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The performance of gold-mouth turban *Turbo chrysostomus* larvae in different temperature and salinity media

Kinerja larva siput mata bulan *Turbo chrysostomus* pada suhu dan salinitas media yang berbeda

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ABSTRACT

This study aimed to evaluate the effect of temperature and salinity on the development, growth, and survival rate of gold-mouth turban *T. chrysostomus* larvae. The temperature was adjusted by heater and salinity was by the freshwater dilution. The temperature treatments were A1 (27 ± 0.5°C) and A2 (30 ± 0.5°C), while the salinity treatments were B1 (29 ± 0.5 g/L), B2 (32 ± 0.5 g/L), and B3 (35 ± 0.5 g/L). These treatments were repeated three times. The results showed that the pre-torsion veliger stage was formed at about 11 hours 36 minutes after fertilization or at about 3 hours after the trocophor stage. The A1B3 treatment obtained the fastest early post-torsion veliger and late post-torsion veliger stage period after fertilization. Temperature had no significant effect, while salinity had a significant effect in the specific growth rate of gold-mouth turban larvae. The highest specific growth rate at 27 ± 0.5°C (A1) was obtained in the B3 treatment and insignificantly different from the B2 treatment. Temperature and salinity had a significant effect, but the interaction between these factors had no significant effect in the survival rate of gold-mouth turban larvae. The A1B3 treatment obtained the highest percentage of survival rate and was significantly different from the A1B2 treatment. The optimum temperature and salinity ranges for maintaining the gold-mouth turban larvae are 26.5–27.5°C and 31.5–35.5 g/L, respectively. The water quality parameters obtained could still support the larvae development until the juvenile stage.

Keywords: temperature, salinity, larvae, gold-mouth turban

ABSTRAK

Tujuan penelitian ini yaitu mengevaluasi pengaruh suhu dan salinitas terhadap perkembangan, pertumbuhan, dan kelangsungan hidup larva siput mata bulan *T. chrysostomus*. Suhu diatur menggunakan heater dan salinitas dengan melakukan pengenceran air tawar. Perlakuan suhu yaitu A1 (27 ± 0.5°C) dan A2 (30 ± 0.5°C), sementara salinitas yaitu B1 (29 ± 0.5 g/L), B2 (32 ± 0.5 g/L) dan B3 (35 ± 0.5 g/L) diulang sebanyak 3 kali. Hasil pengamatan menunjukan bahwa stadia veliger pra-torsi dicapai sekitar 11 jam 36 menit setelah fertilisasi atau sekitar 3 jam setelah trocophor. Perlakuan A1B3 memberikan waktu pencapaian stadia veliger pasca-torsi awal dan veliger pasca-torsi akhir tercepat setelah pembuahan. Suhu tidak berpengaruh nyata sedangkan salinitas berpengaruh nyata terhadap laju pertumbuhan harian larva siput mata bulan. Laju pertumbuhan harian tertinggi pada suhu perlakuan A1 didapatkan pada perlakuan B3 dan menunjukan nilai tidak berbeda nyata dengan perlakuan B2. Suhu dan salinitas memberikan pengaruh signifikan, tetapi interaksi keduanya tidak menunjukan pengaruh yang signifikan terhadap tingkat kelangsungan hidup larva siput mata bulan. Perlakuan A1B3 memberikan persentase tingkat kelangsungan hidup tertinggi dan tidak menunjukan nilai yang berbeda nyata dengan perlakuan A1B2. Kisaran suhu dan salinitas optimum bagi pemeliharaan larva siput mata bulan yaitu suhu 26.5–27.5°C dan salinitas 31.5–35.5 g/L. Parameter kualitas air yang diperoleh masih mendukung perkembangan larva siput mata bulan hingga mencapai stadia juvenil.

