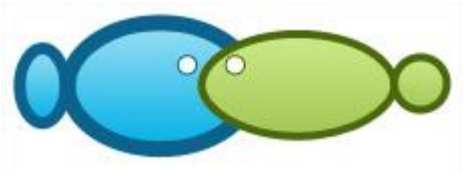

Length-weight relationship and condition factor of wild caught juvenile tiger grouper *Epinephelus fuscoguttatus* (Forsskål, 1775) after culture period

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Abstract. Tiger grouper (*Epinephelus fuscoguttatus*) is a highly valuable species and one of the most important fish traded in the live reef fish food trade (LRFFT). However, this species requires a desired growth pattern to command a high price in the market. Moreover, this species changes its growth pattern throughout the culture period, which may compromise its price value. Thus, the present study was conducted to determine the length-weight relationship and condition factor of this species for three (3) months of culture. There were 150 *E. fuscoguttatus* juveniles (mean total length: 24.24 ± 0.26 cm; mean weight: 252 ± 7.93 g) collected from the coral reef of Tandubas Island, Tawi-Tawi, Philippines. Fish were fed with 5% of their average body weight and individually measured for their length and weight using a measuring board and a digital weighing scale. Parameters, such as length-weight relationship and condition factor of *E. fuscoguttatus* were calculated before and after the cultured period. Results exhibited a lowering b value (i.e., from 3.00 to 2.96) and showed no significant difference between the wild caught *E. fuscoguttatus* at the time of capture and after their culture period ($p > 0.05$), suggesting an isometric growth pattern in both wild and cultured conditions. Apparently, an increasing condition factor (i.e., from 1.89 to 1.92) was observed in cultured fish. Moreover, a cultured grouper exhibited a significantly higher condition factor than the wild ones ($p < 0.05$), suggesting improved health condition when it is cultured as compared to the wild ones. Moreover, the results also suggested that growth patterns and condition factors can be manipulated through feeding management and dietary interventions. Overall, it implies that the growth pattern from the wild may be imitated in captivity, with appropriate cage management. Hence, it is feasible to produce cage-cultured grouper with body characteristics comparable to wild individuals.
Keywords: cage, cultured, growth pattern, LRFFT.

Introduction. Tiger grouper *Epinephelus fuscoguttatus* (Forsskål, 1775) is a highly marketable fish species in aquaculture for both subsistence and commercial fisheries (Bunlipatanon et al., 2014) due to its good taste and firm, white flesh. Tiger grouper contributed to 13.65 % of grouper production in the second quarter of year 2024 (Philippine Statistics Authority, 2024). Simultaneously, tiger grouper has a significant contribution to the seafood economy and in local communities (Rimmer & Glamuzina, 2019). This species is farmed in numerous countries, such as the Philippines, Indonesia, Malaysia, Taiwan, Thailand, Hong Kong, Southeast China, Vietnam, Sri Lanka, Saudi Arabia, South Korea, Australia, and the USA (Ranjan et al., 2017). In the Asia-Pacific region, tiger groupers belong to the most important fish traded in the live reef fish food trade (LRFFT) network,

which has a high market demand (Halim, 2001). Despite its high market demand and economic importance, there is always a risk ahead. The high demand for tiger groupers has significantly influenced wild stocks (Shapawi et al., 2019) and leads to catching undersized *E. fuscoguttatus*. Instead of allowing them to grow, they are being caught, resulting in low market value. It iss affecting the profitability of fishers due to lower value per unit of fish (Sadovy & Cornish, 2000). Consequently, the present study assesses the cage culture management to obtain a desirable growth pattern of *E. fuscoguttatus*, similar to the wild state, by monitoring the length-weight relationship.

