

## Effects of Stocking Density, Hiding Material and Photoperiod Manipulation on Growth and Survival Rate of Marble Goby (*Oxyleotris marmorata* Bleeker, 1852) Juveniles

Kriengkrai Seetapan<sup>1</sup>, Narongsak Puanglarp<sup>2,3</sup>, and Oraporn Meunpol<sup>1\*</sup>

### ABSTRACT

The optimal culture conditions (stocking density, hiding material and photoperiod manipulation) for marble goby were investigated separately. In the first experiment, marble goby juvenile ( $2.42 \pm 0.17$  cm in length) at different stocking densities (50, 250 and 500 fish/m<sup>2</sup>) were released in small cages (0.50x0.50x0.50 m<sup>3</sup>) floating in 50 tons concrete indoor-tank. For the second experiment on effect of hiding material, 250 fish/m<sup>2</sup> marble goby juveniles were reared with or without a piece of car corrugated pipe in the fish cage. Finally, for the experiment on photoperiod manipulation, 250 fish/m<sup>2</sup> marble goby juveniles were reared in plastic tanks (0.40 x 0.50 x 0.30 m<sup>3</sup>), each of which were exposed to different photoperiod arrangements (natural photoperiod or NP, 0D/24L, 6D/18L, 12D/12L, 18D/6L, 24D/0L and 6D/6L/6D/6L). Fish were fed with live feed and all experiments in triplicates were conducted for 60 days. Upon termination, growth performance of fish was evaluated. The highest growth performance and survival rate of fish were achieved with fish reared at 250 fish/m<sup>2</sup> with hiding materials and at 6D/6L/6D/6L photoperiod manipulation.

**Keywords:** *Oxyleotris marmorata*, marble goby, stocking density, hiding material, photoperiod manipulation

### INTRODUCTION

The marble or sand goby (*Oxyleotris marmorata* Bleeker 1852) is a high value fish in Thailand. However, its production does not meet the demand of the market due to its slow growth. One reason for the slow growth may stem from its culture conditions which are not optimized. Although at juvenile stage,

the behavior of marble goby at different size varies depending on culture conditions, these conditions are still unknown. Therefore, our study aimed to explore these conditions in order to increase growth performance of the marble goby.

Generally, carnivorous fish such as marble goby needs lots of space and hiding

<sup>1</sup>Department of Aquaculture, Faculty of Fisheries, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, Bangkok 10900 Thailand

<sup>2</sup>Center of Excellence for Marine Biotechnology, Department of Marine Science, Faculty of Sciences, Chulalongkorn University, Bangkok, Thailand

<sup>3</sup>National Center for Genetic Engineering and Biotechnology (BIOTEC), National Science and Technology Development Agency (NSTDA), Bangkok 10400, Thailand

\*Corresponding author, e-mail address: fforp@ku.ac.th

places to escape from their peers. The influence of stocking density on growth and survival of the commercial fish has been documented by several studies such as Senegalese sole (*Solea senegalensis*) (Salas-Leiton *et al.*, 2011), and snakehead fish (*Channa striatus*) (Rahman *et al.*, 2012). Optimal stocking density varies by age and species.

For carnivorous fish, adding hiding material into the culture system is beneficial in numerous ways such as helping to reduce stress (Verhoef and Austin, 1999), decreasing energy consumption, hastening the start of exogenous feeding (Benhaïm *et al.*, 2009), supporting fish growth (Hossain *et al.*, 1998), and decreasing aggressiveness (Hossain *et al.*, 1998) and cannibalism of juvenile super-predators (Britz and Pienaar, 1992).

Photoperiod is another important physical factor for growth of fish (Boeuf and Le Bail, 1999). For example, African catfish (*Clarias gariepinus*) juveniles cultured under 24D:0L showed highest growth followed by 24L:0D, while those under 12D:12L showed the least growth increase (Mustapha *et al.*, 2012). Research on effect of photoperiod on growth of marble goby has never been conducted. There is one study on a nearly similar species *i.e.* common gobies (*Pomatoschistus microps*) showing delayed ovarian regression when female fish was exposed to a shorter photoperiod (8L/16D), compared to females exposed to longer photoperiod (20L/4D) (Tipping and Miller, 1997).