Kata kunci: suhu, salinitas, larva, siput mata bulan

INTRODUCTION

The gold-mouth turban *Turbo chrysostomus* is a quite potential invertebral spesies due to easier maintenance and having a good survival ability against the environmental changes (Setyono *et al*., 2013). Gold-mouth turban can be found in the Indo-Pacific, South-East Asia, Fiji Islands coastal regions. This snail species can also be found in the Ryukyu Islands, Japan coastal region and Northern Melanesia to Southern New Caledonia water areas (Soekendarsi, 2018). Gold-mouth turban often becomes the local community target, due to the savory taste and high nutrient contents. The gold-mouth turban also becomes a popular aquarium organism. Based on this condition, gold-mouth turban (*T. chrysostomus*) has been rarely found in the Indonesian water areas (Ubaidillah *et al*., 2013). Ruf (2007) also added that the fairly high price of the carved shells around IDR 258,000 (US $ 18) per kg is thought to likely occur due to the drastic decline of these organisms in Sabah water area. Moreover, the coral reef damage and environmental change are also thought to be the main factors of the declined population in nature (Seinor *et al*., 2020).

Culture can become a solution to overcome these problems. However, the current gold-mouth turban (*T. chrysostomus*) culture in Indonesia has not been commercially performed due to less information about the culture process, specifically in the breeding stage. The larval phase often occurs a high mortality, either in the early development (veliger) to the larval final development. The larvae phase is a transitional period, as mishandling and water condition changes can lead to a mortality that directly impacts the seed quantity and quality produced. Temperature and salinity are the water quality parameters that play the important roles in supporting the gold-mouth turban breeding activity. The optimum temperature can induce the larval appetite, which implicates in the larval performance. Meanwhile, the extreme temperature can interfere with the physiological response of larvae and cause a high mortality (Huo *et al*., 2017). In the juvenile phase, gold-mouth turban is also influenced by temperature, which tended to grow faster at 26 ± 0.5°C and were thought to be associated with the high daily feed intake (Hamzah, 2015).

The salinity change can cause the increased energy demand, especially in balancing the osmotic pressure between body and environment, which impacts on the energy sharing. The higher total energy used to balnce the osmotic pressure, the less reserved energy utilized for growth, movement, and other biological requirements (Amin *et al*., 2016). The giant abalone *Haliotis gigantean* can adapt to low salinity in a long period and produce higher survival rate than the disc abalone (*H. discus discus*) (Manuel *et al*., 2019). Morash and Alter (2015) stated that larvae are more easily exposed to diseases due to temperature and salinity fluctuations. Both parameters can influence the body immune system. The optimum temperature and sainity interactions in the pearl oyster larvae obtained the highest survival and growth rates by improving the protease enzyme activity and a higher $CaCO_3$ content than the other treatments (Hamzah *et al*., 2016b). Lah *et al*. (2016) stated that the biotic factors and environmental conditions, namely, temperature and salinity can also influence the marine organism fatty acid composition.

The gold-mouth turban breeding often fails due to the water quality change. Temperature and salinity can cause egg and larvae abnormalities, inhibited larvae development, and mortality. High mortality occurs whenever during the metamorphosis stage; therefore, the fluctuative temperature and salinity in the maintenance media extremely influence the gold-mouth turban production (Kimani, 1996; Setyono *et al*., 2013). This study aimed to evaluate the effect of temperature and salinity on the development, growth, and survival rate of gold-mouth turban *T. chrysostomus* larvae.

MATERIALS AND METHOD

Experimental design

This study contained two temperature levels and three salinity levels. The temperature treatments were A1 (27 ± 0.5°C) and A2 (30 ± 0.5°C), while the salinity treatments were B1 (29 ± 0.5 g/L), B2 (32 ± 0.5 g/L), and B3 (35 ± 0.5 g/L), which were repeated three times. The maintenance tank contained 18 units of containers which were randomly distributed. The container tanks used were made of white colored plastic at 73×52×42 cm (P × L× T) volume.

Procedures

Tank preparation

The preparatory step began by sanding the maintenance container and plate (larval attachment medium) until quitely coarse. This aimed to facilitate the *Navicula* sp. attachment as

a live feed. The plate used was white colored fiber media at 25×20 cm (P×L) size. After sanding, the maintenance container and plate were cleaned until sterilized and dried. Three plate units were hung in each maintenance container, and the container was filled with the sterilized marinewater.