Length-weight relationship (LWR) is an important biological indicator used to assess the growth pattern of fish (Karna et al., 2012), whether it is isometric (b = 3), i.e., the fish grows proportionally; positive allometric (b > 3), meaning the fish grow bulkier or thicker; or negative allometric (b < 3), meaning the fish grow elongated and slender (Karachle & Stergiou, 2012). The condition factor is also one of the parameters used to determine the overall health of fish (Sekitar et al., 2015). This parameter is widely applied in aquaculture to determine the status, growth performance, and cultured condition of fish (Abdul et al., 2017). Some studies stated that there is a difference in the taste of *E. fuscoguttatus* and in its health between cultured and wild states (Shapawi et al., 2019). These issues were leading to a lower market value of cultured *E. fuscoguttatus* (Li et al., 2020) compared to the wild state. The growth pattern of cultured fish changes when it is farmed due to environmental factors and feeding practices (Muhammadar et al., 2014). Throughout the literature, so far, the existing studies of *E. fuscoguttatus* were limited on disease/diet studies (Chiu et al., 2008), population dynamic (Fatma et al., 2021), growth transcriptomics (Qiu et al., 2024), genome sequencing (Zhao et al., 2021), hybrid genetics (Cao et al., 2023), reproductive biology (Palma et al., 2019), and aquaculture review (Shapawi et al., 2019). Thus, the present study aimed to monitor the length-weight relationship and condition factor of tiger grouper *E. fuscoguttatus* over a three-month culture period. By examining these factors, the present study provides valuable insights into imitating the growth pattern and conditions of *E. fuscoguttatus* depending on the overall cage management, which contributes to the sustainable development of the aquaculture industry.

Material and Method

Study site and source of organisms. The study was conducted for 3 months (September 22, 2024 to December 21, 2024) using a floating net cage of the Ministry of Agriculture, Fisheries, and Agrarian Reform (MAFAR), Sanga-Sanga, Bongao, Tawi-Tawi, Philippines (5º02’05.8’’N, 119º44’33.0’’E) (Figure 2). A total of 150 juvenile tiger grouper (*Epinephelus fuscoguttatus*) with a mean length of 24.24 ± 0.26 cm and a body mean weight of 252 ± 7.93 g (Figure 2) were collected from the coral reef of Tandubas, Tawi-Tawi, using a fish trap (bubu).

Figure 1. Experimental fish (*Epinephelus fuscoguttatus*): a) measuring weight (g); b) measuring length (cm).

