International Research Journal of Biological Sciences ISSN 2278-3202
Vol. **3(5),** 45-52, May **(2014)** *Int. Res. J. Biological Sci.*

Effects of Different Light Intensities on Fry Growth, Survival and Cannibalism Control of Asian Seabass (*Lates calcarifer*)

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Available online at: www.isca.in, www.isca.me
Received 10th December 2013, revised 2nd January 2014, accepted 3rd February 2014

Abstract

Successful fish culture depends on an understanding of the optimum environment of particular species to maximize survival and development. A 4-week experiment was carried out to investigate the effects of light intensity on survival, growthand cannibalism of Asian seabass, Lates calcarifer. Four light intensities, 0, 500, 1,000 and 2,000 lx were tested in triplicates. Asian seabass with an initial total length (TL) of 9.88 ± 1.23 mm were fed to satiation four times a day. Other morphological changes such as body length (BL), head length (HL), body height (BH), pectoral height (PH) and eye diameter (ED) were recorded once a week. In addition, survival and cannibalism rates were calculated at the end of the experiment. The results showedthat light intensity significantly affected (P<0.05) the survival, growth, and cannibalism of Asian seabass. Optimum survival and growth were observed in 500-1,000 lx. This information can be used to establish stable mass-scale and sustainable rearing technology for Asian seabass.

Keywords: Light intensity, photoperiod, Asian seabass, growth, survival, Cannibalism.

Introduction

Asian seabass also known as Barramundi (*Lates calcarifer*) is one of the most important food fish species in South East Asia[1]. Since 1980, this species has been cultured in many Asian countries such as Hong Kong, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand[2]. Asian seabass is recognized as a fast growing fish, and is highly resistant in extreme environments such as high turbidity and varying salinity[3]. Furthermore, there isa high demand and a good market price for the Asian seabass because it has white flesh which is preferred by consumers[2]. Current global annual production is almost 400,000 MT and more than 90% of production originates from Singapore and Thailand, Taiwan and Hong Kong. Thus, the cultured seabass industry has great potential in the tropical Asia Pacific region[1].

Nonetheless, the survival of fingerlings has been one of the most critical problems[4]. There are several constraints in maximizing the production and survival of fish such as poor production, poor quality of seed[5-6]; low survival rate[7] and cannibalism in hatchery rearing[8]. To maximize production in aquaculture, an understanding of the environmental preferences of the fish is really crucial. Optimizing the environmental parameters, such as light intensity, leads to improved growth and survival rates, decreased rearing periods and reduced production cost. All these factors are crucial in intensive culture. Thus, understanding the parameters of optimum light intensity is an important prerequisite in ensuring sustainable development of the Asian seabass culture.

Several studies related to optimal light intensities have been done to investigate the growth and survival of particular species of fish. High light intensitiescan increase the feeding time and improve growth and survival of *Gadus morhua, Melanogrammus aeglefinus* and *Penaeus merguiensis*[9]. In order to grow and develop normally, the fish need a minimal light intensity threshold[10]. Since light can be manipulated, it is possible for the survival and growth of larvae to be improved. Thus, research on light intensity is important in order to aid in the advancement of culture techniques for Asian seabass. The present study was carried out to assess the effects of light intensities and to determine the optimal light intensity parameters for the survival and growth of Asian seabass.

Material and Methods

An experiment of the effect of different light intensities on the fry stage of the Asian seabass was conducted at the Marine Hatchery of Borneo Malaysian Research Institute, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia from 9 June 2013 to 7 July 2013. The fry stage begins when the fish has completed metamorphosis, and takes on a sub-adult appearance. It starts from 21- 41 dAH.

