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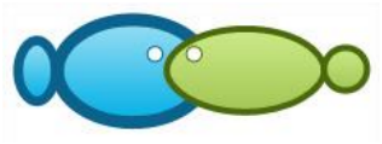

The use of different water volume to measure the growth and survival rates of *Anguilla bicolor* caught from Nusawungu riverines, Cilacap, Indonesia

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Abstract. Indonesian shortfin eel, *Anguilla bicolor,* is nowdays o5 of Indonesia's leading fishery commodities, but the culture system has not yet been developed. The aim of this study was to determine the effect of different water volumes on specific growth rate (SGR) and survival rate (SR) of *A. bicolor* specimens of the size of a pencil. Four treatments, consisting in different water volumes in each tank: 0.4 (A), 0.6 (B), 0.8 (C) and 1 m^3 (D), were applied in three replications. Approximately 15 kg of elvers (ranging from 18–22 g per fish) were used in each treatment (±5 kg for each replication). *A. bicolor* specimens were fed with a commercial shrimp feed at the dose of 2.2% d^{-1} (wet basis) or 1.26±0.001% d^{-1} (dry basis) for a 70 days culture period. Specific individual growth (SGRi), specific biomass growth (SGRb), total biomass growth (TbG), daily weight gain (DwG) and food conversion ratio (FCR) were also calculated. The results showed no significant difference ($\alpha>0.05$) in individual growth rate (SGRi) between A and B, as well as between C and D. However, there are significant differences in SGRi between A and C, A and D, B and C, and B and D ($\alpha<0.05$). The patterns of SGRi and SGRb were similar. The highest SGRi result was recorded in the tank A (0.72±0.09% d^{-1}), followed by tanks B (0.71±0.09% d^{-1}), C (0.55±0.06% d^{-1}) and the lowest was recorded in tank D (0.50±0.02% d^{-1}). The survival rate for the culture period had no significant difference among the treatments ($\alpha>0.01$), however, its value slightly varied around 98%. The highest value of TbG was found in tank A (63.73±9.71%). The best FCR value was also found in tank A (1:1.72±0.26) and the worse was found in tank D (1:2.63±0.13). The recorded values of the water parameters, dissolved oxygen (DO, 6.12±0.36–6.40±0.27 mg L^{-1}), temperature (28.25±1.86-28.35±1.46ºC) and pH (7.38±0.02-7.64±0.37), were normal during the study. Based on these results, it can be concluded that the growth of the studied specimens increased by decreasing the water volume. The SR of *A. bicolor* specimens remained unchanged between the treatments.
Key Words: specific individual growth, specific biomass growth, feeding rate, seed sources, FCR.

Introduction. Indonesian shortfin eel of *Anguilla* sp. is known as a catadromous fish that spawn in the deep ocean, then their larvae drift to coastal area and swim up to grow in fresh water and eventually swim back to the sea after attaining maturation, for reproduction (McCosker 1998; Aoyama 2009; Minegishi et al 2012). *Anguilla* sp. represents a pre-eminent commodity for aquaculture activities in Indonesia, but it has not been developed yet either due to the absence of breeding technologies or to an undeveloped cultivation technique (Lukas et al 2017). However, shortfin eels, either in juvenile and adult sizes (consumption size), are still quite abundant in Indonesia (Sugeha et al 2008). This fish have high economic value and high protein content (Pangerang et al 2018), being exported to several countries such as Japan, China, and Korea, at high prices (Shiraishi & Crook 2015).

The shortfin eels are widely spread in tropical and subtropical waters. This dispersal pattern classifies the eels into tropical and subtropical shortfin eels (Aoyama 2009). Eel species living in the Indonesian tropical waters include *Anguilla bicolor*, *A. marmorata*, *A. bornensis*, *A. celebesensis*, *A. interioris*, *A. nebulosi nebulosi*, and *A. bicolor pasifica*. They can be found along the southern coast of Java Island, the southwest coast of Sumatra, the eastern coasts of Kalimantan, Sulawesi and Bali (Tomiyama & Hibya 1977; Affandi 2005). In addition, *A. bicolor* has also been known as *A. sidat* (Kottelat 2013), referring to the local name of "ikan sidat".

