

Biological aspects of brown-marbled grouper (*Epinephelus fuscoguttatus*) from Taka Bonerate National Park, District of Selayar Islands, South Sulawesi, Indonesia

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Abstract. Fatma, Mallawa A, Najamuddin, Zainuddin M, Ayyub FR. 2022. Biological aspects of brown-marbled grouper (*Epinephelus fuscoguttatus*) from Taka Bonerate National Park, District of Selayar Islands, South Sulawesi, Indonesia. Biodiversitas 23: 1140-1153. Knowledge regarding biological aspects of fishes such as the brown-marbled grouper can provide important information for fisheries management. This research was conducted from February 2020 to February 2021 to determine the length-weight relationship, condition factor, gonad maturity stage and spawning pattern, size at first maturity and feeding habits of brown-marbled groupers in Taka Bonerate National Park. The sample caught comprised 1042 brown-marbled groupers with a total length (TL) range of 23-97 cm and a weight range of 0.5-17.6 kg. The length-weight equation was $W = 0.0001 \cdot L^{2.5955}$ ($R^2: 0.8935$). For male brown-marbled grouper ($n: 569$), TL range was 47-97 cm, weight range 1.65-17.60 kg, regression equation $W = 0.0002 \cdot L^{2.4731}$ ($R^2: 0.7716$), condition factor range 0.56-2.36 (mean 1.236 ± 1.019), and length at first maturity 66.34 cm. For female brown-marbled grouper ($n: 473$) TL range was 23-73 cm (mean 46.84 cm), weight range 0.50-6.6 kg (mean 2.23 kg), regression equation $W = 0.0007 \cdot L^{2.1057}$ ($R^2: 0.7416$), condition factor range 0.55-2.17 (mean 1.225 ± 1.018), and length at first maturity 45.43 cm. The growth pattern was negative allometric with regression coefficient $b < 3$ for both sexes separately and combined. The majority of both male and female fish caught had mature gonads with indications of a partial spawning pattern. The fish diet was carnivorous, predominantly piscivorous (74%), with gut contents comprising 64% unidentified fish and 26% unidentified decapod crustaceans. Over-exploitation of fish can cause negative impacts on populations, so the relationship between length and weight, condition factors and maturity level gonad of fish can be used in fisheries management.

Keywords: Condition factor, *Epinephelus*, feeding habit, length-weight

INTRODUCTION

The Taka Bonerate National Park is situated in the Flores Sea, with waters rich in fisheries resources. Local fishermen are still using traditional fishing gears and capture fish mainly in the traditional fishing zone, which has an area of 481,334 ha. This zone was designated for the benefit of the local communities who have used these marine resources for the needs of their generations. The utilization of reef fish resources by the local community should be in accordance with the agreements and provisions of the legislation in vigor (Taka Bonerate National Park Authority 2019). Andon fishing in Indonesia is a system whereby fishermen/fishing vessels from one administrative area in Indonesia can fish in waters under the aegis of another administrative area within Indonesia.

Many fishermen in coastal communities benefit directly from catching groupers (both live and dead grouper trades), which are important for their livelihoods and also contribute to national food security (Khasanah et al. 2019). The ever-increasing market demand and high economic value of groupers have led to an increase in fishing

intensity so that an increasing number of grouper stocks are vulnerable to extirpation (Cheung et al. 2013). There has been a decline in the abundance of many Indonesian grouper populations due to heavy fishing pressure (Halim et al. 2020; Khasanah et al. 2020). However, there is a lack of data on the biological aspects of brown-marbled grouper (*Epinephelus fuscoguttatus*) in Taka Bonerate National Park, South Sulawesi, Indonesia.

Based on the situation described above, research is needed on biological aspects of brown-marbled grouper is needed in the Taka Bonerate National Park, including their growth pattern, condition factor, gonad maturity stage, size at first maturity and spawning pattern, and eating habits. This study provides important basic data on the biological condition of fish in the Serranidae family, specifically brown-marbled grouper. These data can be used to inform policymaking and support the sustainable management of groupers in the waters of the Taka Bonerate National Park, Selayar Islands District, South Sulawesi Province, Indonesia.

