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Effect of light intensity on growth, survival and skin color of juvenile Chinese longsnout catfish (*Leiocassis longirostris* Günther)

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Abstract

An 8-week experiment was carried out to investigate the effects of light intensity on growth, survival and skin color of Chinese longsnout catfish juveniles. Five light intensities, 0.15, 0.98, 2.46, 3.82 and 5.28 $\mu mol \cdot s^{-1} \cdot m^{-2}$ (5, 74, 198, 312 and 434 lx, respectively), were tested in triplicates. Fish (4.8 ± 0.01 g) were fed to satiation twice a day (0900, 1600 h). The photoperiod was 12L:12D (0800–2000 h). At the end of the experiment, three fish per tank were sampled to measure skin color by instrumental color analysis. The results showed that growth rate was significantly reduced at lower or higher intensities while light intensity did not affect the survival. The skin color of Chinese longsnout catfish was darkest under 434 lx. It is concluded that light intensity significantly affected growth and optimal light intensity for Chinese longsnout catfish juveniles was about 312 lx.

Keywords: Light intensity; Growth; Skin color; Chinese longsnout catfish

1. Introduction

Most fishes are visual feeders and need a minimal threshold light intensity to be able to develop and grow normally (Blaxter, 1986; Ounais-Guschemann, 1989; Boeuf and Le Bail, 1989). High light intensity may be stressful or even lethal (Boeuf and Le Bail, 1989). Many studies have been focused on the combined influence of light 'quality' (meaning the different wavelengths which are absorbed by water to various extents), light 'quantity' (different light intensities) and light 'periodicity' (different photoperiod) (Boeuf and Le Bail, 1989). Gardner and Maguire (1998) used only two light intensity treatments and concluded that further research was required to clarify the effect of light intensity on survival and growth, especially with higher intensities.

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The effect of light intensity on the survival and growth of larvae or juveniles has been studied in flatfish larvae (Blaxter, 1986), cod larvae (Huse, 1994), Australian giant crab larvae (Gardner and Maguire, 1998), larval haddock (Downing and Litvak, 1999), Atlantic cod larvae (Puvanendran and Brown, 2000), sea bass post-lavae (Cuvier-Péres et al., 2001) and juvenile haddock (Trippel and Neil, 2003). Light intensity was also reported to affect swimming activity and feeding (Petrell and Ang, 2001; Almazán-Rueda et al., 2004), cannibalism (Hecht and Pienaar, 1993; Gardner and Maguire, 1998; Kestemont et al., 2003), skin color (Rotllant et al., 2003), physiological hormone (Boeuf and Le Bail, 1989), metabolism (Appelbaum and Kamler, 2000), initiation of ecdysis (Waddy and Aiken, 1991), and metamorphosis (Eagles et al., 1986; Puvanendran and Brown, 2002).

Chinese longsnout catfish is one of the most important high-value aquaculture species in China. To improve the culturing effectiveness of the juveniles, many rearing conditions such as ration level, fish size and water temperature have been studied (Han et al., 2004). In Chinese longsnout catfish culture, domesticated individuals exhibit much darker skin than wild ones, which is similar to red porgy (Rotllant et al., 2003). It leads to a reduced marketability of the cultured fish. Pale skin color is favoured by the market (Yin and Zhang, 2003). Studies concerned the effects of culturing conditions on skin color have been executed (Fujimoto et al., 1991; Fernandez and Bagnara, 1991; Rotllant et al., 2003). Few documents are concerned with the relationship between light intensity and skin color adaptation (Booth et al., 2004). There is no information about light intensity or photoperiod on Chinese longsnout catfish.

The objectives of the present study are to determine: (1) the effect of light intensities on the growth and survival of Chinese longsnout catfish; (2) whether this fish would change skin color under different light intensities.