The development of *A. bicolor* farming is influenced by the natural conditions. Indonesian water temperatures facilitate the development of eels farming (Sasongko et al 2007), compared to a temperate climate. Studies testing eel farming conditions, such as temperatures, water exchange, diets and inoculation, have been previously conducted on other sub-species. Luzzana et al (2003) used different sources of lipid and protein to raise European eel *A. anguilla*. The best result shows that a combination of herring, soybean and beef tallow, resulted in a 0.53% specific growth rate (SGR), while the other ingredients generated only a SGR of 0.21–0.47%. Angelidis et al (2005) raised the glass eel of *A. anguilla* at 20-23ºC in a recirculating water system for 328 days, obtaining a daily growth rate of 0.35 to 1.94%. Karipoglou & Nathanailides (2009) have tested different sizes of eel inoculation to determine their SGR. The best growth rate was found in the group size of 10–30 g (0.67%), folowed by group sizes of >30 g (0.6%) and <10 g (0.48%). *A. bicolor* farming studies have also been conducted by combining different water exchange systems and diets to test the feeding and growth rates performance. The growth process performed better in higher water exchange (0.44–0.72% d^{-1}) (Taufiq-Spj et al 2017) and for a combination of lipid and protein content in the feed ranging from 0.35 to 0.53% d^{-1} (Taufiq-Spj et al 2018). Another study used the *A. bicolor* seed from Citandui riverines at western Cilacap fed with different mannan oligosaccharide (MOS) doses. A higher percentage of MOS (0.03%) gave the best growth performance (0.69% d^{-1}) (Taufiq-Spj et al 2019). The different sources of seeds offer various environmental conditions. As a possible pattern, small size specimens seemed to grow faster in lower water levels. The purpose of this study was to determine the effect of different water volumes on the growth and survival rates of *A. bicolor* of the size of a pencil, by using different sources of seeds.

Material and Method

Culture system. The *A. bicolor* were cultured in the circular HDPE (high density poly ethylene) tank with diameter 1.2 m and 1.1 m height with approx. 5% slope at the bottom of the tank. The basic recirculating water system used PG8000 pump with Qmax 8,000 L h^{-1} placed in a reservoir and a single bio-filter. The flow water was adjusted to a bio-filter capacity of approximately to 4,200 L h^{-1}. A perforated hose installed at the midle of the tank, as a water outlet, together with a flush hose underneath and another hose to the biofilter. The *A. bicolor* seeds were obtained from Nusawungu of eastern Cilacap (Central Java), where the riverine gets connected to the Bendung Gerak (river dam) irrigation canal. The seeds were kept at the quarantine tanks for a week, while fast morphometric tests and class sizing were conducted. This study was conducted during the wet seasons of October-December 2018.

Four treatments were used in this study: 0.4 m^3 in tank A, 0.6 m^3 in tank B, 0.8 m^3 in tank C and 1.0 m^3 in tank D, with three replications. Approximately 15 kg of pencil size *A. bicolor* were used in each treatment, hence approx. 5 kg of seeds were used in every replication. The treatment was applied to an initial density of 12.5 kg m^{-3} in tank A, 8.33 kg m^{-3} in tank B, 6.25 kg m^{-3} in tank C and 5 kg m^{-3} in tank D. Each replication contained approximately 250 specimens with an initial weight of 18–22 g $fish^{-1}$, with a mean value between 19.9±0.4 and 20.3±0.7 g $fish^{-1}$ (Table 2).

Feed given. Commercial shrimp feed (Table 1) was given twice a day at a concentration of 2.2% d^{-1} on a wet basis food (WBF) (Taufiq-Spj et al 2017), by mean of pasted feed containing water, up to 75% of the dry food given (DFg). Hence, the DFg had a portion of approximately 1.26% of the body weight. The shrimp feed, before being mixed with the

water (pasted), was mixtured with mannanoligosaccharides (MOS) at a maximum dose of 0.03%, as reported by Taufiq-Spj et al (2019). The feed was used in a powdered format (30–50 µ). The MOS used was produced by Alltech Bio-MOS. The pasted food was then given to the fish on a floating device, in order to keep it in whole pieces and to avoid the fractionated feed to sink. Data on food given (WFg) were evaluated fortnightly, against data on the fish growth.