MATERIALS AND METHODS

Study site and time

This research was conducted from February 2020 to February 2021 in the waters of the Taka Bonerate National Park, Selayar Islands District in the South Sulawesi Province, Indonesia (Figure 1). The Grouper fish samples were collected from fish landing sites (fishing bases). Grouper samples were caught using several fishing gears (i.e., hand line fishing, spearfishing, and trapping) with a total catch of 1042 specimens. Where local fishermen land their catch, as well as from fish collectors (intermediary traders), which were located in several islands in the Taka Bonerate National Park. The islands include, Pulau Rajuni, Pulau Jinato and Pulau Tarupa.

Collection and measurement of brown-marbled grouper samples

Fish samples were collected through the following fishing activities and visits to fish collectors. Brown-marbled grouper samples were selected using the Stratified Random Sampling method, in which the levels were fishing grounds, fish landing sites and fish size. The number of samples taken was adjusted to the catch volume

(Rahman et al. 2013); if many fish had been caught, the sample comprised 10% of the individual brown-marbled grouper caught if the catch was small, the fish caught were taken as samples.

Each fish was measured and weighed in the field (Figure 2). Total length (TL) was measured to the nearest mm using a tape measure or fish ruler from the tip of the snout to the tip of the tail fin. Digital scales were used to measure wet weight to the nearest 0.1 g. The samples were divided into five groups or length size classes based on TL.

Sample preservation and gut contents

For feeding habit analysis, the samples were preserved in a container filled with a 10% solution of formalin (Formaldehida) and transported to the Fish Parasite and disease Laboratory, Faculty of Marine Science and Fisheries, Universitas Hasanuddin in Makassar, Indonesia. Each sample was dissected to remove the digestive tract or gut (stomach and intestines) and reproductive organs (gonads). The contents of each gut were observed and the contents were identified, counted and weighed following the methods described in Natarajan and Jhingran (1961).