2. Materials and methods

2.1. Fish and rearing conditions

The experimental juveniles (*Leiocassis longirostris* Günther) were obtained from the Chinese Longsnout Catfish Hatchery Farm, Shishou, Hubei, PR China. Before the experiment, the juveniles were acclimated in rearing tanks for 2 weeks. Fish were fed twice daily (0900, 1600 h) during the acclimation with the experimental diet (Table 1). The experimental diet (2 mm, diameter) was made into semi-dry pellet (about 23.8% moisture) and stored at 4 °C.

The experiment was carried out in a semi-recirculation system consisting of 15 polythene tanks (60 × 47 × 50 cm, water volume: 140 l). Flow rate of water to each tank was 101 l/h. During the experiment, water temperature and pH were measured daily and dissolved oxygen and ammonia-N measured weekly. Water temperature was maintained at 28 °C. The dissolved oxygen content was kept above 7.5 mg O_2/l, pH between 7.0 and 7.6, and ammonia-N was less than 0.1 mg/l.

2.2. Experimental design

Five illumination levels, 0.15, 0.98, 2.46, 3.82 and 5.28 $\mu mol \cdot s^{-1} \cdot m^{-2}$ (5, 74, 198, 312 and 434 lx,

Table 1
Formulation and chemical composition of the experimental diet (in wet weight)

Ingredients	Contents (%)
White fish meal[a]	70.31
Fish oil[b]	2.45
α-Starch	8.00
Corn starch	12.48
Mineral premix[c]	5.00
Vitamin premix[d]	0.65
Vitamin C	0.11
Cr_2O_3	1.00
Chemical composition (% or kJ/g dry matter)	
Crude protein	43.69
Crude fat	9.37
Ash	19.70
Gross energy (kJ/g)	17.48

[a] Pollock fish meal from American Seafood Company, USA.
[b] Fish oil from Coland Enterprises Company, Fujian, PR China.
[c] Mineral premix (mg/kg diet): NaCl, 500; $MgSO_4 \cdot 7H_2O$, 7500; $NaH_2PO_4 \cdot 2H_2O$, 12,500; KH_2PO_4, 16,000; $Ca(H_2PO_4)_2 H_2O$, 10,000; $FeSO_4$, 1250; $C_6H_{10}CaO_6 \cdot 5H_2O$, 1750; $ZnSO_4 \cdot 7H_2O$, 176.5; $MnSO_4 \cdot 4H_2O$, 81; $CuSO_4 \cdot 5H_2O$, 15.5; $CoSO_4 \cdot 6H_2O$, 0.5; KI, 1.5; starch, 225.
[d] Vitamin premix (mg/kg diet): thiamin, 20; riboflavin, 20; pyridoxine, 20; cyanocobalamine, 2; folic acid, 5; calcium patotheniate, 50; inositol, 100; niacin, 100; biotin, 5; starch, 3226; Vitamin A (ROVIMIX A-1000), 110; Vitamin D_3, 20; Vitamin E, 100; Vitamin K_3, 10; Choline chloride, 1100.

respectively), were used as experimental treatments. Triplicate tanks were used for each treatment. Artificial light was provided by a 40 W fluorescent tube over each tank. Light intensity at the bottom of tank was approximately 3.20 $\mu mol \cdot s^{-1} \cdot m^{-2}$ (260 lx). Each aquarium was covered by different layers of black plastic cloth except for the control group to obtain different light intensities. Light intensities were adjusted through a combination of the shade cloth and distance of light source. Light intensity was measured in $\mu mol \cdot s^{-1} \cdot m^{-2}$ at the water surface of each tank using a light meter (Li-Cor Quantum photometer, Li-1400, USA).

Before the experiment, fish were deprived of feed for 1 day. Twenty-six fish (about 5 g/fish) were randomly transferred into each tank. During the experiment, the fish were hand-fed to satiation twice a day (0900, 1600 h). Daily feed intake was recorded and uneaten feed was siphoned 1 h after feeding, dried and weighed. During the first week, dead fish were weighed and replaced. Later, dead fish were removed and weighed. At the end of the experiment, the fish in each tank were batch-weighed after 1-day food deprivation and the survival was calculated.