In this study, the experiments were undertaken with one factor at a time. Juvenile marble goby were reared in triplicate for 60

days. Growth performance and survival rate of fish from each experiment were analyzed. The results would help goby farmers to improve fish culture conditions which will lead to higher yields.

## MATERIALS AND METHODS

### Fish and experimental set-up

The experiments were conducted at Pathumthani Inland Fisheries Research and Development Center, Pathumthani, Thailand, where five thousand marble goby juveniles with mean body weight of  $0.17 \pm 0.05$  g and total length of  $2.42 \pm 0.17$  cm were readily available. Prior to the experiment, fish were transferred into two concrete tanks ( $6 \times 6 \times 6$  m<sup>3</sup>) and were then acclimatized for 1 week. Fish were fed to satiation twice a day at 08:00 am and 05:00 pm with live *Moina*. The tanks were kept at 12 h light and 12 h dark conditions. The water in the tanks was at  $29 \pm 2$  °C, with constant aeration and 50% water exchange every three days.

### Experiments

The optimal culture conditions (stocking density, hiding material and photoperiod manipulation) for marble goby ( $2.38 \pm 0.17$  cm in standard length and  $0.15 \pm 0.04$  g in body weight) were investigated in this research.

The first experiment looked at the effect of stocking density on growth and survival of juvenile marble goby for a period of 60 days. A completely randomized experiment in triplicates was designed to investigate the effects of three stocking densities (50, 250,

and 500 fish/m<sup>2</sup>). Small cages (0.50x0.50x0.50 m<sup>3</sup>) were installed at 20 cm above the concrete tank bottom to allow sufficient flow of water underneath the cage. During the experimental period fish were hand-fed with living *Moina* and *Chironomus* larvae to satiation twice a day at 08:00 am and 05:00 pm, respectively. The experiment was conducted under the natural photoperiod.

The second experiment focused on the effect of hiding material on growth and survival for a period of 60 days. The experiment was conducted under the natural photoperiod and the cages were prepared as mentioned earlier. Treatment tank in triplicates consisted of hiding material while the control had none. The hiding material was made of black plastic corrugated pipe cut in half (70 mm external diameter). The tube had both internal and external grooves, creating a 35.0 cm length hiding material with 12 grooves on both sides (Figure 1). The hiding material had a screw at the beginning and end of the tube for weighing. Student's *t*-test with 95% significance level was designed for this experiment.

The third experiment focused on the effect of photoperiod manipulation on growth and survival rate was conducted also for 60 days. Light was provided by a 58 W fluorescent bulb (Philips TLD 58W-865, Norway) and supplied 300 lux of light at the water surface. Light intensity was measured by using a light meter (lux meter, model ANA-F9, Tokyo Photo Electric Co. Ltd., Tokyo, Japan) before the start of the experiment. The tanks for each treatment were permanently covered from all sides by a black plastic sheet to avoid external light penetration, except the natural photoperiod.

Seven treatments in triplicates, randomly assigned to 21 plastic tanks (0.40 x 0.50 x 0.30 m<sup>3</sup>), were exposed to various photoperiod arrangements as follows: (i) natural photoperiod (NP), (ii) continuous dark, 24 h dark : 0 h light (24D:0L), (iii) short days, 18 h dark : 6 h light (18D:6L), (iv) simulated natural photoperiod, 12 h dark : 12 h light (12D:12L), (v) long days, 6 h dark : 18 h light (6D:18L), (vi) continuous light, 0 h dark : 24 h light (0D:24L), and (vii) two cycles light exposures, 6 h dark : 6 h light; (6D/6L/6D/6L).

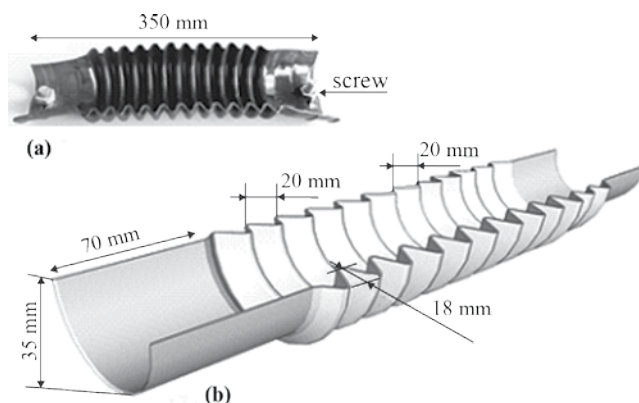


Figure 1. Shelter made of car corrugated pipe, a) overall view of the shelter, and, b) lateral view showing height, the groove width and height of one groove

For all photoperiods with the exception of the continuous light and dark, light source was programmed to switch on at 06:00 am and switch off at appropriate time by a timer to get desired light period.