Fish were kept in aerated media with dissolved oxygen (DO), temperature, and pH were measured every two days. To maintain the water quality, daily dirts, such as uneaten feed (UEF) and faeces, were removed, collected and measured separately.

Table 1

Feed proximate analysis (shrimp feed) given to *Anguilla bicolor*

Water (%)	*Ash (%)*	*Protein (%)*	*Lipid (%)*
10.18	8.65	34.11	4.84

Sampling and formulas. Fish were sampled based on their weight every fortnight, during the 70 days of the culture period, by using an electronic balance (LQS) with max-min load 10 kg and 0.5 g and a deviation of 0.1 g. The data series on individual and total biomass weight were used for calculating the individual (SGRi% d^{-1}) or biomass (SGRb% d^{-1}) specific growth rates, as mentioned by Taufiq-Spj et al (2018). Feeding rate (FR) was also based on the biomass content of the food, namely 2.2% d^{-1} wet basis of the given food. Death rate (DR) was monitored fortnightly and the survival rate (SR) was calculated using the sum of fortnight DR (from the three replications of each treatment) for the 70 days of observation. In order to shape the distribution of the SR values, the mean SR values were also calculated as the surviving fish at the t time (f_t) of each replication (see formula). Absolute weight gain (AwG) resulted from the difference between the final biomass weight (W_t) and the initial biomass weight (W_0). The total biomass growth (TbG) resulted from the difference between the biomass growth, as sum of the biomass weight at the end of treatments (ΣW_t), and the sum of the biomass weight for each treatment, at the initial innoculation (ΣW_0). Further calculations were done: the mean of daily weight gain (mDwG) for the 70 days of culture and the food conversion ratio (FCR), as the ratio between the dry food given (DFg) and AwG.
Hence the formulas used, were:

WBF (% d^{-1}) = (2.2/100)xbiomass
DFg (% d^{-1}) = (4/7)xWBF=(1.26/100)xbiomass
SGR (% d^{-1}) = $100x(Ln(W_t)-Ln(W_0))/\Sigma d$
FR (% d^{-1}) = $100x((WBF - UEF)/b)/\Sigma d$
SR (%) = $100x(\Sigma f_t/\Sigma f_0)$
AwG (g) = $W_t - W_0$
TbG (%) = $100x(\Sigma W_t - \Sigma W_0)/\Sigma W_0$
mDwG (g d^{-1}) = $(\Sigma W_t - \Sigma W_0)/\Sigma d$ .... (where $\Sigma d=70$)
FCR = $(\Sigma$ DFg/AwG)

Statistical analysis. Absolute and specific growth of either individual or biomass, feeding rate, survival rate, total biomass growth and food conversion ratio, were analyzed by using a generalized linear mixed model and repeated measures ANOVA, followed by a post hoc test using multiple comparisons based on observed means.

Results. The culture overall performance showed similar patterns for the measured data, but the growth responsehad different patterns. Starting on the dry basis of food (DFg), the wet basis was derived (WBF=2.2% of the body weight). There were not found any significant differences ($\alpha>0.05$) of DFg among the treatments (1.26±0.001%). Uneaten food (UEF) tended to increase with the water volume, while the feeding rate was quite similar between A and B as well as C and D treatments. However, the response was different in the final biomass, final mean weight, absolute weight gain and total biomass

gain. The survival rate performed similarly, without any significant variation ($\alpha>0.05$) with the treatments and the water parameters (DO, temperature and pH), as shown in Table 2.

Table 2

Results of calculated parameters measured during the 70 days period of *Anguilla bicolor* culture