2.3. Sampling

Three fish samples were randomly taken (4 fish/each sample) at the beginning of the experiment from the original batch and three fish from each tank were randomly sampled at the end of the trial for the chemical analysis of initial and final body composition. At the end of the experiment, three fish from each tank were randomly sampled for measuring skin color.

2.4. Color measurement

Fish skin color was measured in three fish of each tank using a chromameter WSC-S equipped with a D65 light source and a 10° observing angle (SPSIC Inc., Shanghai, P.R. China) calibrated to black and white standards. The value of L^* represents lightness (0 for black and 100 for white), the a^* value represents the red/green dimension with positive values for red and negative ones for green and the value of b^* represents the yellow/blue dimension with positive values for yellow and negative ones for blue (CIE, 1976). Colorimetric values of skin color were performed on two sides of each fish body.

2.5. Chemical analysis

For the experimental diet and fish body, crude protein, lipid, ash and energy content were analyzed. Dry matter content was determined by drying to constant weight at 105 °C. Nitrogen content was analyzed by the Kjeldahl method. Crude lipid was determined by chloroform–methanol extraction, ash by combustion at 550 °C in muffle furnace, and energy by bomb calorimeter (Phillipson microbomb calorimeter, Gentry Instruments Inc., Aiken, USA.).

Table 2
Effect of light intensity on growth and feed utilization for Chinese longsnout catfish (means ± S.E.M.)[a]

Light intensity (lx)	5	74	198	312	434
IBW (g)	4.88 ± 0.05	4.81 ± 0.01	4.80 ± 0.02	4.80 ± 0.01	4.81 ± 0.02
FBW (g)	35.76 ± 1.50[ab]	40.45 ± 3.01[a]	34.63 ± 1.34[bc]	39.07 ± 0.25[ac]	30.77 ± 1.19[b]
FR (%/day)	1.76 ± 0.08	1.73 ± 0.07	1.86 ± 0.10	1.97 ± 0.10	1.80 ± 0.16
SGR (%/day)	3.32 ± 0.05[ab]	3.54 ± 0.13[a]	3.29 ± 0.07[ab]	3.49 ± 0.01[a]	3.09 ± 0.06[b]
FCE (%)	126.7 ± 3.44[ab]	129.5 ± 0.91[a]	119.6 ± 4.34[b]	125.1 ± 2.18[ab]	123.8 ± 1.26[ab]
Survival (%)	79.62 ± 4.44	79.62 ± 8.01	80.77 ± 10.18	84.62 ± 7.69	83.33 ± 8.97

IBW: initial body weight, FBW: final body weight.

FR: feeding rate (%/day) = 100 * feed intake / (((initial body weight + final body weight) / 2) * days).

SGR: specific growth rate in wet weight (%/day) = 100 * (ln(FBW) − ln(IBW)) / day.

FCE: feed conversion efficiency in wet weight (%) = 100 * wet weight gain / total feed intake.

Survival = (Final fish number − Initial fish number) * 100 / Initial fish number.

[a] Means with different superscripts are significantly different ($P < 0.05$).

Table 3
Effect of light intensity on body composition (in wet weight) of Chinese longsnout catfish (means ± S.E.M.)[a]

Light intensity (lx)	Dry matter (%)	Protein (%)	Lipid (%)	Ash (%)	Energy (kJ/g)
Initial	22.00 ± 0.05^{a}	13.21 ± 0.17	4.64 ± 0.12^{a}	3.01 ± 0.05^{a}	4.74 ± 0.04^{a}
5	23.36 ± 0.41^{b}	13.08 ± 0.27	6.83 ± 0.42^{b}	2.86 ± 0.05^{bc}	5.50 ± 0.14^{b}
74	23.32 ± 0.55^{b}	12.88 ± 0.26	6.74 ± 0.46^{b}	2.76 ± 0.06^{bc}	5.37 ± 0.31^{b}
198	23.68 ± 0.15^{b}	12.70 ± 0.07	7.14 ± 0.14^{b}	2.86 ± 0.04^{bc}	5.36 ± 0.04^{b}
312	23.72 ± 0.34^{b}	13.05 ± 0.32	7.22 ± 0.28^{b}	2.73 ± 0.03^{c}	5.40 ± 0.10^{b}
434	23.49 ± 0.14^{b}	13.25 ± 0.16	6.54 ± 0.25^{b}	2.90 ± 0.04^{ab}	5.31 ± 0.08^{b}

[a] Means with different superscripts are significantly different ($P<0.05$).