### Data collection

On a daily basis, dead fish from each cage or tank were gently siphoned before feeding time and fish mortality was recorded. Growth performance was measured bi-weekly. Fish were weighted using an electrical analytical balance calibrated to 0.01 g. Data on specific growth rate (SGR) and survival rate of the fish were calculated as followed:

$$\text{SGR (\% /day)} = 100 (\ln(\text{FW}-\text{IW})) / \text{dt}$$

where

FW = final weight;

IW = initial weight of fish at stocking time;

dt = the duration of the experiment in days

$\ln$  = natural log (g) of fish

Survival rate (%)

$$= (\text{Final fish number} / \text{Initial fish number}) \times 100$$

### Data analysis

The results of the first and third experiments were analyzed by one-way analysis of variance (ANOVA) and the significance of the difference between means was tested using Duncan's Multiple Range Test. Statistical methods were calculated and expressed as mean  $\pm$  S.D. Unless otherwise specified, a significance level of 95% was considered to indicate statistical differences ( $P \leq 0.05$ ). The result of the second experiment was compared using *t*-tests.

## RESULTS

### Effect of stocking density on growth and survival rate

The highest growth performance (length and weight) and survival rate were found in stocking density of 50 fish/m<sup>2</sup> (6.33 $\pm$ 0.29 cm and 2.81 $\pm$ 0.40 g) (Table 1, Figure 2). These results were not significantly different to those at 250 fish/m<sup>2</sup> (5.16 $\pm$ 0.13 cm and 1.74 $\pm$ 0.10 g) ( $P > 0.05$ ). However, both the growth and survival rate of fish stocked

Table 1. Growth performance and survival rates of marble goby juveniles under different stocking densities after 60 days of rearing (mean $\pm$ SD). Different superscripts in the same row indicate significant difference among treatments by Duncans' test ( $P \leq 0.05$ ), SGR means specific growth rate.

Parameters	Stocking density (fish/m <sup>2</sup> )		
	50	250	500
Initial length (cm)	2.61 $\pm$ 0.04 <sup>a</sup>	2.61 $\pm$ 0.06 <sup>a</sup>	2.61 $\pm$ 0.05 <sup>a</sup>
Final length (cm)	6.33 $\pm$ 0.29 <sup>a</sup>	6.00 $\pm$ 0.06 <sup>a</sup>	5.16 $\pm$ 0.13 <sup>b</sup>
Length gain (cm)	3.72 $\pm$ 0.29 <sup>a</sup>	3.30 $\pm$ 0.12 <sup>a</sup>	2.55 $\pm$ 0.15 <sup>b</sup>
Initial weight (g)	0.22 $\pm$ 0.01 <sup>a</sup>	0.22 $\pm$ 0.01 <sup>a</sup>	0.22 $\pm$ 0.01 <sup>a</sup>
Final weight (g)	2.81 $\pm$ 0.40 <sup>a</sup>	2.57 $\pm$ 0.12 <sup>a</sup>	1.74 $\pm$ 0.10 <sup>b</sup>
Weight gain (g)	2.59 $\pm$ 0.40 <sup>a</sup>	2.35 $\pm$ 0.13 <sup>a</sup>	1.51 $\pm$ 0.12 <sup>b</sup>
SGR (%/day)	4.21 $\pm$ 0.30 <sup>a</sup>	4.07 $\pm$ 0.16 <sup>a</sup>	3.42 $\pm$ 0.19 <sup>b</sup>
Survival rate (%)	100.00 $\pm$ 0.00 <sup>a</sup>	92.67 $\pm$ 2.13 <sup>a</sup>	68.00 $\pm$ 5.57 <sup>b</sup>

