doi: 10.7541/2013.2

REARING TANK COLOR INFLUENCES SURVIVAL AND GROWTH OF THE EARLY LARVAE OF THE YELLOW CATFISH, *PELTEOBAGRUS FULVIDRACO*, RICHARDSON

PICHIRIKKAT Rajeev Raghavan[1, 2], ZHU Xiao-Ming [1], LEI Wu [1], HAN Dong [1], YANG Yun-Xia [1] and XIE Shou-Qi [1]

(1. *State Key Laboratory of Freshwater Ecology and Biotechnology*, *Institute of Hydrobiology*, *Chinese Academy of Sciences*, *Wuhan* 430072, *China*; 2. *University of Chinese Academy of Sciences*, *Beijing* 100049, *China*)

Abstract: A 15 day rearing trial was undertaken to determine the influence of rearing tank color on the survival, growth and whole body physiological indices of stress in the larvae of yellow catfish, *Pelteobagrus fulvidraco*. Early larvae (4dph) reared in tanks of five different colors (dark blue, black, light green, white and maroon) and fed with freshly hatched *Artemia nauplii* showed significant differences among treatments with regard to survival and growth. High survival and weight gain were observed among larvae reared in tanks with dark blue and black background. Elevated levels of immunoreactive corticosteroid (IRC), glucose and lactate as well as decreased lysozyme activities were observed in larvae reared in light green and maroon colored tanks throughout the trial, indicating a state of chronic stress. The present study provides the first evidence on the importance of background color during the larviculture of yellow catfish, *Pelteobagrus fulvidraco* and indicates that dark blue and black are ideal as tank colors to improve survival and growth in early larvae.

Key words: Growth; Larvae; *Pelteobagrus fulvidraco*; Tank color
CLC number: S965.1 **Document code:** A **Article ID:** 1000-3207(2013)02-0177-08

Intensive hatchery operations often expose fishes to various kinds of stressors. These factors influence the success of rearing operations and affect larval survival, development and growth, and also have a bearing on the health of the resultant fry and juveniles. Hatchery related stressors could be acute (transportation, handling, grading and vaccination) as well as chronic (water quality, crowding and light). These factors, either individually, or in combination are known to elicit different kinds of stress responses affecting the survival, development and health of the fish [1]. Rearing tank color is an important factor that influence survival, growth and stress response in fish under culture conditions. It has been previously observed that rearing tank color could cause a considerable level of stress to fish such as tiger puffer [2], common carp [3] and tilapia [4]. Research has linked tank color to neural and hormonal processes, behavior and feed acceptance or, to their combined effects in many species of fish [5—7]. Although research on the influence of tank color in culture conditions is available [8—10], much of these have focused on marine species, and information pertaining to freshwater species is scarce. In addition, compared to adult or juvenile fish, information on larval performance vis-a-vis tank color is very limited.

The yellow catfish, *Pelteobagrus fulvidraco*, is one of the most important and highly preferred freshwater catfish in China. The high dress-out weight, less intramuscular bones, delicious flavour, nutritional value, recuperative and medicinal properties, and a ready market acceptance has made *P. fulvidraco* highly popular not only in China but also in Japan and Korea [11]. Increasing demand for this species has resulted in the development and intensification of aquaculture operations and several hatcheries throughout China now produce larvae for pond stocking. Previous research on *P. fulvidraco* has focused on general embryonic development [12], nutrition [13—15] and diseases [16]. However, fundamental information on better management practices for both larval and grow-out culture is still absent and basic research still need to be undertaken to identify, and study the influence of various

Received Date: 2012-05-23; **Accepted date:** 2012-12-19
Foundation item: National Natural Science Foundation of China 31123001
Brief introduction of the author: Pichirikkat Rajeev Raghavan, E-mail: rajeev.raghavan@hotmail.com
Corresponding author: Xie Shou-Qi (1969—), E-mail: sqxie@ihb.ac.cn

environmental and husbandry related factors affecting survival and growth in this species.

Our present experiment was driven by the hypothesis that certain tank colors could cause chronic stress for the yellow catfish, *Pelteobagrus fulvidraco*, affecting its survival, health and development during early larval rearing.

1 Materials and Methods

1.1 Experimental design, rearing system, animals and husbandry

Early larvae (2dph) of the yellow catfish, *Pelteobagrus fulvidraco*, obtained from a hatchery at Jinzhou, Hubei Province, China, were transferred to the experimental laboratory at the Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, China, where the rearing trial was subsequently carried out. After transportation to the laboratory, larvae were kept in the dark for 48h prior to starting the rearing trial in an indoor recirculation freshwater system, provided with mechanical and biological filters, UV-sterilizer and compressed air supply.

A single-factor experimental design was used to evaluate the influence of rearing tank color on the early larvae of *P. fulvidraco*. Fifteen 120 L glass tanks (with 100 L of water) stocked with 1050 larvae each were used for the trial. Water-proof colored papers were used as background for the rearing tanks. The five colors were black, dark blue, light green, white and maroon. Three replicates were used for each of the five color treatments (n =15; 5×3).