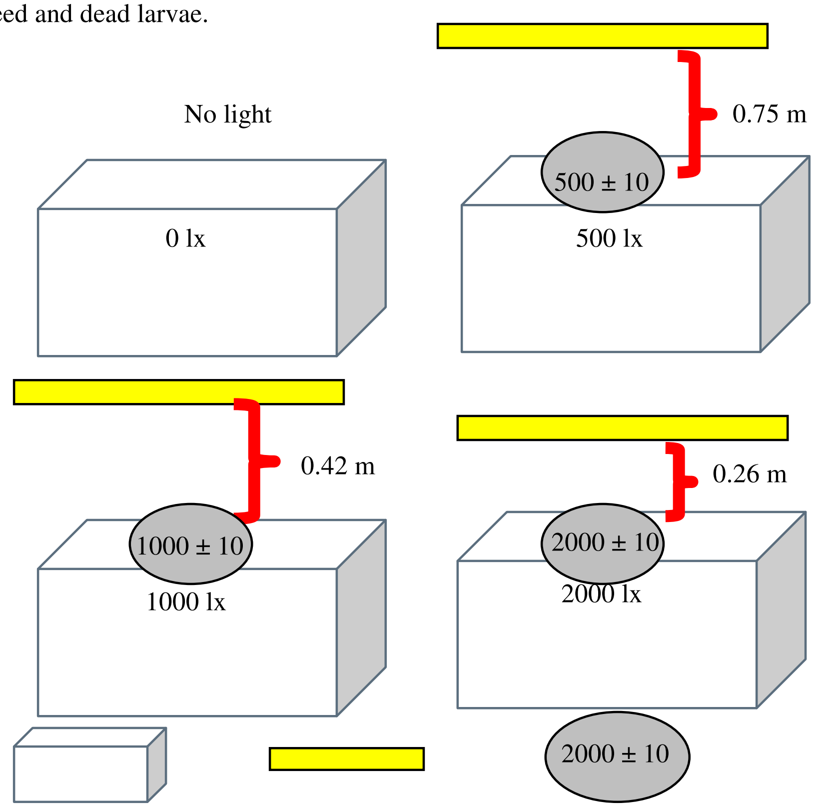
Experimental Design: Four different light intensity regimes (0, 500, 1,000 and 2,000 lx) were carried out in this experiment with three replicate tanks and sampling tanks for each treatment. The sampling tank was provided for sampling purposes. Artificial light was provided continuously by 30 watt white fluorescent tube lamps (LifeTech, MW1-y, China). Light intensity was adjusted by the height of the light from the water surface for all treatments except for 0 lx treatment where no light was provided. For 500, 1,000 and 2,000 lx, the heights of the lamps from the water surface were 0.75, 0.42 and 0.26 m respectively and this was measured by a lux meter (EXTECH instruments, 401025, Taiwan) (figure-1). Each treatment tank was isolated by shielding the tank with an opaque Garbadine fabric partition. To avoid the effects of any background light in the experiments, the experimental tanks were wrapped with black plastic, excluding the top area.

Rearing Conditions: Fry of Asian seabass, 21dAHwere obtained from the Marine Hatchery of Borneo Malaysian Research Institute, Universiti Malaysia Sabah. The range of the total lengths was 8-10 ± 0.23 mm. The Asian seabass were transferred to the 7 liter experimental tanks.The tanks were supplied with filtered seawater and provided with aeration to maintain the oxygen level. Dissolved oxygen was maintained above 7.5 mg/L, salinity was maintained at 15 ppt and water temperature was maintained at 28-30 C. The Asian seabass were fed to apparent satiation with a commercial diet, Otohime (B1, 250-360 µm, Tokyo Japan). Bottom cleaning and water renewal were carried out once a week to maintain the water quality of the rearing water. The purpose of bottom cleaning was to remove debris, excessive feed and dead larvae.

Growth performance: Ten of the Asian seabass (n=10) were sampled from each treatment and anesthetized with Transmore at 25 ppm (alpha-methylquinoline) (Nika Trading, Puchong, Malaysia).Samples were observed under a light microscope (Nikon, Eclipse E600, Japan) and a profile projector (Mitutoyo, PJ-3000, Japan). Morphometric measurements such as total length (TL), head length (HL), body length (BL), body height (BD), eye diameter (ED), and pectoral height (PH) weretaken. Measuring of samples was carried out once a week.

Survival (%): Survival rate (%) was determined based on the total number of living Asian seabass at the end of the experiment. The formula used was: $S(\%) = 100 \times \sum_j N_j/N'_{j-1}$, where N_j is the number of fish on day j (before sampling); N'_j is the number of fish after sampling[11].