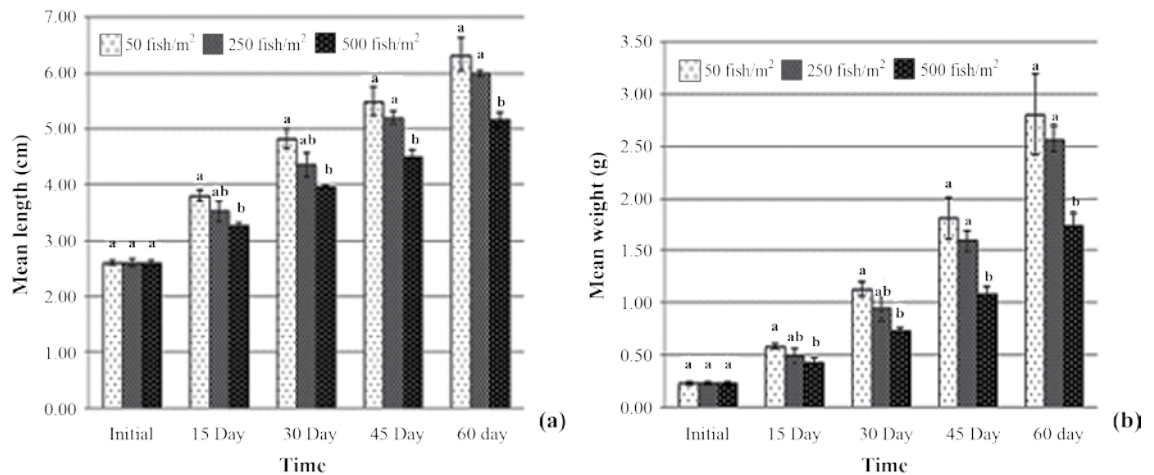


Figure 2. Average length-weight of marble goby juveniles at three stocking densities after 60 days rearing: (a) average lengths (mean  $\pm$  SD), and (b) average weights (mean  $\pm$  SD). Groups with the same letter index on the same day do not differ significantly statistically (Duncans' test;  $P > 0.05$ ).

at 50 and 250 fish/ m<sup>2</sup> was significantly different to fish stocked at 500 fish/ m<sup>2</sup> ( $6.00 \pm 0.06$  cm and  $2.57 \pm 0.12$  g) ( $P \leq 0.05$ ).

### Effect of hiding material on growth and survival rate

There was no significant difference in initial average body length and weight among the fish with or without hiding material. Until day 60, the average length and weight of fish were found to be higher in fish provided with hiding material than that without hiding material ( $P \leq 0.05$ ) (Figure 3). The fish lived with hiding material showed the higher length gain ( $2.92 \pm 0.08$  cm), weight gain ( $1.86 \pm 0.09$  g) ( $P \leq 0.05$ ) and survival rate ( $P > 0.05$ ) than fish lived without hiding

material (Table 2).

### Effect of photoperiod manipulation on growth and survival rate

Culturing marble goby juveniles under 6D/6L photoperiod ( $4.18 \pm 0.04$  cm and  $0.86 \pm 0.03$  g) gave highest growth (length and weight) and survival rate, followed by 18D/6L ( $0.82 \pm 0.13$  cm and  $4.10 \pm 0.14$  g), 12D/2L ( $4.01 \pm 0.03$  cm and  $0.74 \pm 0.05$  g) and 6D/18L ( $3.94 \pm 0.08$  cm and  $0.73 \pm 0.04$  g), whereas fish in control group (NP) ( $3.57 \pm 0.10$  cm and  $0.60 \pm 0.05$  g) possessed lowest growth (Table 3, Figure 4). However, growth of fish from 6D/6L/6D/6L treatment was not significantly different from 18D/6L, 12D/12L photoperiod arrangement ( $P > 0.05$ ).

Table 2. Growth performance and survival rates of fish provided with or without hiding material after 60 days of rearing (mean±SD). Different superscripts on the same row indicate significant difference among treatments by *t*-test ( $P \leq 0.05$ ). SGR means specific growth rate.