Rearing trial was started on the fourth day post hatch (4dph) and lasted for 15 days (larvae were hence 19dph at the end of the experiment). Fifty larvae (n=50) were collected from all the rearing tanks and weighed prior to starting the trial. Larvae in each of the rearing tanks were fed with live food (newly hatched *Artemia nauplii*) to satiation four times daily at 08:45, 12:15, 15:45 and 19:15. Uneaten feed as well as unhatched Artemia eggs were siphoned out from the tanks approximately one hour after each feeding. Dead larvae were collected from the tanks during each of the cleaning operation and subsequently counted to calculate the survival.

Temperature was maintained at (28.5 ± 1)℃ and oxygen varied between 6 and 7 mg/L. Total ammonia-nitrogen [(NH_4^+ NH_3)-N] was always maintained below 0.5 mg/L and the pH-value varied from 6.5 to 6.8. A photoperiod of 12L：12D cycle (light period from 08:30 to 20:30) was maintained throughout the duration of the experiment.

1.2 Sampling and analyses

Most often, physiological indicators of stress are determined by analyzing their levels in blood sample. Since the present experiment was carried out by using early larvae, it was impossible to obtain blood samples for such an analysis. We therefore used whole body levels of physiological parameters determined from homogenates as indicators of stress. Whole body levels have been previously reported to be a reliable indicator of stress response in many species of fishes [17—19].

Larvae from each tank were sampled on day 5, 10 and 15 for recording their weight as well as for analysis of whole body cortisol, glucose, lactate and lysozyme levels. Sampling was carried out in the early hours of the morning between 07:30 and 08:30, after larvae were anaesthetized in MS222 bath (25 mg/L) and transferred to polypropylene tubes and deep frozen (–70℃) until further processing. Frozen larval samples were thawed, weighed, minced and placed in 4 mL polypropylene tubes. The samples were then homogenized by adding 0.02 M Phosphate Buffer Solution (PBS) using a hand homogenizer. The larval homogenates were subsequently centrifuged (4000 g) for 20 min at 4℃. The supernatants, free from lipid layer, were used for determining levels of glucose, lactate, lysozyme and cortisol.

Steroid data obtained from extracts of whole-body homogenates were normally reported as immunoreactive corticosteroid concentrations (IRC). IRC levels were determined by Radio Immuno Assay (RIA) at the Nuclear Medicine Unit of the Renmin Medical College, Wuhan University, Wuhan, China, after preliminary extraction process using a commercially available cortsiol kit (Beijing North Biotechnology Institute, China). Commercially available laboratory assay kits were used to determine whole body levels of glucose (Shanghai Rongsheng Biotechnology Company, China), lactate and lysozyme (Nanjing Jiancheng Bioengineering Institute, China).

The effect of different treatment variables on the larval survival (%), weight gain (mg) and specific growth rate (SGR %/day) were also determined. Mortality was estimated daily by counting all dead fish removed from the tanks during cleaning. Final observed survival was estimated taking into account the daily counting of the dead larvae and the number of larvae removed for sampling purposes. All data were analyzed by one way ANOVA followed by Duncan’s test using STATISTICA 6.0 program for Windows. Results are expressed as mean ± SE. We used a significance level of $P < 0.05$.

2 Results

2.1 Activity and body color

Daily observations of the rearing tanks indicated that larvae reared in dark blue and black tanks were more active and evenly distributed in the water column than those reared in light green and maroon tanks. In addition we observed that larvae in light green and maroon tanks were more or less confined to the bottom of the tank and were rising up only at feeding time, while large numbers of larvae were seen to accumulate along the walls and edges of the tank. After the termination of the experiment, larvae reared in white, light green and maroon colored tanks appeared paler than those reared in darker backgrounds (black and dark blue), which appeared darker and black.

2.2 Survival and growth

Data on survival and growth (Tab. 1) indicated that tank color has a profound influence on these parameters during the larval rearing of *P. fulvidraco*. The highest survival (94.33 ± 0.63)% was observed among the larvae in dark blue colored tanks and the lowest among those reared in light green colored tanks (67.83 ± 2.33)%. A general trend was that larvae reared in dark blue, black and white background showed better survival than those from light green and maroon tanks (Tab. 1).

Tab. 1 Survival and growth of early larvae of yellow catfish, *Pelteobagrus fulvidraco* reared in different color tanks for 15 days

Tank color	Survival (%)	Weight gain[1] (mg)	*SGR*[2] (%/d)
Dark blue	94.33±0.63[a]	37.98±0.21[a]	20.60±0.03[a]
Black	85.23±7.32[a]	38.13±0.83[a]	20.62±0.14[a]
White	90.73±0.50[a]	28.88±0.52[b]	18.84±0.11[b]
Light green	67.83±2.33[b]	21.53±0.89[c]	17.02±0.25[c]
Maroon	73.70±2.28[b]	20.49±0.99[c]	16.71±0.29[c]

Note: All values are mean ± SE (n=3); Means followed by different superscript letters are significantly different (P<0.05); 1. Weight gain (mg) = Final body weight (mg) – Initial body weight (mg); 2. *SGR* (Specific growth rate) %/d = 100 (ln Final body weight – ln Initial body weight) /trial duration (days)

Data for weight gain and growth rate (expressed as specific growth rate-SGR %/day) also showed significant differences among different treatments. Larvae from dark blue and black backgrounds had a significantly higher weight gain compared to those from white, light green and maroon backgrounds (Tab. 1). As with survival, larvae from tanks with light green and maroon background showed poor weight gain and SGR. Although there was no significant differences in survival rates among larvae grown in black, dark blue and white background (P >0.05), weight gain and SGR in larvae from white colored tanks was significantly different (P < 0.05) from those reared in blue and black tanks (Tab. 1).