Cannibalism (%): Cannibalism rate (%) was calculated using the formula: $C(\%) = N_d/N_i - p$, where $N_d = N_i - N_f - p - M_r$; N_i is the initial number of fish; N_f is the final number of fish; p is the number of larvae removed and M_r is the number of dead fish[11]. Dead fish due to cannibalism were described based on physical appearance such as scars and wounds.



(: tanks; : light; : lux meter)

Figure-1
Illustration of experimental design; adjustment the height of light from water surface while light intensity measured by lux meter. The height of light for 500, 1,000 and 2,000 lx are 0.75 mm, 0.42 mm and 0.26 mm respectively

Statistical Analysis: All quantitative data were tested for normality and homogeneity of variance. Treatment means of all other variables of interest were compared using one way ANOVA, followed by the Tukey HSD test with $P<0.05$ taken as the statistically significant threshold (SPSS 15.0 for Windows).

Results and Discussion

Survival (%): The highest survival was observed in 1,000 lx (90.0 ± 10.0%) but there were no significant differences ($P<0.05$) with those observed in 500 lx (83.0 ± 15.0%) and 2000 lx (56.6 ± 9.3%) (figure-2). However, a significant difference ($P<0.05$) was detected when compared to 0 lx.

Growth performance: No significant difference was observed in terms of larval growth from 14-28 dAH. A significant difference ($P<0.05$) in total length (figure-3) was first observed on 35 dAH and subsequently until the end of the experiment, with the mean total length of Asian seabass reared at 1,000 and 2,000 lx being significantly larger than those reared at lower light intensities (0 and 500 lx) (figure-4). The highest TL recorded at the end of the experiment (41 dAH) for Asian seabass reared in 2,000 lx, was 27.0 ± 1.7 mm. There were significant differences between 2,000 lx and lower light intensity treatments (500 and 0 lx) but insignificant differenceswere detected between 2,000 lx and 1,000 lx. The results showed that Asian seabass reared at 0 and 500 lx exhibited slow growth during the experiment.

Morphometric changes: Changes in morphometric characteristics of Asian seabass due to different light intensity treatments (0, 500, 1,000 and 2,000 lx) are illustrated in figure 5 (A-F). Overall, based on the illustration for all morphometric characteristics, all treatments showed an increase except for the 0 lx treatment. No significant differences ($P<0.05$) were observed for various morphometric characteristics between different treatments for the first 21 days. Morphometric characteristic changes were observed on 28 dAH onwards until the end of the experiment.

At the end of the experiment, the highest BL was observed in the 2,000 lx treatment. There were significant differences ($P<0.05$) with 0 and 500 lx but insignificant differences ($P<0.05$) with 1,000 lx. For HL, no significant difference ($P<0.05$) was observed between 500 lx and other treatments but there were significant differences ($P<0.05$) between 0 lx and 1,000, 2,000 lx. This same pattern was observed in BH. However, significant differences were detected in mean PH and ED($P<0.05$) between 0 lx and 500,1,000 and 2,000 lx treatments.

Cannibalism (%): The lowest cannibalism rate was recorded in 1,000 lx treatments with 10 ± 1.0 % (Figure-6). In contrast, 0 lx exhibited the highest cannibalism rate, 60 ± 1.0 %. There was significant difference ($P<0.05$) between 0, 500, and 1,000 lx treatments, but no significant differences ($P<0.05$) were observed between 2000 lx and 0, 500, and 1,000 lx treatments.

Figure-2
Effect of light intensities on survival of Asian seabass on 41 dAH. Latter a and b denotes a value that is significantly different (P<0.05) from other treatments. Means sharing a letter showed not significantly different (P<0.05) at the end of experiment while error bars representative as standard deviation