Parameters	Treatments	
	without hiding material	with hiding material
Initial length (cm)	2.48±0.07 <sup>a</sup>	2.53±0.07 <sup>a</sup>
Final length (cm)	5.19±0.09 <sup>b</sup>	5.45±0.13 <sup>a</sup>
Length gain (cm)	2.71±0.02 <sup>b</sup>	2.92±0.08 <sup>a</sup>
Initial weight (g)	0.17±0.01 <sup>a</sup>	0.17±0.02 <sup>a</sup>
Final weight (g)	1.76±0.07 <sup>b</sup>	2.04±0.10 <sup>a</sup>
Weight gain (g)	1.59±0.07 <sup>b</sup>	1.86±0.09 <sup>a</sup>
SGR (%/day)	3.88±0.15 <sup>b</sup>	4.10±0.14 <sup>a</sup>
Survival rate (%)	90.00±3.46 <sup>a</sup>	95.33±2.31 <sup>a</sup>

Table 3. Growth performance and survival rates of marble goby juveniles under different photoperiod manipulation after 60 days of rearing (mean±SD). Different superscripts on the same row indicate significant difference among treatments by Duncans' test ( $P \leq 0.05$ ). SGR means specific growth rate.

Parameters	Treatments						
	NP	24D/0L	18D/6L	12D/12L	6D/18L	0D/24L	6D/6L/6D/6L
Initial length (cm)	2.22±0.04	2.26±0.05	2.24±0.06	2.28±0.01	2.23±0.03	2.22±0.06	2.23±0.02
Final length (cm)	3.57±0.10 <sup>c</sup>	3.63±0.14 <sup>c</sup>	4.10±0.14 <sup>ab</sup>	4.01±0.03 <sup>ab</sup>	3.94±0.08 <sup>b</sup>	3.62±0.05 <sup>c</sup>	4.18±0.04 <sup>a</sup>
Length gain (cm)	1.35±0.10 <sup>c</sup>	1.37±0.09 <sup>c</sup>	1.86±0.08 <sup>ab</sup>	1.73±0.04 <sup>ab</sup>	1.71±0.05 <sup>b</sup>	1.40±0.11 <sup>c</sup>	1.95±0.04 <sup>a</sup>
Initial weight (g)	0.12±0.00	0.12±0.01	0.12±0.01	0.12±0.01	0.12±0.00	0.12±0.02	0.12±0.02
Final weight (g)	0.60±0.05 <sup>c</sup>	0.63±0.06 <sup>c</sup>	0.82±0.13 <sup>ab</sup>	0.74±0.05 <sup>b</sup>	0.73±0.04 <sup>b</sup>	0.61±0.02 <sup>c</sup>	0.86±0.03 <sup>a</sup>
Weight gain (g)	0.48±0.05 <sup>c</sup>	0.51±0.06 <sup>c</sup>	0.70±0.12 <sup>ab</sup>	0.62±0.05 <sup>b</sup>	0.61±0.04 <sup>b</sup>	0.49±0.03 <sup>c</sup>	0.74±0.03 <sup>a</sup>
SGR (%/day)	2.68±0.11 <sup>b</sup>	2.78±0.16 <sup>b</sup>	3.19±0.19 <sup>a</sup>	3.04±0.03 <sup>ab</sup>	3.03±0.09 <sup>ab</sup>	2.73±0.23 <sup>b</sup>	3.32±0.21 <sup>a</sup>
Survival rate (%)	59.17±8.04 <sup>b</sup>	80.83±5.20 <sup>a</sup>	79.17±7.64 <sup>a</sup>	73.33±3.82 <sup>a</sup>	77.50±2.50 <sup>a</sup>	79.17±7.64 <sup>a</sup>	80.00±7.50 <sup>a</sup>