2.3 Indices of stress response

Elevated and significantly higher (P < 0.05) whole body IRC levels were observed in larvae reared in green and maroon colored tanks throughout the trial (Fig. 1). The IRC levels among larvae sampled from light green and maroon colored tanks were three to four fold the levels of those in the blue, black and white tanks throughout the 15 day trial. Significant differences (P < 0.05) in whole body glucose levels were also observed among the different treatments (Fig. 2) and indicated a similar trend as with the IRC. Whole body glucose showed higher values from larvae reared in light green and maroon tanks when compared to the other groups throughout the trial. Larvae originating from light green and maroon tanks also had higher whole body lactate levels when compared to other groups (Fig. 3). Whole body lysozyme levels in larvae reared in light green and maroon tanks were significantly lower (P < 0.05) than those

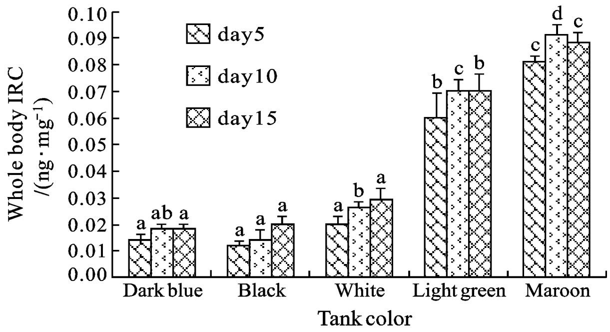

Fig. 1 Immuno Reactive Corticosteriod (IRC) levels in early larvae of *Pelteobagrus fulvidraco* reared in different color tanks for 15 days
Values are mean ± SE. Different superscript letters denote differences between treatments on sampling days 5, 10 and 15; the same bellow

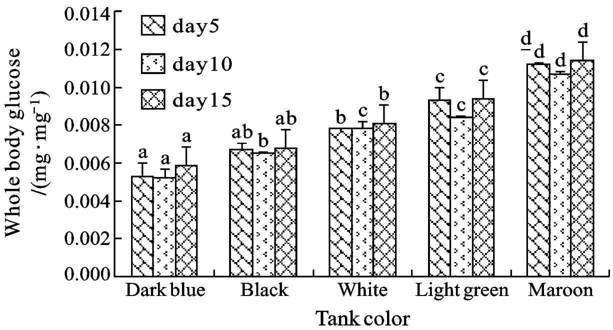

Fig. 2 Whole body glucose levels in early larvae of *Pelteobagrus fulvidraco* reared in different color tanks for 15 days

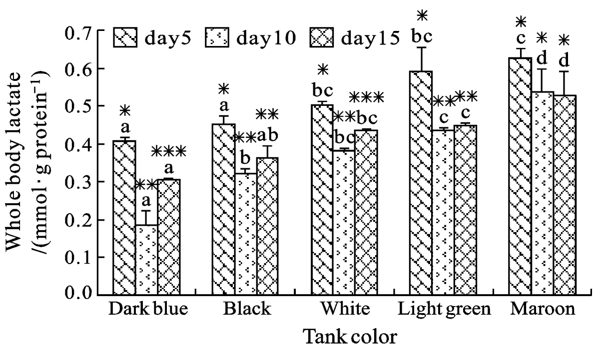

Fig. 3 Whole body lactate levels in early larvae of *Pelteobagrus fulvidraco* reared in different color tanks for 15 days
Different superscript symbols (*) denote differences within a treatment on sampling days 5, 10 and 15; the same bellow

reared in the white, blue and black tanks (Fig. 4).

Values of IRC and whole body glucose in the different treatments varied significantly ($P < 0.05$) between the sampling days. Significant differences were also observed in the whole body lactate and lysozyme levels within various treatments on the different sampling days (Fig. 3 and Fig. 4).

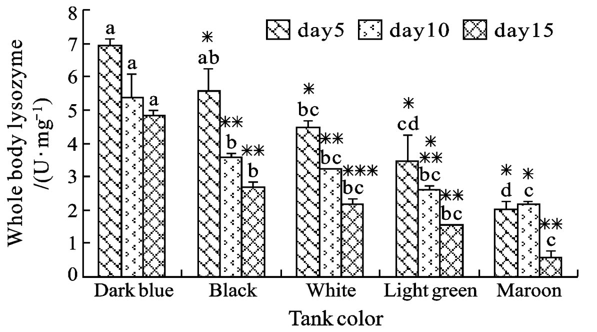

Fig. 4 Whole body lysozyme levels in early larvae of *Pelteobagrus fulvidraco* reared in different color tanks for 15 days

2.4 Relationship between growth and physiological indices

The relationship between various whole body physiological indices and larval body weight were described in Fig. 5. The relationship between body weight and IRC (Fig. 5A) was marked more than those of body weight with glucose (Fig. 5B), lactate (Fig. 5C) and lysozyme (Fig. 5D).