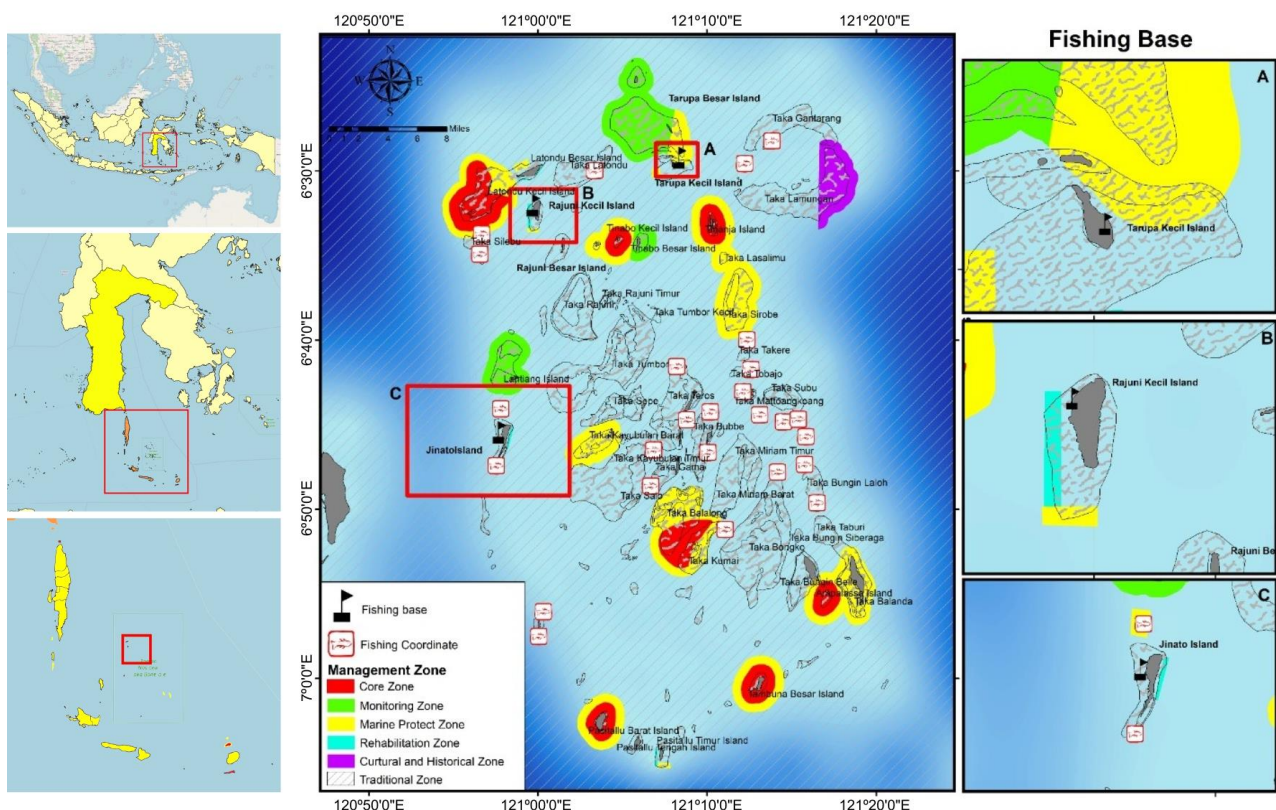


Figure 1. Map of the Study Sites in Taka Bonerate National Park. Red and white boxes indicate fishing grounds. Zone legend: Red: core zone; green: monitoring zone; yellow: marine protected zone; turquoise: rehabilitation zone; purple: cultural and historical protection zone; grey: land; uncolored (with blue depth scale): traditional fishing zone. (Source: Bakosurtanal published a landscape-scale 1:50.000 edition I map of Indonesia in 1991, the National Statistics Agency published a digital administrative map of Indonesia (Podes) SP_2016, and map of the spatial plans of the Selayar Islands District in 2016)



Figure 2. Measure of a brown-marbled grouper sample from the Taka Bonerate National Park, Selayar Islands, Indonesia. Bar: 5 cm

Gonad maturity stage

Each sample was dissected to remove the reproductive organs (gonads). The sample comprised 23 brown-marbled grouper based on the size class distribution of the total 1043 sample. The gonads of each specimen were weighed on digital scales with a precision of 0.001 g and preserved in 10% formalin. Each gonad was prepared for histological examination. The preserved gonads were dried and cut into sections then placed in 70% alcohol. Each sample was dehydrated in stages using alcohol, clarified using xylene, and fixed in paraffin. Slices of 6 micron in thickness were

stained with hematoxyline and eosin (Luna 1968; Panigoro et al. 2007). The prepared histological slides of each gonad were observed under a binocular microscope (Olympus CX23) to determine the gonad maturity stage using an adapted version of the gonad maturity stage description for brown-marbled grouper (Pears et al. 2007), as shown in Table 1.

Data analysis

Length-weight relationship

The length-weight relationship was calculated based on the formula in Ricker (2001):

$$W = a L^b$$

This formula was converted into the following linear equation through logarithmic transformation:

$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

Where, W: sampled fish weight (g); L: sampled fish length (cm); a: Intercept Log a: intercept so a: antilog (intercept); b: Slope (regression coefficient).