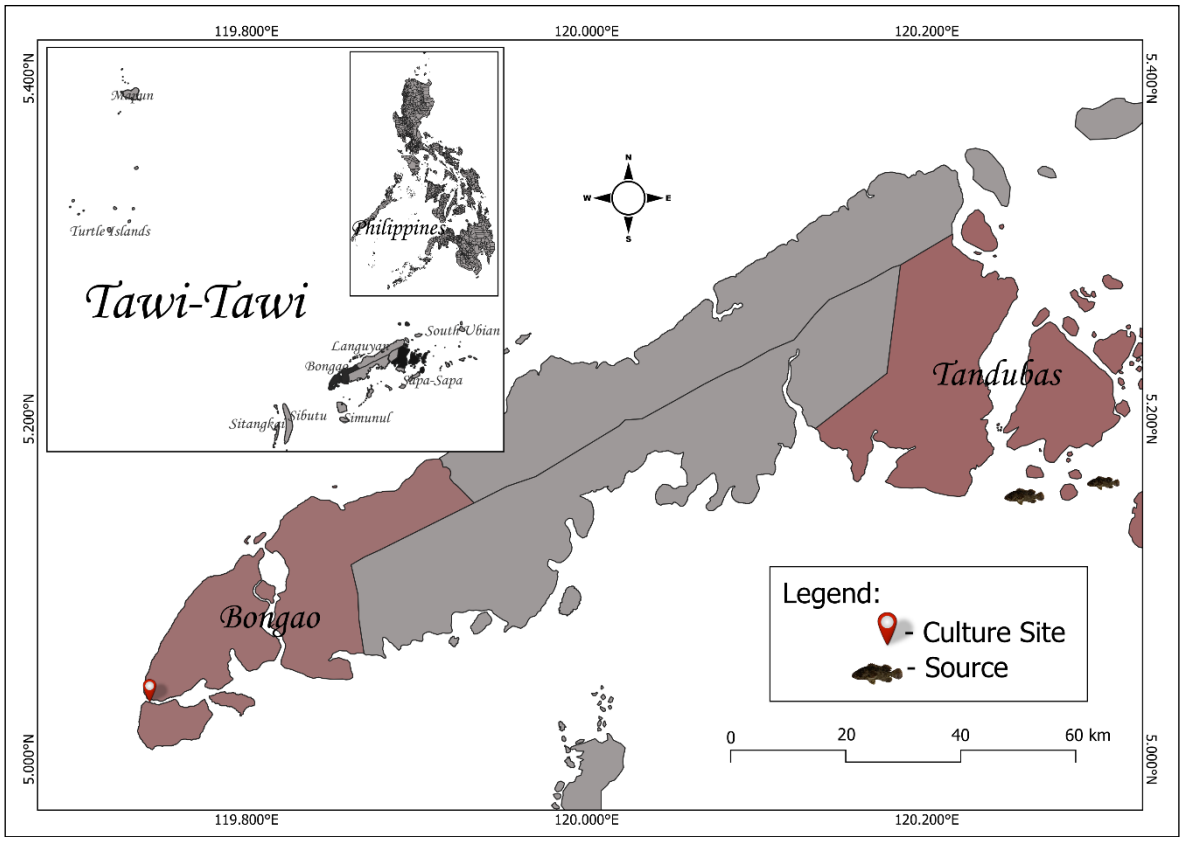

Figure 2. Map location of study site and source of experimental fish at Tawi-Tawi, Philippines (QGIS Version 30).

Experimental cage and water parameters monitoring. The fish were stocked in the experimental cage (3 x 3 meters with a height of 2 meters), using poly net (Ding fishing supply™, Philippines) with a mesh size of 0.40 inch. The cage was tied up with a cemented anchor (5 kg) on the four (4) corners and provided with a net covered above (shading net). Fish were fed with small reef fish (*Apogon* spp.) at 5% of their average body weight twice a day during early morning (7 AM) and late afternoon (4 PM). The water parameters (i.e., temperature, salinity, pH, dissolved oxygen, water movement, and water depth) were monitored using thermometer (Yieryi™, China), refractometer (Yieryi™, China), pH meter (Yieryi™, China), dissolved oxygen meter (EagleTech™), improvised drogue, and Secchi disc twice a day after feeding.

Sampling of the study. Sampling was done before stocking and after culture period (i.e., 90-day) by anesthetizing the fish using clove oil (Cedar Alley™, Philippines) at 1 drop L^{-1}. The anesthetized fish was measured for the total length using a measuring board, from the tip of the mouth to the tip of the tail, while the total weight (TW) was measured using portable digital weighing scale (SENS™ Precision Instruments, USA) (Figure 1). Analysis of the length-weight relationship was done by using the power function of Pauly (1984):

$$W = a\, L^b$$

Where: W = weight (g); L = total length (cm); a = intercept; b = slope.

The condition factor is expressed as the ratio between total body weight (observed weight) and the calculated length according to the length-weight equation (Le Cren, 1951). The data used for length-weight relationships were also used to calculate the Fulton's condition factor (*K*) using the formula:

$$K = 100\, \frac{W}{L^3}$$

Where: W = weight (g); L = total length (cm).

Data analysis. Data collected after the study was subjected to one-way analysis of variance (ANOVA) using JASP version 0.19, and the Tukey test was employed as post hoc analysis to compare the significance between fish status at the beginning and the end of the experiment. The length and weight relationship data were analysed using the Microsoft Excel™ software.

Results

Length-weight relationship and condition factor of E. fuscoguttatus. The regression of the length-weight relationship of *E. fuscoguttatus* revealed a lowering b value (i.e., from 3.00 to 2.96) (Figures 3, 4) and showed no significant difference between the wild and cultured state of *E. fuscoguttatus* ($p > 0.05$), suggesting an isometric growth pattern in the wild state, while the cultured state exhibited isometric growth as well. The length-weight relationship of this study was shown to be positively correlated ($p < 0.05$), and the r^2-value for both wild and cultured state was almost 1.0 (Table 1.). Apparently, an increasing condition factor (i.e., from 1.89 to 1.92) was observed in cultured fish. Moreover, a cultured state of *E. fuscoguttatus* exhibited a significantly higher condition factor than the wild state ($p < 0.05$).