3 Discussion

Rearing tank color has been considered to be an important factor influencing larval rearing success in aquaculture. Our results also substantiate the fact that rearing tank color affects the survival and growth of fish, through increasing the stress. In general, a clear affinity to darker backgrounds was observed, with the larvae reared in tanks with dark blue and black backgrounds performing better than those reared in white, light green and maroon backgrounds. Suppression of growth, as an indicator of chronic stress in fish [20], was observed among larvae reared in maroon and light green backgrounds. The reduced growth could be attributed to the mobilization of energetic input of food and the corporal reserves by the physiological alterations caused by the stress condition [21].

One of the most important mechanisms affecting the survival and growth of fish by rearing tank color is the regulation of hormones - especially those relating to stress [3]. The fact that a range of endocrine (IRC), physiological (glucose, lactate) and immunological (lysozyme) parameters were altered in the larvae reared in light green and maroon tanks in the present study clearly indicated the stressful nature of these colors to the larvae of *P. fulvidraco*.

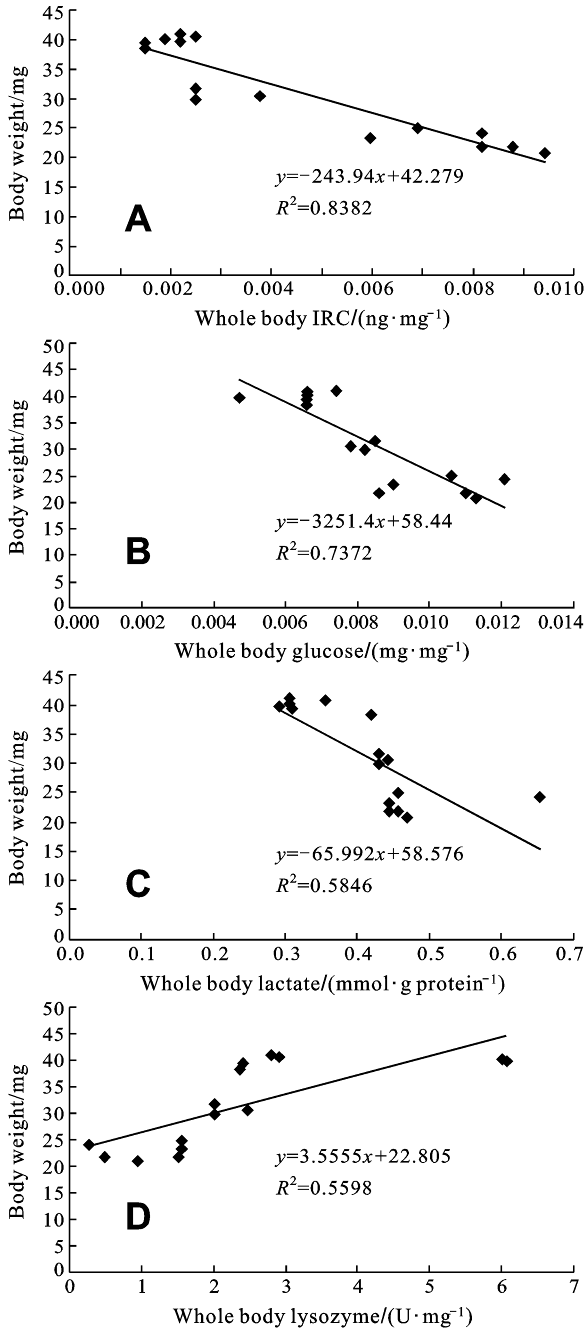

Fig. 5 Relationships between larval body weight and whole body IRC levels (A), glucose levels (B), lactate levels (C), lysozyme levels (D) at day 15

During chronic stress in fish culture, there are often characteristically high circulating levels of cortisol [22]. In the present study, elevated levels of cortisol (measured as IRC) were continually observed in the larvae reared in light green and maroon tanks throughout the experiment, which were often three to four folds higher than those observed in larvae reared in dark blue and black tanks. Such continuous elevations in cortisol levels in response to a chronic stressor over a three week period has been earlier observed in Ayu, which were three to five folds the value in control/unstressed treatments [23].

Since the best survival and growth performance was achieved in the larvae reared in the dark blue colored tanks, we used the same as a control (unstressed treatment) to compare the IRC values to the other treatments as well as previous studies. Our data on the IRC levels in control (dark blue) tank was comparable to previous studies on whole body cortisol levels (resting levels) in developing Japanese flounder [24], chum salmon [25] and Atlantic cod [18]. The IRC values in stressed fish (maroon and green tanks) in the present study are also comparable to the results on larvae of Atlantic cod [18].