Table1. Gonad maturity stage classification for male and female brown-marbled grouper based on histological characteristics (Pears et al. 2007)

| GMS | Reproductive stage | Histological description |
|-----|------------------------------|---|
| F1 | Immature female | No evidence of prior spawning, ovary small and lamellae well-packed with gonial and previtellogenic oocytes (chromatin nucleolar and perinucleolar stages) |
| F2 | Mature resting female | Ovary dominated by pre-vitellogenic oocytes. Prior spawning is indicated by the presence of muscle bundles and occasional atretic vitellogenic oocytes. Ovary generally larger in diameter than those of immature females and maybe vacuolated |
| F3 | Undetermined inactive female | Ovary contains gonial and pre-vitellogenic oocytes but unable to determine if fish has spawned previously (mature) and is in a resting state or is an immature female |
| F4 | Mature ripening female | Stage 3 oocytes the most advanced oocyte present. May contain signs of prior spawning |
| F5 | Mature ripe female | Ovary in active vitellogenesis. Usually dominated by stages 3 and 4 oocytes, although early stages of oocytes also present in varying amounts |
| F6 | Mature near spawning female | Ovary in active vitellogenesis as ripe female but some oocytes have become hydrated (stage 5) indicating imminent spawning likely |
| F7 | Mature spent female | Ovary generally disorganized and undergoing atresia, with muscle bundles and extensive vascularization. Many contain brown bodies. Stage 2 oocytes the most advanced healthy oocyte present |
| | Transitional | Proliferating testicular tissue in a gonad that has evidence of prior spawning as a female (degenerating vitellogenic oocytes and muscle bundles), where spermatozoa have not yet proceeded to fill the dorsal sperm sinuses. Spermatogenesis has progressed at least to the spermatid stage, and areas of testicular tissue with clusters of spermatocytes, spermatids or spermatozoa present within lamellae and associated with the gonad wall. Ovarian tissue dominates and the most advanced healthy female germ cells are stage 2. Atretic and fragmenting oocytes may be present |
| M1 | Primary male | Proliferating testicular tissue in a gonad similar in appearance to an immature ovary, where spermatogenesis has progressed at least to the secondary spermatocyte stage. Ovarian tissue dominates the lamellae, which are not yet of the typical lobular form of the mature testes, and there are no signs of prior spawning as a female |
| M2 | Mature resting male | Testes are dominated by testicular tissue, which may contain crypts of gonial and spermatocytes. Later stages of spermatogenesis (spermatids and spermatozoa) rare or absent. Evidence of prior spawning as a male indicated by well-developed but collapsed major sperm ducts, which are now empty of sperm |
| M3 | Mature ripening male | Testes contain proliferating testicular tissue, including secondary spermatocytes, spermatids and spermatozoa, but major sperm ducts are not yet filled with sperm |
| M4 | Mature ripe male | Testes dominated by crypts of spermatocytes, spermatids and spermatozoa. Crypts of spermatozoa ruptured and joined within the testicular lobules, forming central sperm sinuses, and major sperm sinuses and ducts filled with sperm |
| M5 | Mature spent male | Testes disorganized and vacuolated with numerous brown bodies and well-developed stromal tissue. Some spermatozoa may still be present in lobules, but major sperm sinuses and ducts empty or collapsed |

The growth pattern of the brown-marbled grouper populations was obtained from the value of the regression coefficient b . $b = 3$: isometric growth, meaning a proportional increase in length and weight; $b > 3$: positive allometric growth, meaning weight increases faster than length; $b < 3$: negative allometric growth, meaning length increases faster than weight.

Condition factor

The condition factor is an indicator of the relative condition or fatness of an individual fish and can be calculated based on the length and weight data.

Based on Effendie (2002), if $b = 3$ (isometric growth), the condition factor K is calculated using the equation:

$$K = \frac{W}{L^3} \times 10^5$$

If $b \neq 3$ (allometric growth pattern), then the equation used is:

$$K = \frac{W}{aL^b}$$

Where, K : condition factor; W : measured weight (gram); L : total length (mm); a and b are the length-weight parameters for the population ($W: aL^b$).

The condition factor (K) tends to be in the range 2-4 for fish with slim bodies and in the range 1-3 for more round-bodied fish (Effendie 2002).