The live feed was proliferated at about 2 weeks before larval stocking by growing *Navicula* sp. in the larval attachment media. The live feed grown in the attachment media were cultured by administering 1 mL/L of KW21 liquid fertilizer type equipped with a 15 W lamp to stimulate these diatom growth. KW21 fertilizer is a commercial fertilizer containing 49 g/L nitrogen (N), 4 g/L phosphoric acid (P), boron, manganese, iron, zinc, cobalt, EDTA, amino acid complex, and vitamins (Mukhlis *et al*., 2017). For maintaining the live feed availability in the experimental media, the live feed was provided at 20 000 cells after water exchange.

The spawning technique was modified from the methods developed by Setyono *et al*. (2013), whereas the shell-cleaned snails were distributed into a 20 L plastic container equipped with strong aeration for 30 minutes. Snails were induced with desiccation method by remaining the broodstock without water for 15 minutes as a low-tide artificial method. Broodstocks containing 16 females and 22 males were distributed into the maintenance tank equipped with small aeration and remained unfed. Spawning occurred at about 19.30 (GMT+8) as male broodstock initially released clear colored spermatozoa, followed by female broodstock, which released green colored eggs. After broodstock spawning, eggs were filtered and reared to reach pre-torsion veliger stadia. After reaching the pre-torsion veliger stadia, larvae were reared in the maintenance container at 10 000 larvae/60 L water stocking density.

Water and treatment preparations

Marinewater was sterilized from the water tower and flown to the maintenance container through the UV equipped with a filter bag at the end of the hose. By performing this treatment, the water media used for the experimental animal maintenance was clean and away from dirts and particles that can interfere the larvae life.

The maintenance containers were maintained in the temperature and salinity treatments for 20 days. The maintenance containers maintained at 27 ± 0.5°C and 30 ± 0.5°C treatments were set using a heater by regulating it based on the treatments provided. The marinewater obtained had 35 g/L salinity; therefore, to maintain the salinity at 32 ± 0.5 g/L and 29 ± 0.5 g/L treatments, dilution was performed by adding the freshwater. The dilution procedure was referred to Winanto *et al*. (2009):

$$S = \frac{(S1 \times V1) + (S2 \times V2)}{V1 + V2}$$

Note:
S = maintained salinity (g/L)
S1 = marinewater salinity (g/L)
S2 = freshwater salinity (g/L)
V1 = marinewater volume (L)
V2 = freshwater volume (L)

The water quality parameters in the experimental media, mainly temperature and salinity, were monitored gradually twice a day. Moreover, to maintain the experimental water quality media, water exchange was totally performed (100%) three times a day.

Parameters

Stadia development

The larvae stadia development was presented descriptively by showing the shell length and stadium achievement period. The gold-mouth turban snail larvae length measurement was modified from Noble *et al*. (2015) (Figure 1).

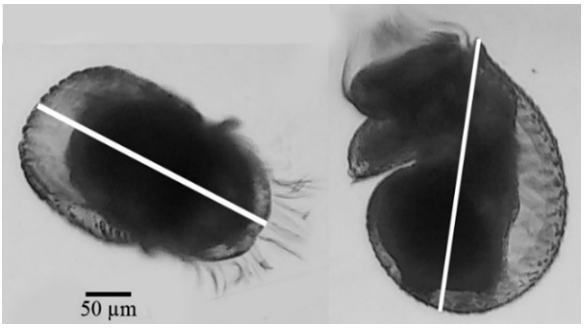

Figure 1. Gold-mouth turban shell length measurement

The stadium achievement period can be defined as the requirement period for larvae to reach one developmental stadium. The larvae achievement period analysis referred to McCormick *et al*. (2016) method through identification, total larvae calculation in each stadium, and larvae required period calculation to reach the stadium.