The primary stress response in fish is known to further trigger and leads to sequential secondary responses (e.g., increases in plasma glucose, hematocrit, lactate, heart rate, metabolic rate, decreases in plasma chloride, sodium, potassium, liver glycogen, and muscle protein) [26, 27]. Whole body levels of glucose have been observed to increase [28] or decline [17] post stress. One reason suggested by Pottinger *et al*. [17] for the reduction in glucose levels following stress was the absence of feeding during the experiment. However, in the present study, larvae in all treatments were fed newly hatched Artemia continually and may have been one reason for the increased glucose level in response to stress. The inter-species differences in glucose utilization could also be another possibility for the differential trends (higher and lower values) in whole body glucose levels post stress [17]. Stress has profound effects on metabolism and is therefore reasonable to anticipate that these effects can be detected at the whole-body level [17]. Therefore, the increased values of whole body glucose levels in the larvae reared in light green and maroon colored tanks could be an indication of the fact that the fish in these tanks were under a considerable degree of stress.

The level of tissue lactate content acts as an index of anaerobiosis, which might be beneficial for the animal to bear hypoxic condition [29]. Tissue lactate levels in fish are known to increase post stress [30]. The increase in tissue lactate content may also be due to its involvement in osmoregulation. During stress, a decrease in osmolarity of internal body media of the animal by loss of mono- as well as divalent cations is known to take place and is generally compensated with the increase of organic ions like lactate [31]. In the present study, whole body lactate levels were seen to increase in the larvae reared in light green and maroon colored tanks.

Immune system can be severely affected by various stress conditions [32, 33]. In larval stage, lysozyme is one of the most important proteins involved in non-specific defences, when the specific immunological response is yet to be developed [34]. Stress is known to decrease [35, 36] or increase lysozyme activity [37, 38] in fish. Because stress is known to reduce physiological condition and increase susceptibility to disease in fish [39], lysozyme activity could be used as a valuable indicator of the health (immunity) status of the fish. The lower lysozyme activity among larvae reared in maroon and light green color tanks supports the corresponding data on high mortality and reduced growth observed in these tanks since the larvae could have been susceptible to secondary infection due to lower immunity.

There were no significant differences in the values of IRC and whole body glucose within various treatments at the three sampling days. The fact that values for these two important stress indices showed no significant decline at 15 days when compared to day 5 and 10 could indicate that the larvae did not show any adaptation to the rearing tank color until 15 days.

The relationship of whole body IRC to body weight was more prominent than those involving whole body glucose, lactate and lysozyme, signifying the important relationship that has been already established between whole body cortisol levels and growth [40, 41].

The reduced survival and weight gain in green and maroon tanks may also be attributed to the poor food particles to background contrast [42] leading to insufficient food intake. Larvae reared in dark blue and black tanks were more active and evenly distributed in the water column than those reared in light green and maroon tanks. In addition we observed that larvae in light green and maroon tanks were more or less confined to the bottom of the tank and were rising up only at feeding time, while some were seen constantly attached to the edges and sides of the tank walls. Martin-Robichaud and Peterson [43] reported that the distribution of larval striped bass was more homogeneous throughout the water column in black tanks when compared to lighter colored tanks. Larvae that aggregate along the wall may experience body damage due to abrasion as well as forage poorly and their growth and survival could be severely affected [44]. In addition, larvae accumulating at the bottom are more susceptible to bacteria. Because of these factors, many culturists recommend the use of black colour tanks for larval rearing [45].

Literature suggests contrasting evidence regarding ideal background colors for rearing fin-fishes. White colored tanks have been observed to be both positively [3] and negatively [5] related to behavior, growth and development. Larvae of some species like turbot [46] and striped bass [43] showed better survival and growth performance when reared in dark tanks while others including Eurasian perch [42] showed more affinity to the lighter tanks. There are also quite a few neutral species that seem to have no particular affinity to both light or dark colored tanks like Atlantic salmon [47] and African catfish [48].

Larvae of common carp reared in green colored tanks had higher levels of cortisol indicating they were stressed [3]. Rearing tanks provided with green light was also observed to be highly stressful for Nile tilapia [49]. A similar opinion by Barcellos *et al*. [50] suggested that green illumination provided in tanks for rearing silver catfish, *Rhamdia quelen*, resulted in an extremely negative influence on survival and growth. Brown tanks were found to induce agonistic behavior and increased stress response (through elevated cortisol levels) in Nile Tilapia [51]. Rearing tanks lit with blue color light has been reported to reduce stress in Nile tilapia [49]. The above mentioned observations on the negative influence of green and brown colored tanks and better results with blue colored ones agree with our present study. However data from Rabbani and Zeng [52] on the mud crab *Scylla serrata* suggested that crustacean larvae reared in green and maroon colored tanks showed higher survival when compared to those reared in white, blue and black tanks. Comparable results on the efficacy of green colored tanks were observed by Yasharian *et al*. [53] with the larvae of freshwater prawn, *Macrobrachium rosenbergii*. These observations therefore indicate that the preference for different background colors is species specific.