Size at first maturity and spawning pattern

The mean size at first maturity and spawning was calculated as the length at which 50% of fish had mature gonads and has spawned using the formula in King (1995) as follows:

$$P = 1/(1 + \exp^{-r(L-L_m)})$$

Where, P : proportion of fish with mature gonads or having spawned at a given length; LM_{50} : mean length at which 50% of fish had mature gonads; L : fish total length; r : curve slope angle.

Feeding habit

The gut content data were analyzed to determine the feeding habit and preference using the index of preponderance (IP) following Natarajan and Jhingran (1961) and Effendie (2002). The equation used was:

$$IPI = \frac{V_i \times O_i}{\sum (V_i \times O_i)} \times 100$$

Where, IPI : index of preponderance of the i^{th} food; V_i : percentage of the i^{th} food by volume; O_i : frequency of occurrence of the i^{th} food; $\sum V_i \times O_i$ = sum of ($V_i \times O_i$) for all food types.

The percentage by volume and frequency of occurrence of each food were calculated as follows:

$$V_i = \frac{\text{volume of food (prey) item } i}{\text{total volume of food (gut contents)}} \times 100$$

$$O_i = \frac{\text{the number of fish guts containing food (prey) } i}{\text{the number of all fish guts containing some food (prey)}} \times 100$$

The feeding habit analysis follows the method from Nikolsky (1963), divided the food items identified into three categories based on the IP value of each food (prey) type, $IP > 40\%$: main food; IP in the range 4-40%: complementary food; $IP < 4\%$: additional food.

RESULTS AND DISCUSSION

Length-weight relationship

The length-weight Relationships (LWR) of the brown-marbled grouper males, females, and both sexes combined sampled from the Taka Bonerate National Park are presented on a logarithmic scale (Figures 3-5). Descriptive statistics and LWRs for the brown-marbled grouper males, females, and both sexes combined are presented in Table 2.

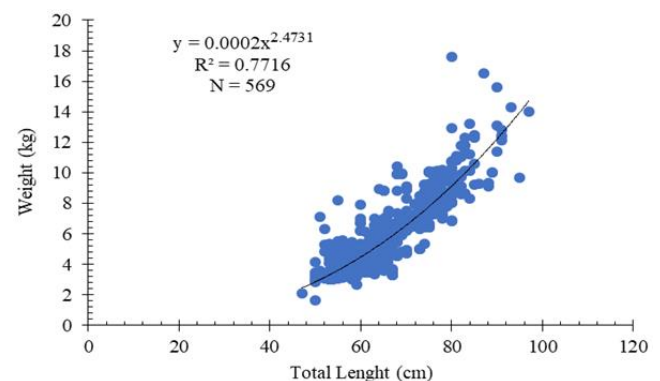


Figure 3. Length-weight relationship of male brown-marbled grouper (n: 569)

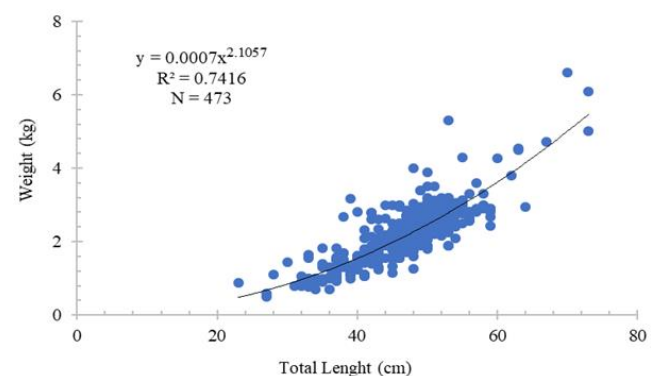


Figure 4. Length-weight relationship of female brown-marbled grouper (n: 473)