Measurements	*Treatments*			
	A	*B*	*C*	*D*
Water volume (m^3)	0.4	0.6	0.8	1.0
Initial biomass (g)	5,014.9±24.2	5,013.9±24.1	5,008.2±12.8	5,037.9±14.7
Initial density (kg m^{-3})	12.54±0.06	8.36±0.04	6.26±0.02	5.04±0.01
Σ Fishes (f) innoculated	251.7±3.5	246.7±5.8	250.7±5.1	248.0±7.8
Initial mean weight (g f^{-1})	19.9±0.4	20.3±0.4	20.0±0.5	20.3±0.7
Σ WBF (2.2%) (g)	9,472.7±106.5	9,376.5±212.2	8,960.4±106.9	8,935.5±151.2
Σ Dry food given (DFg) (g)	5,416.7±55.1	5,360.0±121.2	5,130.0±95.4	5,113.3±78.2
DFg (% d^{-1})	1.26±0.001	1.26±0.001	1.26±0.001	1.26±0.002
Wet basis food given (g)	9,479.2±96.4	9,380.0±212.2	8,977.5±166.9	8,948.3±136.8
Σ UEF during 70 days (g)	1,367.0±35.8	1,363.0±52.0	1,462.0±24.4	1,503.3±35.1
UEF for 70 days (%)	14.42±0.49	14.53±0.33	16.29±0.44	16.80±0.15
Feeding during 70 days (g)	8,112.2±122.5	8,017.0±170.2	7,515.5±173.8	7,445.0±102.7
FR (% d^{-1})	1.88±0.01	1.88±0.01	1.84±0.01	1.83±0.01
Final biomass (g) after 70 days	8,209.2±448.4	8,113.0±595.1	7,227.2±325.6	6,985.9±79.5
Σ Fishes after 70 days	248.0±3.0	242.7±6.7	246.3±6.4	243.0±7.8
SR (%)	98.54±0.21	98.37±0.44	98.27±1.16	97.98±0.06
Final mean weight (g f^{-1})	33.1±1.5	33.4±2.2	29.3±0.6	28.8±0.6
AwG (g)	3,194.3±472.7	3,099.1±571.6	2,219.0±337.9	1,948.0±91.5
DO (mg L^{-1})	6.17±0.26	6.40±0.27	6.12±0.36	6.16±0.46
Temperatures (^{0}C)	28.25±1.86	28.35±1.46	28.27±1.80	28.32±1.90
pH	7.52±0.28	7.64±0.37	7.52±0.38	7.47±0.35

Growth and feeding rate. Growth rate varied with the treatments: both individual and biomass growth increased with the decrease of the water volume. Individual growth rate (SGRi) had no significant difference ($\alpha>0.05$) between the treatments A and B, but significant differences ($\alpha<0.05$) were found between treatments C and D, A and C, and B and D The highest individual growth was found in the tank A (0.72±0.09% d^{-1}) and the lowest individual growth was found in the tank D (0.50±0.02% d^{-1}). Similar patterns were also found in the biomass growth rate, where the tank A had the highest SGRb, while the tank D had the lowest one (Table 3). Both tanks A and B showed significantly different patterns compared to tanks C and D ($\alpha<0.01$), while tanks A to B didn't show any difference ($\alpha>0.01$) and tanks C and D also had a different SGRb ($\alpha<0.05$).

Table 3

Specific individual (SGRi) and biomass (SGRb) growth rate (% d^{-1}) of *Anguilla bicolor* for different water volumes of the captivity tanks, during the 70 days of observations

Ponds	*A*	*B*	*C*	*D*
SGRi±SD (%)	0.72±0.09	0.71±0.09	0.55±0.06	0.50±0.02
SGRb±SD (%)	0.70±0.09	0.69±0.10	0.52±0.07	0.47±0.02

The measured daily feed rate varied between 1.77–1.92% d^{-1} among treatments (Table 4). All fortnight FR seemed similar for the first five measurements, only for the period from 29th to 42nd days, tank A showed a slight increase (1.92%), while feeding was not optimal in tanks C and D from day 1st to 14th (Table 4).

Table 4

Measured daily feed rate (FR% d^{-1})

Treatments	FR (% d^{-1})				
	1^{st} - 14^{th}	15^{th} - 28^{th}	29^{th} - 42^{nd}	43^{rd} - 56^{th}	57^{th} - 70^{th}
A	1.87±0.02	1.89±0.01	1.92±0.02	1.86±0.00	1.89±0.01
B	1.89±0.01	1.89±0.00	1.88±0.00	1.86±0.02	1.89±0.01
C	1.78±0.04	1.85±0.00	1.87±0.01	1.85±0.02	1.86±0.02
D	1.77±0.03	1.84±0.01	1.86±0.01	1.84±0.01	1.84±0.03

Survival rate. Total biomass growth and weight gain were associated with the survival rate, since each survivor contributed to the total biomass weight gain and growth. The SR varied along the treatments, SR seems to increased by decreasing water volume, tank D (97.98±0.28) to tank (A 98.54±0.21%) (Figure 1 and Table 2). Statistical analysis shows that eel SR have no significantly different among treatments (α>0.01).