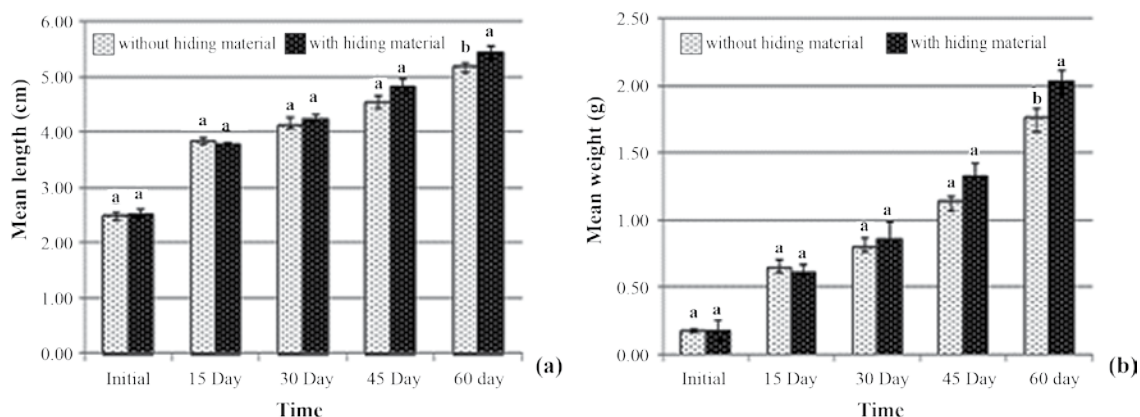


Figure 3. Average length-weight of marble goby juveniles provided with or without hiding material after 60 days rearing: (a) average lengths (mean  $\pm$  SD) and (b) average weights (mean  $\pm$  SD). Groups with the same letter index on the same day do not differ significantly statistically ( $t$ -tests;  $P > 0.05$ ).

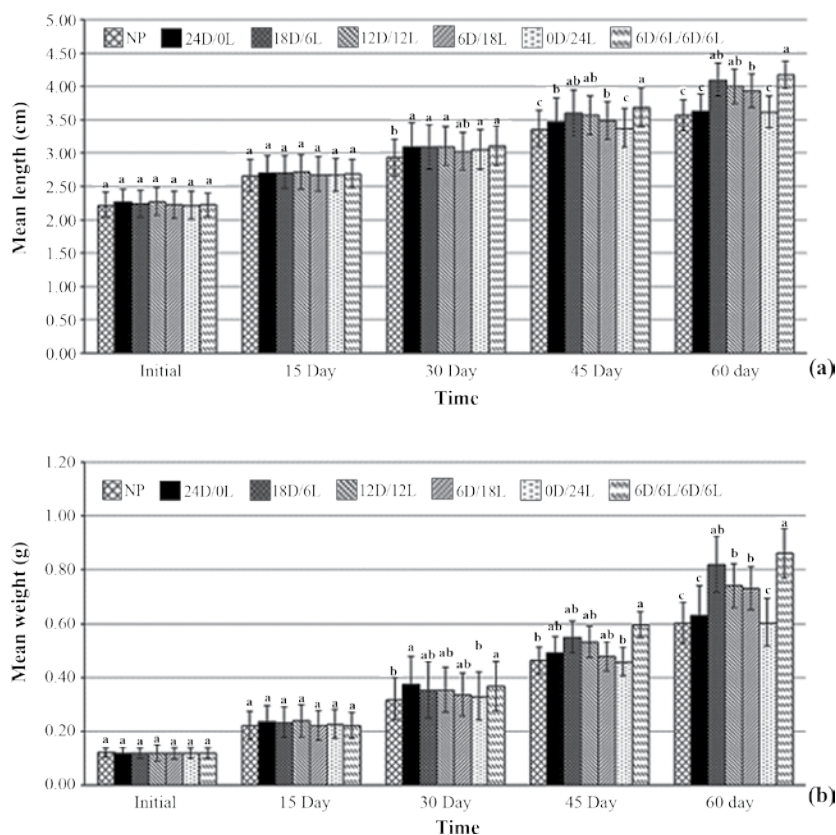


Figure 4. Average length-weight of marble goby juveniles at different photoperiod manipulation after 60 days rearing: (a) average lengths (mean  $\pm$  SD) and (b) average weights (mean  $\pm$  SD). Groups with the same letter index on the same day do not differ significantly statistically (Duncans' test;  $P > 0.05$ ).

## DISCUSSION

From this study, the results showed that stocking density, hiding material and photoperiod manipulation influence growth performance and survival rate of marble goby juveniles. The best stocking density for marble goby juveniles should be 250 fish/m<sup>2</sup> coupled with hiding material. Moreover, the best photoperiod manipulation for marble goby juveniles should be rearing with 6D/6L/6D/6L photoperiod.

### Effect of stocking density on growth and survival rate

The stocking density on aquaculture is an important factor in establishing successful culture. This study revealed that stocking density significantly affected growth performance and survival rate of marble goby juvenile. Marble goby juveniles reared at 50 fish/m<sup>2</sup> and 250 fish/m<sup>2</sup> displayed higher growth performance and survival rate than the one reared at 500 fish/m<sup>2</sup> ( $P \leq 0.05$ ).