Table 1

Summary of the data and condition factor of tiger grouper *E. fuscoguttatus*

Fish	*a*	*b*	*R^2*	*K-value*	*Growth Pattern*
Wild	0.02	3.00[a]	0.95	1.89[b]	Isometric
Cultured	0.02	2.96[a]	0.92	1.92[a]	Isometric

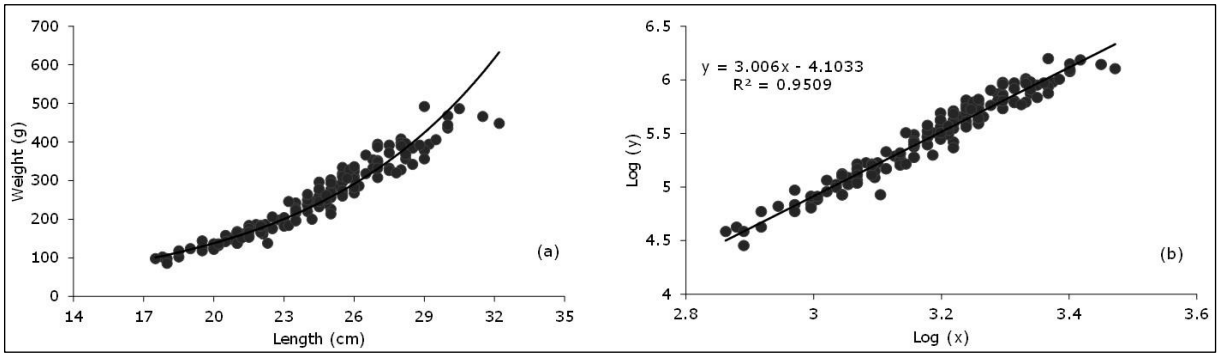

Figure 3. Length-weight relationship of wild caught tiger grouper *E. fuscoguttatus* at harvest; a) length-weight distribution; b) length-weight relationship using linear equation.

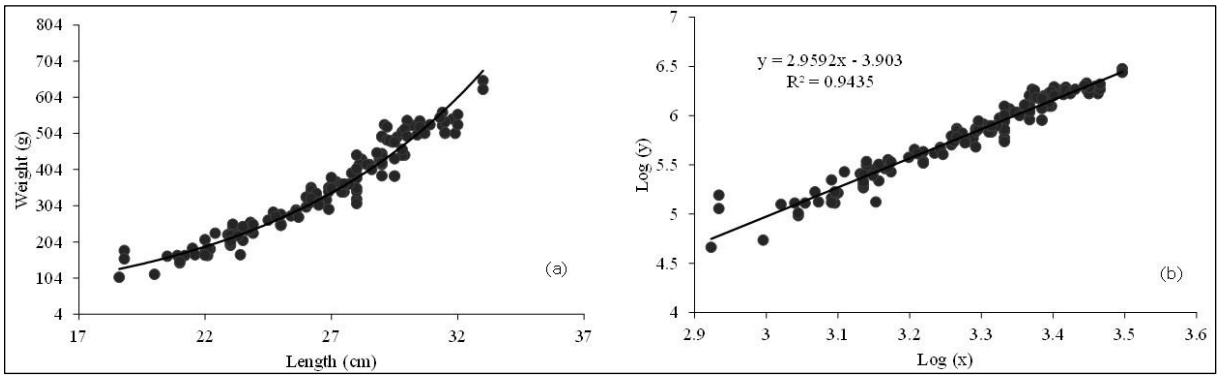

Figure 4. Length-weight relationship of tiger grouper *E. fuscoguttatus* after 3 months of culture; a) length-weight distribution; b) length-weight relationship using linear equation.

Water parameters during fish rearing. Throughout the culture experiment, the water conditions in the cage culture of tiger grouper remained stable (Figure 5). The depth of the water was consistently between 5.81 and 5.98 m. Water movement values slightly

fluctuated, starting at 7.11 cm^2 sec^{-1}, dipping to 4.49 cm^2 sec^{-1}, and ending at 6.64 cm^2 sec^{-1}. The salinity of water remained steady at 30.77 and 31.10 ppt. The temperature stayed at 30°C with a little fluctuation. The pH levels were ranging from 8.19 to 8.36. Dissolved oxygen levels stayed between 5.97 mg L^{-1} and 6.41 mg L^{-1} until the end of the culture experiment.