Larval attachment capability (LA)

The larval attachment capability was calculated in 2 days (48 hours) and 3 days (72 hours) after fertilization. The larval attachment capability was calculated with the formula of Yu *et al*. (2020), namely:

$$AC = \frac{N_p}{N_t} \times 100$$

Note:
AC = larval attachment capability (%)
NP = total attached larvae on the plate (individual)
Nt = total larvae on the plate and water column (individual)

Specific growth rate

The specific growth rate of gold-mouth turban larvae was calculated using the formula of Noble *et al*. (2015), namely:

$$SGR = \frac{(Ln\ L1 - Ln\ L0)}{T} \times 100$$

Note:
SGR = specific growth rate (%/day)
L1 = shell length at the final observation (μm)
L0 = shell length at the initial observation (μm)
T = observational period (day)
Ln = natural logarithm

Survival rate

The survival rate of gold-mouth turban larvae was calculated by using the formula of Hamzah *et al*. (2016a), namely:

$$SR = \frac{N_t}{N_0} \times 100$$

Note:
SR = survival rate (%)
Nt = total final juvenile (individual)
No = total initial juvenile (individual)

Water quality

The water quality parameters, namely, salinity, temperature, pH, and DO were measured before and after the water exchange, while phosphate, nitrate, and nitrite contents were performed in the initial and final maintenance period.

Table 1. Gold-mouth turban larvae shell length in various stadia (mean ± SD)

Stadia	Shell length (μm)					
	A1B1	A1B2	A1B3	A2B1	A2B2	A2B3
V1	250.20 ± 28.52	250.24 ± 28.52	250.24 ± 28.52	250.24 ± 28.52	250.24 ± 28.52	250.24 ± 28.52
V2	257.57 ± 27.14	266.50 ± 28.93	269.11 ± 34.81	256.52 ± 30.21	266.39 ± 36.57	267.31 ± 33.90
V3	263.39 ± 29.18	280.04 ± 28.74	280.87 ± 33.16	261.96 ± 26.46	278.27 ± 27.33	278.89 ± 29.65

Note: A1B1 = 27 ± 0.5°C and 29 ± 0.5 g/L, A1B2 = 27 ± 0.5°C and 32 ± 0.5 g/L, A1B3 = 27 ± 0.5°C and 35 ± 0.5 g/L, A2B1 = 30 ± 0.5°C and 29 ± 0.5 g/L, A2B2 = 30 ± 0.5°C and 32 ± 0.5 g/L, A2B3 = 30 ± 0.5°C and 35 ± 0.5 g/L, pre-torsion veliger stage (V1), early post-torsion veliger stage (V2), and late post-torsion veliger stage (V3).

Table 2. Gold-mouth larvae stadia development

Development	Period (hour.minute)					
	A1B1	A1B2	A1B3	A2B1	A2B2	A2B3
Pre-torsion veliger	11.36	11.36	11.36	11.36	11.36	11.36
Visible cilia	11.36	11.36	11.36	11.36	11.36	11.36
Covering shell	14.46	14.35	14.23	14.40	14.36	14.30
Developed Feet clumps	14.46	14.35	14.23	14.40	14.36	14.30
Visible retractor muscle	14.46	14.35	14.23	14.40	14.36	14.30
Eye-spot	16.46	16.36	16.23	16.40	16.36	16.30
Early post-torsion veliger	20.30	19.49	19.36	20.28	19.50	19.40
Perfectly-formed shell	20.30	19.49	19.36	20.28	19.50	19.40
Late post-torsion veliger	23.25	22.48	22.36	23.20	22.54	22.50
Operculum	26.56	26.19	26.07	26.51	26.25	26.21
Formed feet	28.25	27.48	27.36	28.20	27.54	27.50
Visible propodium	36.55	36.18	36.06	36.50	36.24	36.20

Note: A1B1 = 27 ± 0.5°C and 29 ± 0.5 g/L, A1B2 = 27 ± 0.5°C and 32 ± 0.5 g/L, A1B3 = 27 ± 0.5°C and 35 ± 0.5 g/L, A2B1 = 30 ± 0.5°C and 29 ± 0.5 g/L, A2B2 = 30 ± 0.5°C and 32 ± 0.5 g/L, A2B3 = 30 ± 0.5°C and 35 ± 0.5 g/L.

Data analysis

The growth, larval attachment capability, and survival rate data were analyzed with an analysis of variance (ANOVA), while the stadia development and water quality data were analyzed descriptively. The data analysis was assisted by IBM SPSS Statistics 23.0 software program.

RESULTS AND DISCUSSION

Results

Larval development

The observational results of shell length and stadium achievement period in the gold-mouth turban are presented in Table 1 and Table 2, respectively.