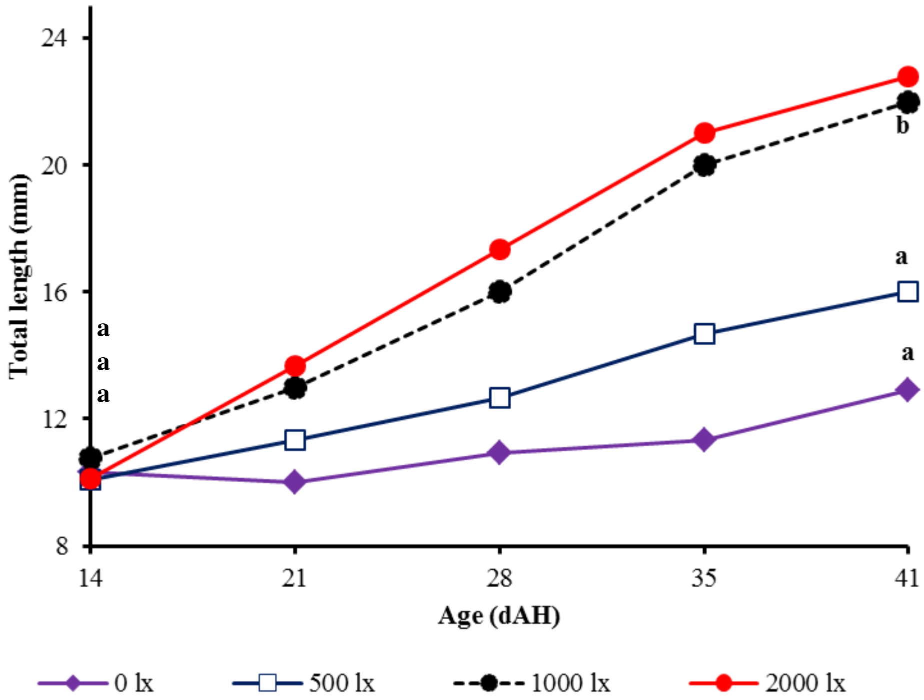


Figure-3
Total length of Asian seabass from 14 dAH until 41 dAH. Letter a and b indicate significant difference of total length of Asian seabass, marked as representative of growth performance of Asian seabass. There are significant differences was detected on 41 dAH between 0, 500 lx and 1000, 2000 lx. Means sharing a letter showed not significantly different (P<0.05) at the end of experiment. The significant differences were compared by column or by age (dAH)

Figure-4
Differences of Asian seabass from different treatments; 0 ; 500 ; 1000 and 2000 lx. Age of Asian seabass is 41 dAH