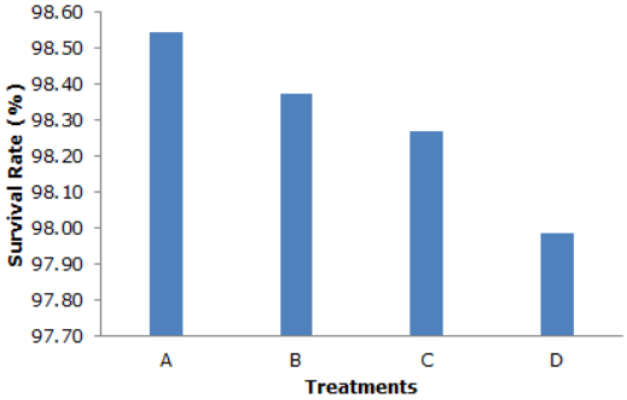

Figure 1. Survival rate occurrence of *Anguilla bicolor* cultured in different water volume (A, B, C, and D) for 70 days.

Total biomass growth and FCR. A combination of the biomass growth, average daily weight gain, SR performance and FCR can be used for predicting the productivity in aquaculture industry. The results showed that TbG and DwG of *A. bicolor* of the size of a pencil followed a growth pattern, where the value increased by decreasing the water volume. Contrarily, the FCR increased by increasing water volume (Table 5).

Table 5

Total biomass growth (%), daily weight gain (g d^{-1}) and FCR of *Anguilla bicolor* cultured in different water volumes for 70 days

Tanks	A	B	C	D
TbG (%)	63.7±9.71	61.78±11.08	44.32±6.85	38.67±1.91
mDwG (g d^{-1})	45.63±6.75	44.27±8.17	31.70±4.83	27.83±1.31
FCR	1:1.72±0.26	1:1.76±0.27	1:2.35±0.35	1:2.63±0.13

Discussion

Growth and feed rate performance. These phenomena of growth variations are presumably due to the variety of habitat conditions met by *A. bicolor* prior to their capture from the riverine, while they were at early stages of development (Binder et al 2011). Hence, *A. bicolor* might find food in abundance along their journey to upstream (Taufiq-Spj et al 2019), while in captivity they are fed only twice a day. The available

volume of water affected the predation ability of the fish, also as they increase in body length they tend to be more piscivorus (May & Marshall 2008). However, *A. bicolor* of the size of a pencil have apparently encountered more difficulties in finding the food in a higher volume of water (tank D). As a result, larger quantities of daily uneaten feed (UEF) were removed when the iwater volume was larger (Table 2). Besides larger water volumes tend to contain more dirts than smaller ones, indicating that the presence of residues of undiscovered food fallen appart. In a higher volume of water, fish take the habit to confine around the centre of the tank, where the perforated hose of the water outlet is placed, which is a behavior rather typical for the young specimens tending to ambush their prey, than for adult predators becoming active (piscivorus) as they grow up. It was also observed that some of the fish moved sluggishly in higher volume of water.

Moreover, the fortnightly growth measurement, individual and biomass growth rate showed similar patterns between individual and biomass growth rate (Figure 2). At the second measurement (day 28th), the growth rate decreased for all the treatments. This condition was apparently due to environmental alterations, such as temperature changes, during the third and fourth week culture. The growth performance found at the first fortnight observations suggested a successful treatment, based on water temperatures ranging between 28.2–28.6ºC. Hence, the individual growth attained 0.74±0.19% d^{-1} for the treatment A, followed by the treatments B (0.69±0.12% d^{-1}), D (0.67±0.18% d^{-1}) and C (0.67±0.22% d^{-1}) (Figure 2). The third week, temperature was adjusted to an average of 26.4ºC and to a mean of 26.6ºC, the fourth week, determining the decrease of the growth rate in all treatments, for most of the studied *A. bicolor* specimens (Figure 2). Luo et al (2013) used two species of tropical eel juveniles: *A. marmorata* and *A. bicolor pacifica*. Individuals of both species had a smaller growth at lower temperatures: SGR of *A. marmorata* had almost no growth (0% d^{-1}) and *A. bicolor pacifica* grew only 0.2% d^{-1}, when cultured at 18ºC. The two species also had a SGR peak at 28ºC, attaining 1.5% d^{-1} for *A. bicolor pacifica* and 0.9% d^{-1} for *A. marmorata* species.