Larval attachment capability and survival rate

The ANOVA results showed that temperature and salinity significantly (P<0.05) influenced the attachment capability and survival rate of gold-mouth turban larvae, therefore the data analysis were continued with the Duncan's test (Table 3).

Specific growth rate

The analysis of variance results showed that temperature insignificantly (P>0.05) influenced the specific growth rate of gold-mouth turban larvae, while the salinity treatments showed a significant influence in the specific growth rate of gold-mouth turban larvae, therefore the data analysis was continued with Duncan's test (Figure 2).

Water quality

The water quality conditions obtained during the study containing pH, DO, phosphate, nitrate, and nitrite are presented in Table 4.

Table 4. Water quality parameters during the gold-mouth turban maintenance period at different temperatures and salinities

Parameter	Result
pH	7.70–8.20
DO (mg/L)	4.10–4.90
Fosphate (mg/L)	0.13–0.50
Nitrate (mg/L)	0.081–0.635
Nitrite (mg/L)	0.001–0.035

Table 3. The attachment capability (AC) and survival rate (SR) of gold-mouth turban larvae (mean ± SB).

Parameter	Treatment					
	A1B1	A1B2	A1B3	A2B1	A2B2	A2B3
AC 48 (%)	34.36 ± 4.52^{b}	43.96 ± 1.92^{c}	46.51 ± 2.64^{c}	22.37 ± 0.93^{a}	36.90 ± 4.80^{b}	37.66 ± 0.98^{b}
AC 72 (%)	64.61 ± 2.06^{b}	75.33 ± 1.99^{d}	79.11 ± 0.54^{d}	54.13 ± 1.45^{a}	69.79 ± 1.70^{c}	72.46 ± 2.30^{c}
SR (%)	4.42 ± 0.41^{b}	5.38 ± 0.13^{c}	5.39 ± 0.20^{c}	3.38 ± 0.42^{a}	4.70 ± 0.21^{b}	4.82 ± 0.13^{b}

Note: A1B1 = 27 ± 0.5°C and 29 ± 0.5 g/L, A1B2 = 27 ± 0.5°C and 32 ± 0.5 g/L, A1B3 = 27 ± 0.5°C and 35 ± 0.5 g/L, A2B1 = 30 ± 0.5°C and 29 ± 0.5 g/L, A2B2 = 30 ± 0.5°C and 32 ± 0.5 g/L, A2B3 = 30 ± 0.5°C and 35 ± 0.5 g/L, AC 48 = attachment capability in 48 hours, AC 72 = attachment capability in 72 hours, SR = survival rate.

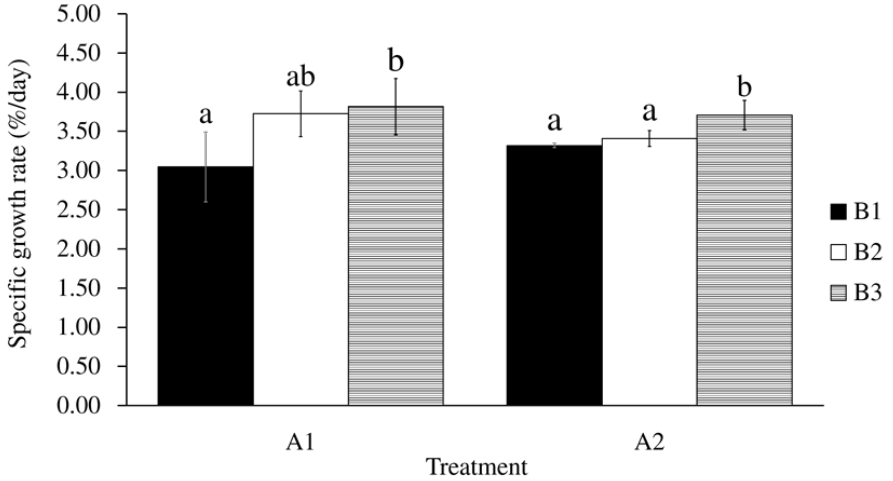

Figure 2. The specific growth rate (SGR) of gold-mouth turban larvae (Note: Different notations showed a significant difference value (P<0.05)). A1 = 27 ± 0.5°C, A2 = 30 ± 0.5°C, B1 = 29 ± 0.5 g/L, B2 = 32 ± 0.5 g/L, B3 = 35 ± 0.5 g/L.