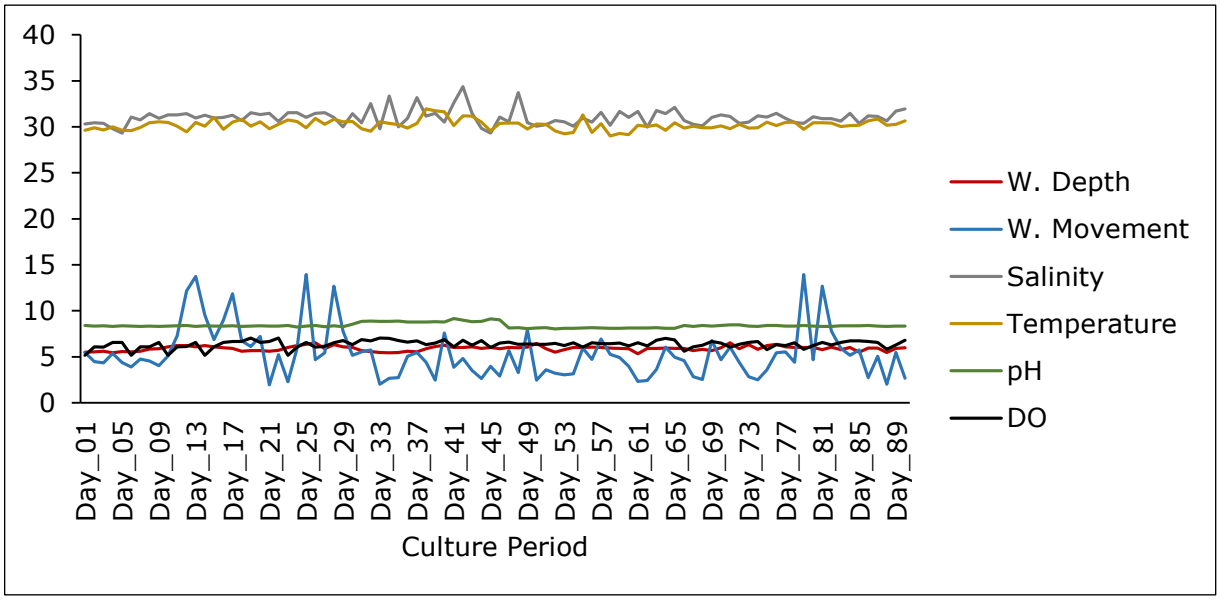

Figure 5. Water parameters throughout the cage culture period *E. fuscoguttatus* (water depth – m; water movement – cm^2 sec^{-1}; salinity – ppt; temperature - ^oC; dissolved oxygen – mg L^{-1}).

Discussion. This study monitored the growth pattern of wild caught tiger grouper *Epinephelus fuscoguttatus* after being cage cultured, aiming to understand the potential impact of overall cage culture on the growth pattern of *E. fuscoguttatus.* The result of the present study on the length-weight relationship of *E. fuscoguttatus* exhibited a higher b value of the wild fish at capture (b = 3.00), compared to the fish after being cultured for 90 days (b = 2.96), suggesting minimal changes on robustness of *E. fuscoguttatus* from wild to cultured state. Previous studies reported an isometric growth pattern of wild-state *Epinephelus aeneus* (b = 3.00) on the southwest coast of Senegal, West Africa (Ndiaye et al., 2015). Their finding indicates a proportional growth for wild state *E. fuscoguttatus,* meaning when the fish increased in size, their body shape remained consistent. However, several studies of wild groupers reported an allometric growth pattern, such as for *E. fuscoguttatus* (b = 2.92) (Mustafa et al., 2015), and *E. malabaricus* (b = 3.08) (Gaspare & Bryceson, 2013). These results show that body proportions change as the fish grow, regardless of the growth rate. Several factors, like feeding regimes and water parameters, including temperature and salinity (Cao et al., 2023), might possibly affect the length and weight of fish, which may compromise the growth pattern. Variations in digestive efficiency and nutrient availability can influence whether the fish provide more energy to weight gain or length increase (Jobling et al., 2001). Additionally, the competition for the resources, genetic factors (Meng et al., 2014), and gut microbiota interactions (Zha et al., 2018) can also influence their growth pattern. Isometric growth was often a desirable growth pattern in the aquaculture industry, as it indicates a proportional body shape and healthy fish (Froese, 2006). The present study suggests that cultured *E. fuscoguttatus* can imitate the wild state of the grouper. Additionally, the controlled environment of the cage culture system significantly influences the growth development of fish (Tacon & Halwart, 2007). It is beneficial to culture fish in terms of minimizing predation and consistent access to feed (Njiru et al., 2019). Due to limited movement, it will reduce their energy expenditure, which will be spent on enhancing the growth of fish. The feeding regimes and limitations of fish movement in cultured conditions might alter the energy allocation between the length and weight of fish, which potentially leads to achieving the ideal isometric growth seen in the wild state. Therefore, the controlled environment, like the cage culture system,