Eventhough the growth rate decrease observed in the current study (*A. bicolor*, day 28th, Figure 2) did not correlate to the feeding rate (FR) change, as in the study conducted by Luo et al (2013), possibly due to the feed remained undetected, there was no significant difference (α>0.05) in the FR values between A and B or C and D during the culture time, at the first and second fortnight measurement. The highest FR was found for the treatment B (1.89±0.01% d^{-1}) (Table 4). Both individual and biomass growth were more stable for the tank B than for the tank A (Figure 2), while, the FR was higher in the smaller water volumes (tanks A and B) than in the larger ones (tanks C and D), as shown in Table 2 and 4. In addition, previous studies (Taufiq-Spj et al 2018), where the temperature was maintained stable along the culture (27.14–27.64ºC), reported increased SGR values for all treatments, at the third sampling (week 4).

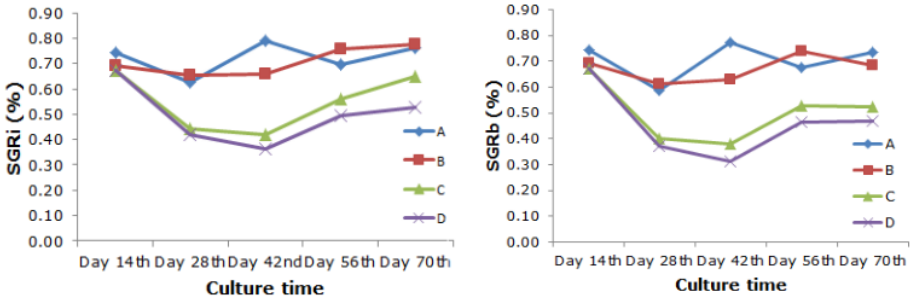

Figure 2. Fortnight measurement of SGRi (left) and SGRb (right) performance (% d^{-1}) of *Anguilla bicolor* cultured in different water volumes for 70 days.

Starting from the end of the fourth week and the beginning of the 5th week, the temperature was raised again to 28.6ºC and the adaptation period was commencing, triggering the SGR increase for all the treatments. However, the treatment A, with 400 L volume of water, showed a steeper increase of both individual growth rate (SGRi) or biomass growth rate (SGRb). Meanwhile, the tanks C and D performances were slower, with a declining growth rate. After the third sampling (6th week), growth rates started to increase in treatments D and C, until the end of the culture period. This was possibly due to a better capacity of the studied specimens to detect the food, as they developed to their piscivorous stage. Contrarily, in a previous study where the temperature was stabilized at 27.14–27.64ºC during the whole culture period and where all the treatments used a volume of 1 m^3 of water, the third sampling (week 6) showed a declining growth rate (Taufiq-Spj et al 2018), due to a combination of water quality parameters. In the current study, the dissolved oxygen (DO) remained higher (6.16±0.46 ppm), compared to the previous study (3.54–4.66 ppm), which stimulated the fish to actively forage and detect food.

For similar conditions, namely a water volume of 1 m^3 and pelleted shrimp feed (Table 1), the SGRi for the treatment D slightly changed from 0.52% d^{-1} in the previous study (Taufiq-Spj et al 2018) to 0.50±0.02% d^{-1} in this study. The variations were already predicted by the different sources of seeds. In the previous study, a farm collector at Purwokerto provided seeds originated from Citandui's riverines (Taufiq-Spj et al 2018), while for the present study the seeds were collected from Larangan creek (Nusawungu Cilacap), which is connected to the drainage canal of Bendung Gerak Banyumas. As the drainage canal irrigates wet rice fields along Banyumas to Cilacap, the water flow might be contaminated with fertilizers and pesticides traces.