Discussion

The larvae development of gold-mouth turban was started from the pre-torsion veliger stadia, which achieved at about 11 hours 36 minutes after fertilization or 3 hours after trocophore stage. The results obtained were not quitely different from Setyono *et al*. (2013) as the early veliger stadia were achieved at about 11 hours 45 minutes after fertilization or 3 hours after the trocophore stage. In the pre-torsion veliger stadia, the shell covered all the soft organs, and the feet were initially developed with visible retractor muscles. The retractor muscles are functioned to move and pull the feet. Moreover, in these stadia, eye-spots were appeared as likely as small black spots. In the pearl oyster *Pinctada maxima*, these black spots indicate that the larvae will soon reach the pediveliger stage and be ready to attach (Hamzah *et al*., 2016a). The pre-torsion veliger larvae formed a shell at 250.24 ± 28.52 µm length and was visibly active to swim using cilia. The shell length of the gold-mouth turban larvae in the pre-torsion veliger stage was smaller than the *Turbo cornotus* (270 ± 6 µm) and *T. stenogyrus* (328 ± 7 µm) (Kono & Yamakawa, 2002), but larger than the *T. argyrostomus*, namely, 170–180 µm (Kimani, 1996).

In the early post-torsion veliger stadia, larvae formed a perfect shell shape. Yang *et al*. (2020) explained that during the torsion stage, the shell anterior and posterior parts will be reversed with the shell posterior end becomes the anterior part in the post-torsion veliger larvae stage. At the same period, the dorsal part will become the visceropallium gastric part. The early post-torsion veliger larvae are still lecitotrophic, which does not require feed from the outside and passively follows the water movement (Banne *et al*., 2017). Zamora *et al*. (2020) stated that the starfish *Stegnaster inflatus* eggs with ~400 µm diameter had a quite higher lipid content than the protein content at lipid:protein ratio of 0.96. Approximately 80% egg proteins were used in the early larval stadia. Meanwhile, lipid was used to reach the early juvenile stage.

The observational results showed that the highest shell length during the post-torsion veliger stage was in the A1B3 at 269.11 ± 34.81 µm, while the lowest shell length was in the A2B1 at 256.52 ± 30.21 µm. This indicates that the 26.5–27.5°C temperature and 34.5–35.5 g/L salinity was optimum to support the gold-mouth turban larval growth in the early post-torsion veliger stadia. This condition was similar to the *Rapana venosa* larvae which showed the highest at 25°C and 30 g/L (Zhang *et al*., 2017). Rippington (2015) explained that low temperature, salinity, and live feed concentration caused the larvae not to grow or develop, and vice versa. This condition was thought due to associated with the larvae metabolism rate, which continuously increased along with the increased temperature at the optimum threshold of 28°C and decreased above the temperature threshold (Winanto *et al*., 2009).

In the late post-torsion veliger stadia, the larvae developed operculum, feet, and propodium. This condition was supported by Kimani (1996), that in the post-torsion veliger, small feet and operculum were visible at about 20–30 hours after fertilization. Operculum is functioned to protect the larvae from the predator attack. Larvae will enter the shell and spread in the base container (Peck *et al*., 2016). In the *Nassarius reticulates*, the feet are enlarged during the larval stadia, and the pigmented propodium appeared on the feet ventral proximal as becoming clearer in the metamorphosis stage (Zupo & Patti, 2009). The veliger larvae still consume yellow-egg (endogenous feeding), therefore the feed provided, namely, *Navicula* sp. diatom, is utilized when the larvae are metamorphosized. The feeding behavior is similar to the turban snails, abalones, and several gastropods that utilize the yellow-egg to achieve the pediveliger stadia (Noble *et al*., 2015; Mccormick *et al*., 2016; Banne *et al*., 2017).