These findings were in agreement with numerous studies in others fish species such as snakehead fish (*Channa striatus*) (Rahman *et al.*, 2012) and mahseer (*Tor putitora*) (Islam, 2002) that growth rate varied conversely with stocking density due to increase chance of cannibalism.

In contrary, some fish, for example, African catfish (*Clarias gariepinus*) (Toko *et al.*, 2007) and European sea bass (*Dicentrarchus labrax*) (Lupatsch *et al.*, 2010), culture at higher stocking density leads to better growth than culture at lower stocking density. Evidently, growth response to stocking density varies with fish species

(Kikuchi *et al.*, 2006), ages and life stages (Huang and Chiu, 1997).

Overcrowding can result in increasing aggression, competition for food, elevating stress response, higher disease incidence, and ultimately leads to decrease growth and survival (DiMaggio *et al.*, 2014).

### Effect of hiding material on growth and survival

Fish reared with hiding material showed better growth performance than those without. Fish reared without any hiding material displayed greater energy loss associated with much agitated mobility (Millidine *et al.*, 2006; Benhaïm *et al.*, 2009). The reason may be because hiding materials reduce energy wastes from stress (Benhaïm *et al.*, 2009). These results are consistent with studies on African catfish (*Clarias gariepinus*) (Hossain *et al.*, 1998) that hiding material is an important means of increasing growth and survival.

### Effect of photoperiod manipulation on growth and survival

Photoperiod manipulation clearly influenced the growth performance and survival of marble goby juveniles. Short periods of light (6D/6L/6D/6L and 18D/6L) resulted in an increased growth when compared to extended periods of light (0D/24L, 6D/18L and 12D/12L). This might be due to higher hourly ingestion rate of marble goby during nighttime than daytime (Hoa and Yi, 2007). Fish that prefer short period of light similar to marble goby are African catfish (*Clarias gariepinus*) (Almazán-Rueda *et al.*, 2005) and beluga sturgeon

(*Huso huso*) (Ghomi *et al.*, 2010). However, marble goby grow better in light condition whereas African catfish has highest growth when reared in total darkness (24D/0L) (Adewolu *et al.*, 2008). African catfish can grow better in total darkness because their free neuromasts are better developed than that of marble goby juvenile. Interestingly optimal photoperiod for marble goby is 6D/6L/6D/6L which is two cycle of light. When normally in one day is only one cycle of light. Controlled photoperiod is better than Normal Photoperiod in term of enhancing growth performance of fish because both light intensity and time exposed to that light intensity are determinable.

## CONCLUSION

In conclusion, these results indicated that the optimal culture conditions for rearing marble goby juvenile affected their survival and growth performance. According to this study's results, the stocking density of 250 fish/m<sup>2</sup> is recommended to rear juvenile fish for commercial enrichments. The provision of shelter is assumed to be a necessary requirement for intensive rearing of marble goby juveniles. The best photoperiod manipulation for marble goby juveniles should be rearing with 6D/6L/6D/6L photoperiod. These results have a potential for application as a tool to improve marble goby juvenile production and finally benefit aquaculture as a whole.

## ACKNOWLEDGEMENT

The authors would like to express their gratitude to the National Research

Council of Thailand (NRCT); Department of Aquaculture, Faculty of Fisheries, Kasetsart University; Pathumthani Inland Fisheries Research and Development Center, Thailand; and Center of Excellence for Marine Biotechnology, National Center for Genetic Engineering and Biotechnology (BIOTEC), National Science and Technology Development Agency (NSTDA), Thailand, for funding of this study.

## LITERATURE CITED

- Adewolu, M. A., C. A. Adeniji, and A. B. Adejobi. 2008. Feed utilization, growth and survival of *Clarias gariepinus* (Burchell 1822) fingerlings cultured under different photoperiods. **Aquaculture** 283: 64-67.
- Almazán-Rueda, P., A. T. M. van Helmond, J. A. J. Verreth, and J. W. Schrama. 2005. Photoperiod affects growth, behaviour and stress variables in *Clarias gariepinus*. **Journal of Fish Biology** 67: 1029-1039.
- Benhaïm, D., C.A. Leblanc and G. Lucas. 2009. Impact of a new artificial shelter on Arctic charr (*Salvelinus alpinus*, L.) behaviour and culture performance during the endogenous feeding period. **Aquaculture** 295: 38-43.
- Boeuf, G. and Le Bail, P.-Y. 1999. Does light have an influence on fish growth? **Aquaculture** 177: 129-152.
- Britz, P.J. and A.G. Pienaar. 1992. Laboratory experiments on the effect of light and cover on the behaviour and growth of African catfish *Clarias gariepinus* (Pisces: Clariidae). **Journal of Zoology** 227: 43-62.