2.6. Statistics

Statistica 6.0 for windows was used for statistical test. Homogeneity was tested (Brown–Forsythe test) before ANOVA. Duncan's multiple range test was used to detect the significance of differences of means between groups after one-way analysis of variance (ANOVA) and the difference was considered to be significant at $P<0.05$.

3. Result

3.1. Survival

The cannibalism of Chinese longsnout catfish was markedly affected by light intensity with the injuries mainly to the tails and fins. The final survival of juveniles varied from 76.9% to 84.6% (Table 2) at different treatments. There was no significant difference between experimental groups while the final survival tended to be higher at high light intensity.

3.2. Growth performance

Table 2 showed that final body weight was significantly higher at 74 lx and lower at 434 lx. Specific growth rate (SGR) in wet weight was significantly lower at 434 lx while there was no significant difference between other groups.

No significant difference in feeding rate was observed at different light intensities, but feed conversion efficiency (FCE) in wet weight at 74 lx was higher than that at 198 lx while there was no significant difference in other groups (Table 2).

The body compositions of initial and final fish were presented in Table 3. The final body content of dry matter, lipid and energy in all treatments was significantly higher than the initial fish body content (Table 3). However, final fish body ash content was markedly lower than that the initial ash content ($P<0.05$).

Table 4
Instrumental color analyses of Chinese longsnout catfish under different light intensities (means ± S.E.M.)[a]

Light intensity (lx)	$L*$	$a*$	$b*$	$W*$	$C*$
5	52.4 ± 1.71^{ab}	-3.1 ± 2.74^{a}	5.2 ± 1.11^{a}	50.4 ± 1.62^{a}	11.1 ± 1.90^{a}
74	55.7 ± 1.26^{a}	-5.5 ± 2.32^{a}	5.4 ± 0.82^{a}	53.8 ± 1.35^{a}	11.5 ± 1.55^{ab}
198	55.3 ± 1.57^{a}	-1.8 ± 2.12^{a}	4.4 ± 0.95^{a}	53.9 ± 1.39^{a}	8.7 ± 1.49^{a}
312	53.1 ± 1.83^{ab}	7.5 ± 3.12^{b}	1.0 ± 1.16^{b}	50.7 ± 2.07^{a}	13.9 ± 1.75^{ab}
434	49.1 ± 1.73^{b}	15.2 ± 2.82^{b}	-0.6 ± 1.02^{b}	45.6 ± 1.9^{b} 5	16.8 ± 2.43^{b}

$L*$: Lightness.
$a*$: Redness.
$b*$: Yellowness.
$W*$: Whiteness $= 100 - \sqrt{\left((100 - L*)^2 + a*^2 + b*^2\right)}$.
$C*$: Saturation $= \sqrt{(a*^2 + b*^2)}$.
[a] Means with different superscripts are significantly different ($P<0.05$).

3.3. Skin color

There were significant influences of light intensity on all color parameters (Table 4). The values of L^* (lightness), b^* (yellowness) and W^* (whiteness) were lower at 434 lx than other treatments. However, a^* (redness) and C^* (saturation) were higher at 434 lx than others ($P<0.05$).