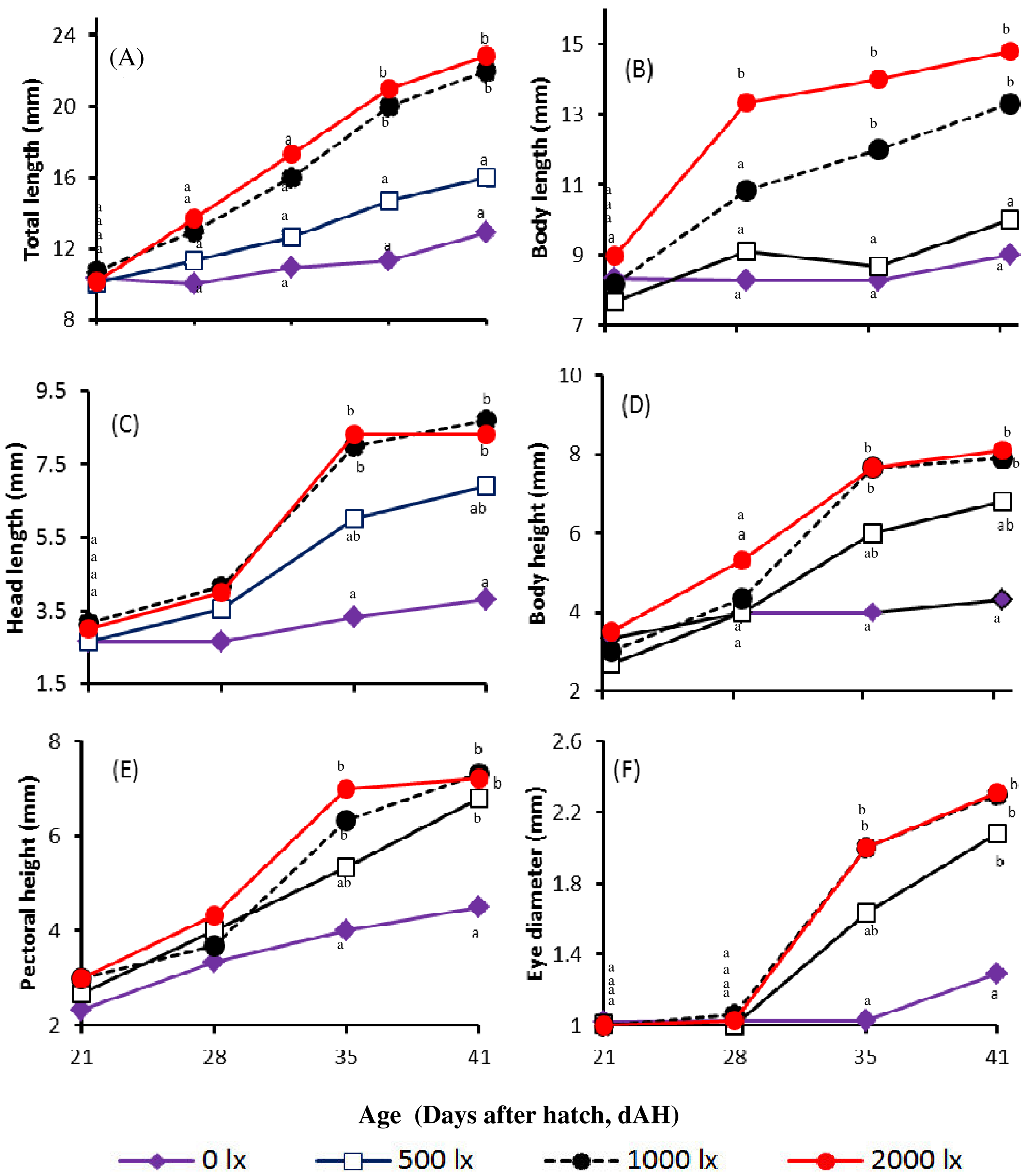


Figure-5

Morphometric changes of Asian seabass under different light intensities treatments from 21 dAH until 41 dAH. (A) Total length, TL (mm), (B) Body length, BL (mm), (C) Head length, HL (mm), (D) Body height, BH (mm), (E) Pectoral height, PH (mm), (F) Eye diameter, ED (mm). Letter a and b denotes a value that is significantly different ($P<0.05$) from other treatments. Means sharing a letter showed not significantly different ($P<0.05$) at the end of experiment. The significant differences were compared by column or by age (dAH)

Figure-6
Effect of light intensities on cannibalism of Asian seabass on 41 dAH. Latter a and b denotes a value that is significantly different ($P<0.05$) from other treatments. Means sharing a letter showed not significantly different ($P<0.05$) at the end of the experiment while error bars represent as standard deviation

Discussion: In the present study, the survival of Asian seabass was significantly affected by light intensity. The best survival rate was observedat 1,000 lx, followed by 500 lx,while poor survival rates were detected at 0 lx and 2,000 lx. These survival variations can be explained by feeding activities which rely on vision development.

A minimal light intensity threshold is needed to allow the fish to develop normal hunting activity and exhibit normal feeding behavior[12]. Below this threshold, the fish is unable to detect and catch food, and will finally die because of starvation[10]. At 0 lx, Asian seabass were observed to have empty stomachs as evidence of starvation. Specifically, they were using the ‘aim-striking’ strategy in feeding activity. Asian seabass rely on their vision to aim for food and to strike directly at the feed. Thus they are visual feeders and require minimum light in order to discriminate and recognize the feed. Therefore, Asian seabass have a higher survival rate in the presence of light such as 500 and 1,000 lx compared to the dark conditions of 0 lx.

Nevertheless, in the brightest light condition, 2,000 lx, the survival rates of Asian seabass decreased. Stress is presumably accountable for the lowest survival rate observed in the present study. Very bright light can be harmful or even lethal to the fish[10]. In the present study it was assumed that Asian seabass in 2,000 lx were swimming very energetically. The higher swimming activity is one of the factors whichincrease aggressive acts, and as a result, the probability of encounters between fish will also increase, making the fish more susceptible to antagonistic behavior[13]. Although light intensity is proven to improve survival,light that is too intense causes stress whilelight that is too low in intensity constrains and restricts the vision of fish for feeding. Nonetheless, the effects of light intensities are different for different species and for different developmental stages[10].