4 Conclusions

The present trial has demonstrated that rearing tank color is an important physical stressor for the early larvae of the yellow catfish, *Pelteobagrus fulvidraco*. Larvae of the yellow catfish showed higher survival and growth when reared in dark blue or black colored tanks, moderate growth and survival when reared in white tanks and poor survival and growth when reared in maroon and green tanks. Light green and maroon tanks should be hence considered stressful for this species and avoided for larval rearing as they have been found to incite a stress response leading to reduced survival and growth. This information could be of potential use to both small scale as well as commercial hatchery operators breeding the yellow catfish in the region.

Acknowledgements:

The authors are grateful to Nie Guang-Han for his expertise in designing the rearing system and for his technical help throughout the experiment. Thanks are also due to the staff at the Nuclear Medicine Unit at the Renmin Hospital of Wuhan University, Wuhan, P. R. China, for their help in the analysis of cortisol samples.

References:

[1] Portz D E, Woodley C M, Cech J J Jr. Stress-associated impacts of short term holding on fishes [J]. *Reviews in Fish Biology and Fisheries*, 2006, **16**(2): 125—170

[2] Hatanaka, H. Influence of the tank colour, light intensity and rearing density on the growth and the shape of caudal fin in juvenile tiger puffer *Takifugu rubricus* [J]. *Nippon Suisan Gakkaishi*, 1997, (63): 734—738

[3] Papoutsoglou S E, Mylonakis G, Miliou H, *et al*. Effect of background colour on growth performances and physiological responses of scaled carp *Cyprinus carpio* reared in a closed circulated system [J]. *Aquacultural Engineering*, 2000, (22): 309—318

[4] Xu J Y, Liu Y. Study on color modification of tilapia *oreochromis niloticus* under environmental background and stress by computer vision [J]. *Acta Hydrobiologica Sinica*, 2009, **33**(2): 164—169 [徐建瑜, 刘鹰. 基于计算机视觉的罗非鱼适应环境的体色变化研究. 水生生物学报, 2009, **33**(2): 164—169]

[5] Fanta E. Influence of background colour on the behaviour of the fish *Oreochromis niloticus* (Cichlidae) [J]. *Brazilian Archives of Biology and Technology*, 1995, **38**: 1237—1251

[6] Papoutsoglou S E. Endocrinology of Fishes [M]. Stamoulis Press, Athens (in Greek). 1998

[7] Höglund E, Balm P H M, Winberg S. Behavioural and neuroendocrine effects of environmental background colour and social interaction in Arctic charr (*Salvelinus alpinus*) [J]. *The Journal of Experimental Biology*, 2002, **205**(16): 2535—2543

[8] Duray M N, Estudillo C B, Alpasan L G. The effect of background color and rotifer density on rotifer intake, growth, and survival of the grouper (*Epinephelus suillus*) larvae [J]. *Aquaculture*, 1996, **146**(3/4): 217—224

[9] Rotllant J, Tort L, Montero D, *et al*. Background color influence on the stress response in cultured red porgy *Pagrus pagrus* [J]. *Aquaculture*, 2003, **223**(1—4): 129—139

[10] Bransden M P, Butterfield T G M, Walden J, *et al*. Tank colour and dietary arachidonic acid affects pigmentation, eicosanoid production and tissue fatty acid profile of larval Atlantic cod (*Gadus morhua*) [J]. *Aquaculture*, 2005, **250**(1—2): 328—340

[11] Weimin W, Abbas K, Ansheng Y. Embryonic development of *Pelteobagrus fulvidraco* (Richardson 1846) [J]. *Chinese Journal of Oceanology and Limnology*, 2006, **24**(4): 378—383

[12] Wang L L, Chou Q R, Zou S P, *et al*. Observation on embryonic and post-embryonic development of yellow catfish [J]. *Freshwater Fisheries*, 1989, **5**: 9—12 (in Chinese with English abstract)

[13] Wang C, Xie S, Zheng K, *et al*. Effects of live food and formulated diets on survival, growth and protein content of first-feeding larvae of *Pelteobagrus fulvidraco* [J]. *Journal of Applied Ichthyology*, 2005, **21**: 210—214

[14] Wang C, Xie S, Zhu X, *et al*. Effects of age and dietary protein level on digestive enzyme activity and gene expression of *Pelteobagrus fulvidraco* larvae [J]. *Aquaculture*, 2006, **254**(1—4): 554—562

[15] Zhou Q B, Wu H D, Wu F X, *et al*. A study on the protein

requirement of young fish of *Pelteobagrus fulvidraco* (Richardson) [J]. *Acta Agriculturae Universitatis Jiangxiensis*, 2003, **25**(5): 763—765 (in Chinese with English abstract)

[16] Su X H. Investigation on diseases of *Pelteobagrus fulvidraco* R and their control techniques [J]. *Chinese Fisheries*, 2005, **3**: 48—49 (in Chinese)

[17] Pottinger T G, Carrick T R, Yeomans W E. The three-spined stickleback as an environmental sentinel: effects of stressors on whole-body physiological indices [J]. *Journal of Fish Biology*, 2002, **61**(1): 207—229