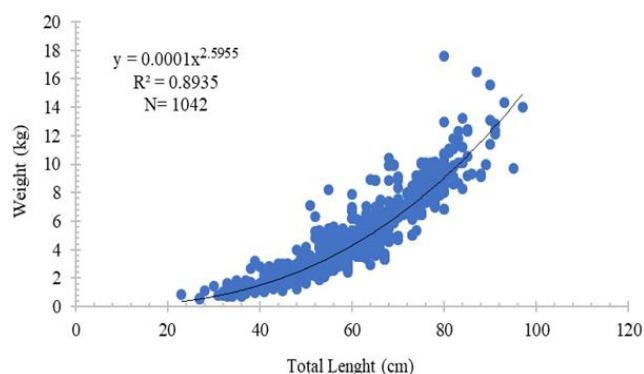


Figure 5. Length-weight relationships of brown-marbled grouper (both sexes combined, N: 1042)

A synopsis of the size range and length-weight relationship of brown-marbled grouper from Taka Bonerate National Park by sex and overall was shown in Table 2. The t-tests show that the values of b were all significantly different from 3 ($b \neq 3$; $t_{\text{score}} > t_{\text{table}}$). All these b values were less than 3, indicating an allometric negative growth pattern for this brown-marbled grouper population. The coefficient of determination (R^2) values indicates that the respective length-weight equations explain around 77% of the variation in weight for a given length for male groupers, 74% for female groupers, and 89% for both sexes combined.

Based on the results of the t-test data analysis to see if the value of $b = 3$ for male and female brown-marbled grouper, as well as combined data in the waters of Taka Bonerate National Park, it seems that the value of $b \neq 3$ ($t_{\text{score}} > t_{\text{table}}$) where brown-marbled grouper (combined) 2.59, male brown-marbled grouper 2.47, and female brown-marbled grouper 2.10 (Table 2). So the value of $b < 3$ is a negative allometric growth pattern for brown-marbled grouper (combined), male brown-marbled grouper, and female brown-marbled grouper. A significant difference ($P < 0.05$) was found in the brown-marbled grouper. As a result, the growth in length outpaces the increase in weight.

According to Ndiaye et al. (2015), differences in the length-weight relationship between male and female fish of

the same species have indicated that one sex gains weight faster than the other for a given increase in length. In this study, the values of b indicated that, relative to their length, male brown-marbled grouper gain weight were faster than females. This difference could be related to the size classes because the female groupers were mostly in smaller size classes than the males, and smaller fish tended to grow proportionally, which were faster in length than in weight compared to larger fish (Saputra et al. 2005). According to Effendie (2002), several factors can substantially affect the length and/or the weight and thereby indirectly influence the value of b . The length-weight parameters for brown-marbled grouper from Taka Bonerate National Park are compared with those for other brown-marbled grouper populations and other grouper species in Table 3.

The allometric negative growth pattern means that weight gain was not proportional to growth in length (Muchlisin et al. 2010). Allometric negative growth patterns have also been reported for brown-marbled grouper populations around Pulo Aceh in Aceh Province and for female brown-marbled grouper from Bobong, Taliabu in Maluku Utara Province (Ramadhani et al. 2017). Isometric growth patterns have also been reported for male brown-marbled grouper from Bobong Taliabu, Maluku Utara (Tangke et al. 2020) and hatchery-raised brown-marbled Grouper in Borneo, Malaysia (Mustafa et al. 2015). Similar to the data on brown-marbled grouper populations, the data for other grouper species in Table 3 showed wide variation in growth patterns.