offers a more manageable and safer environment for *E. fuscoguttatus.* It is important to continuously optimize and assess practices to align closely the growth pattern of fish with those observed in natural habitats, eventually promoting healthier, highly valuable, and marketable fish in cage culture systems.

The condition factor of *E. fuscoguttatus* from the present study, suggested that *E. fuscoguttatus* improved its overall condition more during captivity than the wild state at capture (Table 1). The study reported by Ramadhani et al. (2017) showed a condition factor of 1.82 for wild *E. fuscoguttatus* in northern Aceh, Indonesia, which is slightly lower than the value found in the present study. They suggest that the marine organisms in the wild support balanced ecological conditions and sufficient manageable predation pressure and prey supply. The research on hybrid groupers (*E. fuscoguttatus* × *E. lanceolatus*) has revealed varying condition factors, depending on environmental factors (Hu et al., 2024). In contrast with the study on *Oreochromis niloticus*, it presented that the wild state exhibited a higher value compared to cage culture (1.44 ± 0.1 and 1.38 ± 0.15) (Steve & Okeyo, 2019). The study of De et al. (2016) found that condition factors ranged from 2.08 to 2.32 in initial measurements and from 0.95 to 2.81 in final measurements, with significant variations at different temperatures and diets. Additionally, a reported study by Mustafa et al. (2015) with a condition factor of 1.86 for tiger grouper brood stock in a recirculating aquaculture system, indicated that well-managed aquaculture conditions can maintain fish health. To enhance the well-being and health of fish in cage culture, the water quality parameters necessarily need to be managed well (Steve & Okeyo, 2019). The results of previous studies highlight the influence of specific aquaculture practices and water quality parameters on fish condition. The analysis of the condition factor as observed after the culture period from the present study suggests that the controlled environment of the cage culture might provide beneficial effects such as consistent feed availability and reduced energy expenditure, and when properly managed it can promote healthier and more robust fish (Megarajan et al., 2022). In this case, it will create favourable conditions that support optimal growth and physiological health of fish. Moreover, the present study emphasized that the controlled environment of cage culture systems can positively influence the health condition of tiger grouper *Epinephelus fuscoguttatus and* make it a viable and sustainable solution for commercial grouper production.

Conclusions. Findings revealed that the length-weight relationship of *Epinephelus fuscoguttatus* lowered the b value (i.e., from 3.00 to 2.96) but indicated an isometric growth pattern for both wild fish at the beginning of the experiment and after they have been cultured for 90 days. This suggests a good growth of *E. fuscoguttatus* in cultured state. The condition factor of *E. fuscoguttatus* in this study exhibited a significantly higher value in cultured state (1.92) than the wild state (1.89) ($p < 0.05$). This finding suggested that cage culture can offer better conditions for fish health and growth if properly managed.

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Authors Contributions. Conceptualization: YUM, ANHK. Methodology: ANHK, YUM. Formal Analysis: ANHK, YUM. Investigation: ANHK, RJFR, SWHK. Data Curation: ANHK, YUM, RJFR, SWHK. Writing: ANHK, YUM. Original Draft: ANHK, YUM, RJFR. Writing – Review & Editing: ANHK, YUM, WMJ, GAJT, MQA, AAE, RJFR. Supervision: YUM, WMJ, GAJT, MQA, AAE, RJFR.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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