[18] King W V, Berlinsky D L. Whole body corticosteroid and plasma cortisol concentrations in larval and juvenile Atlantic Cod, *Gadus morhua* L following acute stress [J]. *Aquaculture Research*, 2006, **37**(13): 1282—1289

[19] Ramsay J M, Feist G W, Varga Z M, *et al*. Whole-body cortisol is an indicator of crowding stress in adult zebrafish, *Danio rerio* [J]. *Aquaculture*, 2006, **258**: 565—574

[20] Pickering A D. Stress and the Suppression of Somatic Growth in Teleost Fish [M]. In: Epple A, Scanes C G, Stetson M H (Eds.), Progress in Clinical and Biological Research, Vol 342, Progress in Comparative Endocrinology. New York: Wiley-Liss. 1990, 473—479

[21] Kebus M J, Collins M T, Brownfield M S, *et al*. Effects of rearing density on stress response and growth of rainbow trout [J]. *Journal of Aquatic Animal Health*, 1992, **4**(1): 1—6

[22] Pickering A D, Pottinger T G. Stress responses and disease resistance in salmonid fish: effects of chronic elevation of plasma cortisol [J]. *Fish Physiology and Biochemistry*, 1989, **7**(1—6): 253—258

[23] Iguchi K, Ogawa K, Nagae M, *et al*. The influence of rearing density on stress response and disease susceptibility of Ayu (*Plecoglossus altivelis*) [J]. *Aquaculture*, 2003, **220**(1—4): 515—523

[24] de Jesus E G, Hirano T, Inui Y. Changes in cortisol and thyroid hormone concentrations during early development and metamorphosis in the Japanese flounder, *Paralichthys olivaceus* [J]. *General and Comparative Endocrinology*, 1991, **82**(3): 369—376

[25] de Jesus E G, Hirano T. Changes in whole body concentrations of cortisol, thyroid hormones and sex steroids during early development of the chum salmon, *Oncorhynchus keta* [J]. *General and Comparative Endocrinology*, 1992, **85**(1): 55—61

[26] Mommsen T P, Vijayan M M, Moon T W. Cortisol in teleosts: dynamics, mechanisms of action, and metabolic regulation [J]. *Reviews in Fish Biology and Fisheries*, 1999, **9**(3): 211—268

[27] Barton B A, Morgan J D, Vijayan M M. Physiological and Condition-related Indicators of Environmental Stress in Fish [M]. In: Adams S M (Eds.), Biological Indicators of Aquatic Ecosystem Stress. American Fisheries Society, Bethesda, MD. 2002, 111—148

[28] Krumschnabel G, Lackner R. Metabolic responses of fish larvae [*Rutilus rutilus* (L.)] to forced activity (Cyprinidae, Teleostei) [J]. *Journal of Fish Biology*, 1992, **41**(5): 717—724

[29] Thoye R A. Effect of halothan, anoxia and hemorhage upon canine, whole body skeletal muscle and splanchine excess lactate production [J]. *Anaesthesiology*, 1971, **35**: 394—400

[30] Tiwari S, Singh A. Biochemical stress response in freshwater fish, *Channa punctatus* induced by an aqueous extract of *Euphorbia tirucalli* plant [J]. *Chemosphere*, 2006, **64**(1): 36—42

[31] Sahib K A I, Rao K S R, Rao K R S S, *et al*. Sub-lethal toxicity of malathion on the protease and free amino acid composition in the liver of the teleost, *Tilapia mossambica* (Peters) [J]. *Toxicology Letters*, 1984, **20**(1): 59—62

[32] Saurabh S, Sahoo P K. Lysozyme an important defence molecule of fish innate immune system [J]. *Aquaculture Research*, 2008, **39**(3): 223—239

[33] Ming J H, Xie J, Xu P, *et al*. Effects of emodin, vitamin C and their combination on crowding stress resistance of Wuchang bream (*Megalobrama amblycephala* Yih) [J]. *Acta Hydrobiologica Sinica*, 2011, **35**(3): 400—413 [明建华, 谢骏, 徐跑, 等. 大黄素、维生素 C 及其配伍对团头鲂抗拥挤胁迫的影响. 水生生物学报, 2011, **35**(3): 400—413]

[34] Takemura A. Immunohistochemical localization of lysozyme in the pre-larvae of tilapia, *Oreochromis mossambicus* [J]. *Fish Shellfish Immunol*, 1996, **6**(1): 75—77

[35] Yin Z, Lam T J, Sin Y M. The effects of crowding stress on the non-specific immune response in fancy carp (*Cyprinus carpio* L.) [J]. *Fish and Shellfish Immunology*, 1995, **5**: 519—529

[36] Jeney G, Galeotti M, Volpatti D. Prevention of stress in rainbow trout (*Oncorhynchus mykiss*) fed diets contains different doses of glucan [J]. *Aquaculture*, 1997, **154**(1): 1—15

[37] Fevolden S, Refstie T, Røed K H. Selection for high and low cortisol response in Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*) [J]. *Aquaculture*, 1991, **95**: 53—65