Condition factor

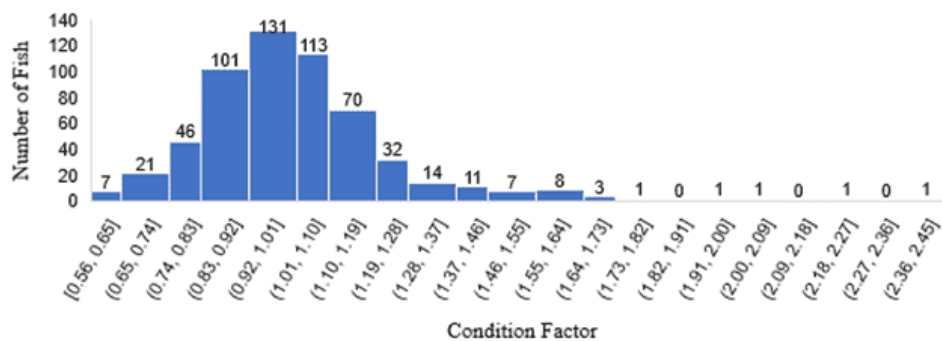
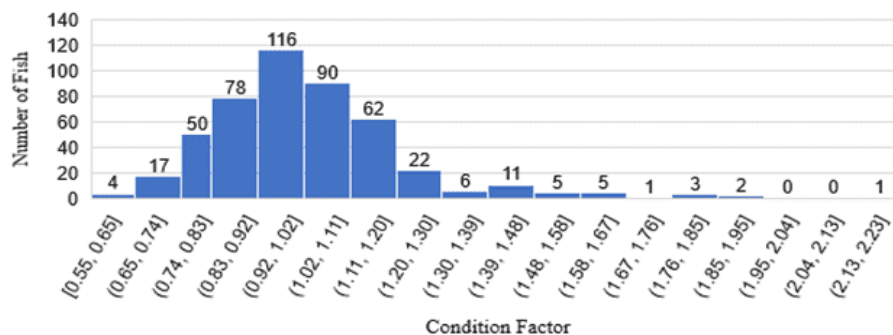
The condition factor (K) has reflected the fatness of an individual fish relative to the length-weight relationship for the population as a whole and generally has in the range 1-3 for round-bodied fishes and 2-4 for fish with laterally or vertically compressed body shapes (Effendie 2002). The condition factor K of brown-marbled grouper from Taka Bonerate National Park varied from 0.56-2.36 for males and 0.55-2.1 for females (Figure 6 and Figure 7). In general, values of K greater than 1 indicate that the fish is plump enough to be suitable for human consumption (Effendie 2002).

Table 2. Length-weight relationship of brown-marbled grouper from Taka Bonerate National Park, Selayar Islands, Indonesia by sex

| Parameter | Male | Female | Combined |
|--|--|--|---|
| Number of fish sampled | 569 | 473 | 1,042 |
| Total length range (cm) | 47-97 | 23-73 | 23-97 |
| Weight range (g) | 1.65-17.6 | 0.5-6.6 | 0.5-17.6 |
| Intercept coefficient | -3.7459 | -3.1857 | -3.9833 |
| Regression coefficient (b) | 2.4731 | 2.1057 | 2.5955 |
| Determination coefficient (R^2) | 0.7716 | 0.7416 | 0.8935 |
| Correlation coefficient (r) | 0.878 | 0.861 | 0.945 |
| Length-weight relationship regression equation | $W = 0.0002L^{2.4731}$ | $W = 0.0007L^{2.1057}$ | $W = 0.0001L^{2.5955}$ |
| t-test result | $t_{\text{score}} > t_{\text{table}(0.05;532)}$ $b \neq 3$ | $t_{\text{score}} > t_{\text{table}(0.05;506)}$ $b \neq 3$ | $t_{\text{score}} > t_{\text{table}(0.05;1041)}$ $b \neq 3$ |
| Growth pattern | Allometric negative | Allometric negative | Allometric negative |

Table 3. Length-weight relationship parameters reported for brown-marbled grouper and some other grouper species from various regions