The observational results showed that the highest larval shell length during the post-torsion veliger stadia was obtained from the A1B3 treatment at 280.87 ± 33.16 µm, while the lowest shell length was obtained from the A2B1 treatment at 261.96 ± 26.46 µm. This indicates that 26.5–27.5°C temperature and 34.5–35.5 g/L salinity were optimum to support the shell length of gold-mouth turban in the late post-torsion veliger stadia. This condition was similar to the *P. maxima* larvae which showed the highest shell length at 28°C and 32–34 g/L (Winanto *et al*., 2009). Nowland *et al*. (2019) also reported that the increased shell length of D-veliger larvae in 48 hours old was caused by the increased temperature and salinity that reached the optimum values, namely 32°C and 32 g/L.

The stadium achievement period is a duration required by larvae to reach one stadium development. The observational results showed that the A1B3 treatment obtained the fastest early and late post-torsion veliger stadia achievement

at 19 hours 36 minutes and 22 hours 36 minutes after fertilization, respectively. Meanwhile, the A1B1 treatment obtained the slowest early and late post-torsion veliger stadia achievement at 20 hours 30 minutes and 23 hours 25 minutes after fertilization, respectively. This indicates that the 26.5–27.5°C temperature and 34.5–35.5 g/L salinity are the best condition to support the gold-mouth turban stadia achievement period. The similar condition also occurred in the pearl oyster (*P. maxima*) which the fastest plantigrade stadia achievement period at 28°C and 32–34 g/L (Winanto *et al*., 2009). Nowland *et al*. (2019) stated that the extreme temperature range (<20°C) and salinity range (<14 and >36 g/L) caused the larval stress to nearly dead by showing a pigment damage in the digestive system.

The larval attachment capability is ratio of the total attached larvae in the substrate and total numbers of larvae. The Duncan's test results showed that the A1B3 and A1B2 treatments at 48 and 72 hours had the best responses in the gold-mouth turban larvae attachment capability. Meanwhile, the A2B1 treatment obtained the worst response and had a significant different value compared to other treatments. This condition indicates that the 26.5–27.5°C temperature and 31.5–35.5 g/L salinity are the optimum temperature and salinity ranges to support the gold-mouth turban larvae attachment capability. The results obtained were similar to the *Tridacna gigas* oyster larvae which achieved the fastest pediveliger larvae achievement in a higher salinity level at 34 g/L (50 ± 6.5%), and the slowest was obtained from 18 g/L salinity (24.1 ± 6.4%) (Sayco *et al*., 2019). Montory *et al*. (2014) also reported that the *Crepipatella peruviana* veliger larvae could migrate to the water column from deeper water to find higher salinity (30–32 g/L) and prevent from low salinity level. The negative impact due to the environmental stressors during the metamorphosis period does not only influence the decreased shell length and lipid storage, but also having a continuous impact (Ko *et al*., 2014). In addition to salinity, temperature also plays an important role in the gold-mouth turban larvae attachment capability. The temperature range of 26.5–27.5°C produced the highest percentage of attachment capability. The results obtained were similar to the *Crassostrea gigas* larvae which obtained the highest attachment capability at 27°C (Rico-Villa *et al*., 2009).

The A1B3 treatment obtained the highest survival rate (SR) and was significantly different from the A1B2 treatment (P>0.05). This condition indicates that the temperature range of 26.5–27.5°C and salinity range of 31.5–35.5 g/L are the optimum temperature and salinity ranges in the gold-mouth turban larval maintenance. This condition was also similar to the pearl oyster *P. maxima* larvae which obtained the highest survival rate at 28°C, and 32 g/L and 34 g/L salinities (Winanto *et al*., 2009). Tao and Qi (2018) reported that the oyster *Crassostrea nippona* juvenile obtained the highest survival rate along with the largest shell length at 25–30 g/L salinity and 24–28°C temperature. In a nursery period, the gold-mouth turban has a quite high temperature tolerance among 25.5–28.5°C (Hamzah, 2015).