- DiMaggio, M.A., C.L. Ohs and J.S. Broach. 2014. Effects of stocking density on growth, survival, and stress physiology of pigfish. **North American Journal of Aquaculture** 76: 201–210.
- Ghomi, M. R., R. M. Nazari, M. Sohrabnejad, M. Ovissipour, M. Zarei, A. Esmaili Mola, C. Makhdoomi, A. Rahimian, H. Noori and A. Naghavi. 2010. Manipulation of photoperiod in growth factors of beluga sturgeon *Huso huso*. **African Journal of Biotechnology** 9(13): 1978-1981.
- Hoa, N. P. and Y. Yi. 2007 Prey ingestion and live food selectivity of marble goby (*Oxyeleotris marmorata*) using rice field prawn (*Macrobrachium lanchesteri*) as prey. **Aquaculture** 273: 443-448.
- Hossain, M.A.R., M.C.M. Beveridge and G.S. Haylor. 1998. The effects of density, light and shelter on the growth and survival of African catfish (*Clarias gariepinus* Burchell, 1822) fingerlings. **Aquaculture** 160: 251-258.
- Huang, W.B. and T.S. Chiu. 1997. Effects of stocking density on survival, growth, size variation, and production of Tilapia fry. **Aquaculture Research** 28:165-173.
- Islam, M.S. 2002. Evaluation of supplementary feeds for semi-intensive pond culture of mahseer, *Tor putitora* (Hamilton). **Aquaculture** 212: 263-276.
- Kikuchi, K., N. Iwata, T. Kawabata and T. Yanagawa. 2006. Effect of feeding frequency, water temperature, and stocking density on the growth of tiger puffer, *Takifugu rubripes*. **Journal of the World Aquaculture Society** 37(1): 12-20.
- Lupatsch, I., G.A. Santos, J.W. Schrama and J.A.J. Verreth. 2010. Effect of stocking density and feeding level on energy expenditure and stress responsiveness in European sea bass *Dicentrarchus labrax*. **Aquaculture** 298: 245-250.
- Millidine, K.J., J.D. Armstrong, and N.B. Metcalfe. 2006. Presence of shelter reduces maintenance metabolism of juvenile salmon. **Functional Ecology** 20: 839-845.
- Mustapha, M. K., B.U. Okafor, K. S. Olaoti and O. K. Oyelakin. 2012. Effects of three different photoperiods on the growth and body coloration of juvenile African catfish, *Clarias gariepinus* (Burchell). **Archives of Polish Fisheries** 20: 55-59
- Rahman, M.A., A. Arshad and S.M.N. Amin. 2012. Growth and production performance of threatened snakehead fish, *Channa striatus* (Bloch), at different stocking densities in earthen ponds. **Aquaculture Research** 43: 297-302.
- Salas-Leiton, E., V. Anguís, A. Rodríguez-Rua and J.P. Cañavate. 2011. High stocking density and food restriction have minimum impact on size dispersal of cultured Senegalese sole (*Solea senegalensis*, Kaup 1858) juveniles. Evidence for individual growth being regulated by population structure. **Aquacultural Engineering** 45: 43-50.
- Tipping, D.R. and P.J. Miller. 1997. Exposure of vitellogenic female common gobies, *Pomatoschistus microps*, to short photoperiod delays ovarian regression. Short communication. **Aquarium Sciences and Conservation** 1(1): 71-74.

- Toko, I., E.D. Fiogbe, B. Koukpode and P. Kestemont. 2007. Rearing of African catfish (*Clarias gariepinus*) and vundu catfish (*Heterobranchus longifilis*) in traditional fish ponds (whedos): Effect of stocking density on growth, production and body composition. **Aquaculture** 262: 65-72.
- Verhoef, G.D. and C.M. Austin. 1999. Combined effects of shelter and density on the growth and survival of juveniles of the Australian freshwater crayfish, *Cherax destructor* Clark, Part 2. **Aquaculture** 170: 49-57.