Survival rate. As mentioned in Table 2 and Figure 1, the SR varied between 97.98±0.06% and 98.54±0.21%, indicating rare death events. The death rate occurrence may be due to a combination of parameters like temperature, feeding rate and seeds origin. Captive specimens cultured at controlled water temperatures of 28ºC showed 100% SR and only 92% SR at 33ºC and 45 days of culture period (Luo et al 2013). Even though eel species are poikilothermic and they do not regulate their body temperatures, the temperature fluctuations affect the feeding and metabolic rates of their organism. Gillooly et al (2001) stated that the first approximation of the metabolic rate is a single, general function of the body size and temperature, for any organism. In the case of this study, a smaller water volume (tank A) will afect the metabolic rate faster than other environmental changes. Contrarily, a larger water volume (tank D) will have an increased thermal energy transfer inertia and specimens of smaller sizes will be more vulnerable to the environmental changes. Death occurrence can be explained by the starving of those individuals which are unable to detect food, being at an earlier stage of development (characterized by: sluggish movements, prey ambushing and aggregation at the centre of the tank). Haemorrhagic dots were observed on the abdominal skin of some dead specimens. However, in this study the SR was still remarkably high.

The ability of the seeds to grow during the culture time is expressed by the total biomass growth and the mean of daily weight gain. Tank A, with an initial seed weight of 5,014±24.2 g, attained 8,209.2±8.17 g of biomass (an AwG of 3,194±427.7 g) during the 70 days culture time, whilst tank D had an AwG of only 1,948.0±91.5 g (Table 2). The mDwG of tank A (45.63±6.75 g d^{-1}) was almost twice (183%) the mDwG of tank D (27.83±1.31 g d^{-1}) (Table 5). Other than to the temperature fluctuation mentioned above (tank D deviation was ±1.90^{0}C, as shown in Table 2), the slower growth of the studied specimens was presumably related to the mode of metabolic rate and aerial respiration. The DO was quite high in all the treatments (6.12–6.40 ppm, Table 2), even though the oxygen was used by *A. bicolor* for metabolism (Alberts et al 2002). The oxygen uptake of the *A. bicolor* specimens was normal in both gill and skin respiration (Moigne et al 1986). The higher volume of water would prevent aerial respiration of the smaller specimens. Hence, their growth rate would be slowed down by limiting the foraging time, most of their energy being presumably already consumed by swimming up and down. This phenomenon could be seen in the growth performance (Figure 1), after day 42nd, in

already piscivorous specimens: the individual growth considerably increased for treatments B, C, and D. However, tank A still had fluctuations in the growth performance (Figure 2).

Food conversion ratio. For the food conversion ratio, tank A had the best FCR (1:1.72±0.26) compared to treatments B, C, D (the worse FCR, 1:2.63±0.13) (Table 5), presumably due to differences in the initial size, water volume, energy for aerial respiration, temperature fluctuation, and other parameters affecting the studied specimens growth and determine the FCR variability. In terms of food ingredients, Luzzana et al (2003) obtained a better FCR (1:1.8) for *A. anguilla*, by using controlled diets of fish meal without soybean, beef tallow and fish oil, while the current study simply used the commercial shrimp feed (Table 1). However, for a combination with 25% soybean meal, 50% of beef tallow, and the combination of fish meal, beef tallow, and soybean meal the FCR found was largely worse 1:2.88, 1:2.04, and 1:4.55, respectively (Luzzana et al 2003). The most efective culture system of this study seems to be the combination: water volume of 0.4 m^3, initial fish weight of 19.9±0.4 g per fish and intial density of 12.54±0.06 kg m^{-3} (Table 2).

Conclusions. The growth rate of *A. bicolor* in different water volumes increased by decreasing the water volume. A similar pattern of growth occured for both individual and biomass specific growth rate. During the 70 days culture period, the *A. bicolor* specimens of the size of a pencil, captured from Nusawungu, attained a survival rate of 97.98–98.54%, an individual biomass growth of 0.72% d^{-1}, a total biomass growth of 63.73% and a FCR of 1:1.72, in 0.4 m^3 water volume.

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