On the other hand, different growth patternsof Asian seabass were observed. Brighter light, at 1,000 and 2,000 lx, showed better growth performance compared to dim light conditions of 0 and 500 lx. Since Asian seabass is a visual feeder, the highest light intensities assist in better feeding activity of larvae. Consequently, the growth performance of Asian seabass improved. Hence, the present study shows that Asian seabass exhibited better growth performance in 2,000 lx but showed poor survival rates.

This result is in agreement with sea bass (*Dicentrarchus labrax*) where better growth performance but poor survival rates at brightest light intensity were observed[14]. In contrast, there are several species that have higher survival and growth rates with increasing light intensity such as Atlantic cod, *Gadus morhua*[9] and Kelp grouper, *Epinephelus bruneus*[15]. Furthermore, there are several species which can survive in dim light conditions such as African catfish[13] and Chinese longsnout catfish[16].

Morphological development is really crucial in order to determine the nutritional status of fish[11]. The morphological development of Asian seabass showed normal development but same as TL. Other morphological development features of Asian seabass in 0 and 500 lx treatments showed slower growth compared to larvae reared in 1,000 and 2,000 lx treatments.

Since Asian seabass are visual feeders, the larvae are unable to recognize and capture the feed in dark conditions. Consequently, Asian seabass in 0 lx treatment suffered starvation. Food shortage often correlates with cannibalism[17]. A lack of food contributes to more cases of cannibalism for the larvae. In this situation, cannibal populations of larvae consumed conspecifics directly. This condition of cannibalism has been referred to as a "life boat mechanism"[18] where a cannibalistic population can survive under conditions of food shortage for the adults to support a non-cannibalistic population under certain condition.

Other than that, cannibalism is caused by dramatic increases in the growth of cannibals, known as growth heterogeneity. Growth heterogeneity is a central problem in aquaculture and especially in predatory species. There are several factors that can lead to growth heterogeneity such as temperature, day length, light intensity, food availability and composition. This was seeninlarvae reared in 0 lx treatment, where only the biggest Asian seabass survived in each replicate.

Nonetheless, a higher cannibalismratewas also recorded in the 2,000 lx treatment. In the brightest condition of 2,000 lx, the Asian seabass had high swimming activity which resulted in stress and frequent contact with each other; consequently, this led to the cannibals attacking the prey. Thus, in brightest light intensity, high incidence of cannibalismwas recorded.

There are two types of cannibalism, which are type I and type II cannibalism. Type I cannibalism can be defined as partial ingestion of prey, mainly at tail-first. This type of cannibalism widely occurs in the larval stage. Ironically, the problem of growth heterogeneity in the larval stage is more dramatic compared with the adult and juvenile stages because larvae have relatively large mouthscompared to the size of their bodies and they are able to cannibalize prey that are slightly smaller. Type II cannibalism can be defined as cannibalism which occursmore often with a head-first ingestion of prey. Type II cannibalism occurs more widely at an older age, where larvae or juveniles shift to becoming complete cannibals. In the present study, type II cannibalism was more frequently observed, where incomplete ingestion occurred. The cannibals expanded their abdomens and ingestedthe head parts of smaller fish intheir mouths.

Based on the present study, appropriate light intensity for Asian seabass, at 500-1,000 lx, is highly recommended fromthe viewpoint of survival, growth performance and cannibalism. Based on the manipulation of light in the present study, 1,000 lx is highly recommended as the optimum light requirement for the aquaculturist who intends to get the highest production of Asian seabass, while 2,000 lx is highly recommended as the optimum light for the aquaculturist who intends to get a high mass of Asian seabass in a short period. Hence, the manipulation of light is a simple, easy and low cost technique to maximize the production of Asian seabass and to establish stable mass-scale and sustainable rearing technology of Asian sea bass.

Conclusion

As conclusion, survival, growth and cannibalism of Asian sea bass were significantly affected ($P<0.05$) by light intensity; a light intensity of 500 – 1,000 lx resulted in better growth and survival rates.

Acknowledgement

This study was supported by RAG0023-STWN-2012 grant.

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