4. Discussion

Light intensity can be a limiting factor in aquaculture depending on turbidity and depth, and different responses in different species and different developmental stages are reported (Boeuf and Le Bail, 1989). Many studies have revealed that, generally, most fish require a minimal threshold light intensity to be able to develop and grow normally (Table 5). However, light that is too intense might be stressful or even lethal. In the present study, fish in lower light (5 lx) showed the lowest growth rate ($3.32\% \cdot day^{-1}$) and survival (79.6%). Similarly, fish appeared restricted in growth in the brightest light (434 lx). Most research on the effects of light intensity has been concentrated on larvae fish, and only a few studies were concerned in juveniles in Table 5. Exact conclusion should be based on the precise light levels rather than the higher or lower light intensity in previous reports because sometimes it could be quite different in different species. For example, the light treatment (300–3500 lx) in sea bass larvae (Barahona–Fernandes, 1979) was much higher than the light intensity of 30–100 lx used in juvenile haddock (Trippel and Neil, 2003).

4.1. Survival and cannibalism

In the present study, no significant effect of light intensity on survival of Chinese longsnout catfish was observed although it tended to improve survival with increasing light intensities. This result is in agreement with Australian giant crab larvae (Gardner and Maguire, 1998), sea bass post-larvae (Cuvier-Péres et al., 2001), and African catfish juveniles (Almazán-Rueda et al., 2004). This trend of lower mortality in

Table 5
Literature reports on the effect of light intensity on the growth and survival of larvae and juveniles of several species

Species	Developmental stage	Best light intensity and/orphotoperiod for		Reference
		Growth	Survival	
Melanogrammus aeglefinus	larvae	$3.15\ \mu mols^{-1}\ m^{-2}$	$3.15\ \mu mols^{-1}\ m^{-2}$	Downing and Litvak, 1999
Latris lineate	larvae	$40\ \mu mol\ s^{-1}\ m^{-2}$	$40\ \mu mol\ s^{-1}\ m^{-2}$	Trotter et al., 2003
Morone saxatilis	larvae	1 lx	–	Chesney, 1989
Gadus morhua	larvae	1 lx	–	Huse, 1994
Salvelinus alpinus	larvae	50 lx	darkness	Wallace et al., 1988
Pleuronectes platessa	larvae	87 lx	–	Huse, 1994
Dicentrachus labrax	larvae	100 lx; 16L:8D	5 lx; 16L:8D	Cuvier-Péres et al., 2001
Lates calcarifer	fry	300 lx; 12L:12D	300 lx; 12L:12D	Fermin and Seronay, 1997
Pseudocarcinus gigas	larvae	500 lx; 12L:12D	2 lx; 12L:12D	Gardner and Maguire, 1998
Sparus aurata	larvae	600–1300 lx	–	Tandler and Mason, 1983
Salmo salar	fry	700 lx	darkness	Wallace et al., 1988
Perca fluviatilis	larvae	800 lx; 14L:10D	250 lx; 14L:10D	Tamazouzt et al., 2000
Scophthalmus maximis	larvae	860 lx	–	Huse, 1994
Sparus aurata	larvae	1300 lx	–	Chatain and Ounais-Guschemann, 1991
Dicentrarchus labrax	larvae	1400–3500 lx; 18L:6D	300–700 lx; 12L:12D	Barahona–Fernandes, 1979
Gadus morhua	larvae	2400 lx; 24L:0D	2400 lx; 24L:0D	Puvanendran and Brown, 2002
Hippoglossus hippoglossus	juvenile	1–10 lx	1–10 lx	Hole and Pittman, 1995
Melanogrammus aeglefinus	juvenile	30 lx; 24L:0D	–	Trippel and Neil, 2003
Penaeus merguiensis	juvenile	750 lx; 14L:10D	750 lx; 12L:12D	Hoang et al., 2003
Mylio macrocephalus	juvenile	3000 lx	–	Kiyono and Hirano, 1981
Clarias gariepinus	juvenile	–	150 lx; 12L:12D	Almazán-Rueda et al., 2004