[38] Røed K H, Larsen H J S, Linder R D, *et al*. Genetic variation in lysozyme activity in rainbow trout (*Oncorhynchus mykiss*) [J]. *Aquaculture*, 1993, **109**(3-4): 237—244

[39] Bonga W S E. The stress response in fish [J]. *Physiological Reviews*, 1997, **77**(3): 591—625

[40] Vijayan M M, Ballantyne J S, Leatherland J F. High stocking density alters the energy metabolism of brook charr, *Salvelinus fontinalis* [J]. *Aquaculture*, 1990, **88**(3—4): 371—381

[41] Tort L. Current Studies on the Physiology of Stress and Physiopathology of Stress [M]. In: FishWelfare. Aqualabs Series, Advanced Laboratory Training in Aquaculture. University of Insubria, Varese, Italy. 2005, 21

[42] Tamazouzt L, Chatain B, Fontaine P. Tank wall colour and light level affect growth and survival of Eurasian perch larvae (*Perca fluviatilis* L.) [J]. *Aquaculture*, 2000, **182**(1—2): 85—90

[43] Martin-Robichaud D J, Peterson R H. Effects of light intensity, tank colour and photoperiod on swimbladder inflation success in larval striped bass, *Morone saxatilis* (Walbaum) [J]. *Aquaculture Research*, 1998, **29**(8): 539—547

[44] Monk J, Puvanendran V, Brown J A. Does different tank bottom colour affect the growth, survival and foraging behaviour of Atlantic cod (*Gadus morhua*) larvae [J]? *Aquaculture*, 2008, **277**(3—4): 197—202

[45] Naas K, Huse I, Iglesias J. Illumination in first feeding tanks for marine fish larvae [J]. *Aquacultural Engineering*, 1996, **15**(4): 291—300

[46] Howell B R. Experiments on the rearing of larval turbot, *Scophothalmus maximus* L. [J]. *Aquaculture*, 1979, **18**(3): 215—225

[47] Stefansson S O, Hansen T. Effects of tank colour on growth and smoltification of Atlantic salmon (*Salmo salar* L.) [J]. *Aquaculture*, 1989, **81**(3—4): 379—386

[48] Bardócz T, Kovács É, Radics F, *et al*. Experiments for the improved use of decapsulated *Artemia* cysts in intensive culture of African catfish larvae [J]. *Journal of Fish Biology*, 1999, **55**(Suppl. A): 227—232

[49] Volpato G L, Baretto R E. Environmental blue light prevents stress in Nile tilapia [J]. *Brazilian Journal of Medical and Biological Research*, 2001, **34**(8): 1041—1045

[50] Barcellos, L J G, Ritter F, Kreutz L C, *et al*. The color of illumination affects the stress response of jundiá (*Rhamdia quelen*, Quoy & Gaimard, Heptapteridae) [J]. *Ciência Rural*, 2006, **36**(4): 1249—1252

[51] Merighe G K F, Pereira-da-Silva E M, Negrão J A, *et al*. Effect of background colour on the social stress of Nile tilapia (*Oreochromis niloticus*) [J]. *Revista Brasileira de Zootecnia*, 2004, **33**(4): 828—837

[52] Rabbani A G, Zeng C. Effects of tank colour on larval survival and development of mud crab, *Scylla serrata* (Forskal) [J]. *Aquaculture Research*, 2005, **36**(11): 1112—1119

[53] Yasharian D, Coyle S D, Tidwell J H, *et al*. The effect of tank coloration on survival, metamorphosis rate, growth and time to metamorphosis freshwater prawn, (*Macrobrachium rosenbergii*) rearing [J]. *Aquaculture Research*, 2005, **36**(3): 278—283

养殖箱颜色对黄颡鱼早期仔稚鱼存活和生长的影响

P. Rajeev Raghavan[1,2] 朱晓鸣[1] 雷 武[1]
韩 冬[1] 杨云霞[1] 解绶启[1]

(1. 中国科学院水生生物研究所, 淡水生态与生物技术国家重点实验室, 武汉 430072;
2. 中国科学院大学, 北京 100049)

摘要： 以孵化 4 天(4dph)的黄颡鱼 *Pelteobagrus fulvidraco* 仔鱼为对象, 通过 15d 的养殖实验, 探讨养殖箱颜色对其存活、生长和鱼体生理指标的影响。实验鱼养殖在 5 种不同颜色(深蓝、黑色、亮绿、白色和褐色)的养殖箱中, 以新鲜孵化的卤虫投喂。实验结果显示, 不同养殖缸的背景颜色显著影响($P < 0.05$)了黄颡鱼仔稚鱼的存活和生长。养殖在深蓝色和黑色背景养殖箱中的黄颡鱼的成活率和增重最高; 在亮绿和褐色背景中, 鱼体的皮质醇(IRC)、葡萄糖和乳酸水平显著升高, 而溶菌酶活性下降, 这表明鱼体处在一种慢性应激状态。研究结果表明在黄颡鱼仔鱼培育阶段, 养殖背景色非常重要, 深蓝和黑色背景有利于提高黄颡鱼仔稚鱼的成活率和生长。

关键词：生长; 仔稚鱼; 黄颡鱼; 养殖箱颜色