The lowest SR was obtained from the A2B1 treatment with insignificant difference among other treatments. This condition indicates that the combination of quite high temperature (29.5–30.5°C) and low salinity (28.5–29.5 g/L) produces a quite high mortality level for the gold-mouth turban larvae. The increased temperature to 3°C from the average annual temperature can decrease the larval survival rate by 25% (Conaco & Cabaitan, 2020). The similar condition was reported by Xue *et al*. (2010), that the temperature and salinity interactions had a significant influence in the increased daily body weight and shell length of *B. areolata*, although the survival rate was relatively low at the highest temperature. The low SR in the extreme temperature and salinity conditions was thought to cause ineffective metabolism and extracellular fluidic osmoregulation processes (Winanto *et al*., 2009). Salinity impacts on the survival rate value. However, a lower temperature tends to increase the salinity tolerance. In contrast, a higher temperature tends to cause more energy loss and decrease the disease resistance for larvae, which implicates on the mass pathogenic bacterial distribution (Lu *et al*., 2016). Montory *et al*. (2016) reported that the *C. peruviana* veliger larvae maintained at about 6 hours in low salinity level obtained high mortality level in the juvenile stage.

The highest specific growth rate at 27°C ± 0.5 (A1) temperature was found in the B3 treatment with a significant different value from the B2 treatment. This condition means that the salinity range of 31.5–35.5 g/L improves the larval specific growth rate until the 20 day old juvenile. Meanwhile at 30°C ± 0.5 (A2) temperature, the B3 treatment also showed the highest performance, but showing insignificant difference

value to other treatments. This condition was almost similar to the hybrid abalone larvae that obtained the optimum growth and development at 30–36 g/L salinity and *T. niloticus* at 30–35 g/L salinity (Dolorosa *et al*., 2013; Amin *et al*., 2016). Apines-Amar *et al*. (2020) stated that the green mussle (*Perna viridis*) larvae from the initial to pediveliger stadia obtained the highest growth rate at 29–30°C temperature and 30–33 g/L salinity.

The lowest specific growth rate at 27°C ± 0.5 (A1) temperature was found in the B1 treatment and showed a significant different value form other treatments. This condition indicates that the larval growth to 20 day old juvenile tends to be optimum in high and low salinity levels (28.5–29.5 g/L). This condition can inhibit the larval specific growth rate to 20 days old juvenile. Meanwhile at 30°C ± 0.5 (A2) temperature, the B1 treatment also showed the lowest percentage and insignificant different value to the B2 treatment. The low larval specific growth rate at low salinity level was thought to be associated with the energy sharing process (Amin *et al*., 2016) and biomineralization process that implicates on the shell formation. As reported by Bashevkin and Pechenik (2015), the interaction of salinity and low temperature can cause the decreased anorganic level percentage in the snail *C. fornicata* larvae. Ivanin *et al*. (2013) also explained that the increased temperature caused more energy loss for osmoregulatiotn than for the protein synthesis, resulting in the decreased glycogen storage and protein level in the tissue. Low salinity causes the lowest feed consumption rate and implicates on lower shell growth rate (Montory *et al.,* 2014).

The water quality parameters obtained during the experimental period were almost similar to the gold-mouth turban habitat condition in the Pelabuhan Ratu water area, namely, pH 7–8, 3–5 mg/L DO, 0.092–0.656 mg/L nitrate, and 0.001–0.029 mg/L nitrite (Soekendarsi, 2018). In addition to affecting the biota, the water quality parameters also play an important role to support the live feed growth (*Navicula* sp.). The optimum concentrations of NO_3^- and PO_4^{3-} for *Navicula* sp. growth are 3.6 mg/L and 0.18 mg/L (Xiaobo *et al*., 2014). Amalah *et al.* (2018) stated that the *Navicula* sp. density is closely affected by the N and P availabilities in the culture media. Microalgae require phosphate at 0.018–0.09 mg/L concentration with the maximum level of 8.90–17.80 mg/L. Moreover, Yang *et al*. (2014) stated that the N and P ranges for the optimum diatom growth are 12.36–74.16 mg/L and 1.70–3.98 mg/L, respectively.

CONCLUSION

Salinity has a greater effect than temperature to support the larval growth. Nevertheless, temperature and salinity are important to support the stadia developments, attachment capability, and survival rate of gold-mouth turban larvae. The optimum temperature and salinity ranges for maintaining the gold-mouth turban are 26.5–27.5°C and 31.5–35.5 g/L, respectively.

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