dim light could be due to that Chinese longsnout catfish is a benthic and crepuscular feeding fish. It seemed the light intensity exerted an indirect effect on juvenile African catfish mortality by increasing locomotor activity and enhancing cannibalism behavior (Appelbaum and Kamler, 2000). As swimming activity increased, the probability of encounters between fish would also increase, making the fish more susceptible to attacking each other (Almazán-Rueda et al., 2004). In bright light, the diurnal feeding fish could increase swimming activity and would have better visual acuity of increasing reactive distances (Barahona-Fernandes, 1979; Batty, 1987; Puvanendran and Brown, 2002). Fish could be classified into different feeding behaviors relied predominantly on vision, chemical, tactile or electrical senses (Schwassmann and Meyer, 1971). The crepuscular feeding fish could use sensory modes other than vision, perhaps involving tactile and/or olfactory stimuli with the increasing activity in dimmer light (Townsend and Risebrow, 1982).

The cannibalism of Chinese longsnout catfish was influenced by light intensity but with substantial damage to skin or the dorsal fin. The damage led to more wounds on the fish's skin, making the fish vulnerable to diseases or even death (Kaiser et al., 1995). Cannibalism had been reported to lead to 70–83% or 40–50% mortality in larvae or juveniles (Hecht and Appelbaum, 1987; Cuvier-Péres et al., 2001). In the present study, most mortality was from the cannibalism and fish could die in earlier 2 weeks after cannibalism. It could probably be caused by the territoriality behavior, which has been observed in the laboratory for Chinese longsnout catfish. In daytime, fish attacked the ones that entered the area they depended and after dusk, fish appeared to establish and rearrange their social hierarchy with spatial organization (Valdimarsson and Metcalfe, 2001). When all fish adapted for the strict hierarchy, few aggression responses were noted.

4.2. Growth and feed utilization

Growth of Chinese longsnout catfish was affected significantly by light intensity. That the best growth was obtained at medium light intensities (74–312 lx) than at others was in accordance with better growth at 3.15 $\mu mol \cdot s^{-1} \cdot m^{-2}$ in haddock larvae (Downing and Litvak, 1999), 87 lx in plaice larvae (Huse, 1994), 100 lx in sea bass (Cuvier-Péres et al., 2001), and 300 lx in Asian sea bass fry (Fermin and Seronay, 1997). Some species can grow and develop at low light intensity, such as striped bass larvae at 1 lx (Chesney, 1989), larvae cod at 1 lx (Huse, 1994), juvenile halibut at 1–10 lx (Hole and Pittman, 1995), juvenile haddock at 30 lx (Trippel and Neil, 2003). On the other hand, some species were reported to show improved growth at very intense light levels, sea bass larvae at 1400–3500 lx (Barahona–Fernandes, 1979), Atlantic cod larvae at 2400 lx (Puvanendran and Brown, 2002), and black porgy juvenile at 3000 lx (Kiyono and Hirano, 1981). It seems that the effect of light intensity on growth and survival are species-specific (Puvanendran and Brown, 2002).

In this study, there was a significantly higher SGR for juveniles reared in 74 lx or 312 lx. The cause for faster growth in medium light was improved feed conversion efficiency not feed intake (Boeuf and Le Bail, 1989). As a crepuscular feeding fish, Chinese longsnout catfish had less activity at suitable light intensity and more food energy could be used for growth (Trippel and Neil, 2003).

4.3. Body color

The differences of the colorimetric values of L^* (lightness) and W^* (whiteness) suggested that the skin color of juveniles turned darker under 434 lx. This was similar to the study that the addition of shade covers significantly increased the skin lightness (L^*), but there was no difference between the lightness of fish held under either 50% or 95% shade cover (Booth et al., 2004). Fish could adapt to the background color by changing the skin color (Fernandez and Bagnara, 1991; Fujimoto et al., 1991) and fish in brighter light normally resulted in concentration of the pigment and paling of the skin (Rotllant et al., 2003).

5. Conclusion

Growth of Chinese longsnout catfish was significantly affected by light intensity and a light intensity of 312 lx resulted in high growth and survival.

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