photoperiod on plasma melatonin
421 rhythms in the goldfish, *Carassius auratus*. J Pineal Res 18: 62-68

422 Johnson DW, Katavic I (1984) Mortality, growth and swim bladder stress syndrome of sea
423 bass (*Dicentrarchus labrax*) larvae under varied environmental conditions.
424 Aquaculture 38: 67-78

425 Martin-Robichaud DJ, Peterson RH (1998) Effects of light intensity, tank colour and
426 photoperiod on swimbladder inflation success in larval striped bass, *Morone saxatilis*
427 (Walbaum). Aquac Res 29: 539–547

428 Mesa MG, Schreck CB (1989) Electrofishing mark-recapture and depletion methodologies
429 evoke behaviour and physiological changes in cutthroat trout. Trans Am Fish Soc
430 118: 644–658

431 Migaud H, Davie A, Taylor JFT (2010) Current knowledge on the photoneuroendocrine
432 regulation of reproduction in temperate fish species. J Fish Biol 76: 27–68

433 Munro, A. D. (1986). Effects of melatonin, serotonin and naloxone on aggression in isolated
434 cichlid fish (*Aequidens pulcher*). J. Pineal Res., 3, 257-262.

435 Nwosu FM, Holzlohner S (2000). Effect of light periodicity and intensity on the growth and
436 survival of *Heterobranchus longifilis* Val. (Teleostei: Clariidae) larvae after 14 days
437 of rearing. J Appl Ichthyol 16: 24-26

438 Papoutsoglou SE, Karakatsouli N, Chiras G (2005) Dietary Ltryptophan and tank colour
439 effects on growth performance of rainbow trout (*Oncorhynchus mykiss*) juveniles
440 reared in a recirculating system. Aquac Eng 3: 277–284

441 Parameswaran S, Selvaraj C, Radhakrishnan S (1970) Observations on the biology, induced
442 breeding and cultural possibilities of *Ompok bimaculatus* (Bloch) in ponds.
443 Proceedings of National Academy of Science of India 40: 145-157

444 Pena R, Dumas S, Saldivar-Lucio R, García G, Trasviña A, Hernández-Ceballos D (2004)
445 The effect of light intensity on first feeding of the spotted sand bass *Paralabrax*
446 *maculatofasciatus* (Steindachner) larvae. Aquac Res 35: 345-349

447 Pradhan P. K. Jena, J.K., Mitra, G., Sood, N., Gisbert, E. (2014) Effects of different weaning
448 strategies on survival, growth and digestive system development in butter catfish
449 *Ompok bimaculatus* (Bloch) larvae. Aquaculture 424–425: 120–130

450 Puvanendran V, Brown J (2002). Foraging, growth, and survival of Atlantic cod larvae in
451 different light intensities and photoperiods. *Aquaculture* 214: 131-151

452 Puvanendran V, Brown JA (1998) Effect of light intensity on the foraging and growth of
453 Atlantic cod larvae: interpopulation difference?. *Mar Ecol Prog Ser* 167: 207–214

454 Rawat P, Biswas P, Patel AB, Saha H (2018) Effect of dietary incorporation of chemo-
455 attractants on growth and survival during seed rearing of *Ompok bimaculatus* (Bloch).
456 *Turkish Journal of Fisheries and Aquatic Sciences* 18: 491-499

457 Ronzani Cerqueira V, Chatain B, Lavens P, Jaspers E, Ollevier F (1991) Photoperiodic
458 effects on the growth and feeding rhythm of European sea bass, *Dicentrarchus labrax*,
459 larvae in intensive rearing. *Larvi'91: Special Publ. Eur. Aquacult Soc* 15 pp. 304–306.

460 Rotllant J, Tort L, Montero D, Pavlidis M, Martinez SE, Wendelaar B, Balm PHM (2003)
461 Background colour influence on the stress response in cultured red porgy *Pagrus*
462 *pagrus*. *Aquaculture* 223: 129–139

463 Ruchin AB (2004) Influence of colored light on growth rate of juveniles of fish. *Fish*
464 *Physiology and Biochemistry* 30: 175-178.

465 Sakakura Y, Tsukamoto K (1997) Effects of water temperature and light intensity on
466 aggressive behaviour in the juvenile yellowtails. *Fish Sci* 63: 42-45

467 Schreck CB, Olla BL, Davis MW (1997) Behavioural responses to stress. In: Iwama GK,
468 Pickering AD, Sumpter JP, Schreck CB (ed) *Fish Stress and Health in Aquaculture*,
469 Cambridge University Press, Cambridge, p 145–170

470 Shi Y, Zhang G, Zhu Y, Liu J (2010) Effects of photoperiod, temperature, and salinity on
471 growth and survival of obscure puffer *Takifugu obscurus* larvae. *Aquaculture* 309:
472 103-108

473 Strand A, Alanara A, Staffan A, Magnhagen C (2007) Effects of tank colour and light
474 intensity on feed intake, growth rate and energy expenditure of juvenile Eurasian
475 perch, *Perca fluviatilis* L.. *Aquaculture* 272: 312- 318

476 Takeshita A, Soyano K (2008) Effects of light intensity and colour of rearing tank on
477 cannibalism in the juvenile orange-spotted grouper (*Epinephelus coioides*). *Aquacult*
478 *Sci* 56: 175-180

- 479 Tandler A, Helps S (1985) The effects of photoperiod and water exchange rate on growth and
 480 survival of gilthead sea bream (*Sparus aurata*, Linnaeus; Sparidae) from hatching to
 481 metamorphosis in mass rearing systems. *Aquaculture* 48: 71-82
- 482 Villamizar N, Blanco-Vives B, Migaud H, Davie A, Carboni S, Sánchez-Vázquez FJ (2011)
 483 Foraging behavior of larval cod (*Gadus morhua*) at low light intensities. *Mar Biol*
 484 158: 1125-1133
- 485 Villamizar N, García-Alcazar A, Sánchez-Vázquez FJ (2009) Effect of light spectrum and
 486 photoperiod on the growth, development and survival of European sea bass
 487 (*Dicentrarchus labrax*) larvae. *Aquaculture* 292: 80–86
- 488
- 489