| Site description | "a" | "b" | R ² | Growth pattern | Grouper species | Reference |
|---|---|----------------------------|----------------------------|---|---|------------------------------------|
| Taka Bonerate National Park, South Sulawesi, Indonesia | 0.0001 (combined) 0.0002 (male) 0.0007 (female) | 2.5955 2.4731 2.1057 | 0.8935 0.7716 0.7416 | Allometric negative Allometric negative Allometric negative | <i>Epinephelus fuscoguttatus</i> | <i>This study</i> |
| Other regions in Indonesia | | | | | | |
| Bobong Taliabu, Maluku Utara, Indonesia | 0.0098 (male) 0.0752 (female) | 3.14475 2.503 | 0.9252 0.90029 | Isometric Allometric negative | <i>E. fuscoguttatus</i> | Tangke et al. (2020) |
| Pulo Aceh, Aceh Besar District, Aceh, Indonesia | -12.34 -12.34 | 2.847 2.847 | 0.8199 0.8199 | Allometric negative Allometric negative | <i>E. fuscoguttatus</i> <i>E. bleekeri</i> | Ramadhani et al. (2017) |
| Padang City, West Sumatra, Indonesia | 0.0000315 (male) 0.0000386 (female) | 2.8613 2.8384 | | Allometric negative Allometric negative | <i>E. coeruleopunctatus</i> | Bulanin et al. (2017) |
| Kurau Fishing Port, Bangka Tengah District, Indonesia | 0.000668 (male) 0.010142 (female) | 3.87 3.0941 | 0.701 0.9379 | Isometric Isometric | <i>Plectropomus leopardus</i> | Fitrianisa et al. (2020) |
| Other countries | | | | | | |
| Borneo Marine Research Institute Hatchery, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia | -1.5855 | 2.9185 | 0.950 | Isometric | <i>E. fuscoguttatus</i> | Mustafa et al. (2015) |
| Coastal waters of Pulau Mafia, Tanzania | 0.0116 | 3.08 | 0.985 | Isometric | <i>E. malabaricus</i> | Gaspare and Bryceson (2013) |
| Southwestern coast of Senegal | 0.006 0.006 0.013 | 2.99 3 2.96 | 0.97 0.98 0.98 | Isometric Isometric Isometric | <i>E. aeneus</i> | Ndiaye et al. (2015) |
| Southwestern India | 0.002 | 2.89 | | Allometric negative | <i>E. diacanthus</i> | Ramachandran and Ramalingam (2020) |

**Figure 6.** Condition factor K of male brown-marbled grouper (n: 569)**Figure 7.** Condition factor K of female brown-marbled grouper (n: 473)

The histograms (Figures 6 and 7) showed that the most frequent condition factor class for male brown-marbled grouper was $K = 0.9203-1.0103$ (23.0%), followed by $K = 1.0103-1.1003$ (19.8%). For female brown-marbled grouper the predominant class was $K = 0.9248-1.0178$ (24.5%) followed by $K = 1.0178-1.1108$ (19.0%). The distributions for both sexes showed a long right-skewed tail, with a small number of exceptionally plump individuals. Overall, throughout the study period, the male groupers sampled tended to have a higher condition factor than female groupers, while condition factor also varied with size, tending to increase with fish length. Seasonal variations in K values were likely linked to reproductive activity, as gonad maturity and spawning affect condition factors, especially for females as ripe ovaries tend to represent a greater proportion of body weight and vary more in weight over the reproductive cycle than testes (Effendie 2002).

Similarly, to growth, the condition factor can be affected by both internal and external factors. These can include general and seasonal environmental conditions, food availability and parasitism, stress levels, gonad development and reproductive cycles, as well as feeding patterns and activity, all of which can have a major effect on fish health and affected condition factor (Zargar et al. 2012; Awasthi et al. 2015). Furthermore, condition factor data can provide information on factors such as prey availability, fish density, climatic conditions, fish behavior and spawning or reproductive cycles (Ighwela et al. 2011). Fluctuations in the mean condition factor values for both male and female fish were caused by non-uniform individual weights in each length class. These differences in K between fish with the same body length could be due to several factors, including feeding (e.g., current gut fullness or recent success in finding prey) and reproduction (gonad maturity stage and spawning cycle stage), as ripe gonads are heavier than immature or spent gonads.

Gonad maturity stage

Gonad maturity stage can be used to estimate the reproductive status of a fish, the size and age at first maturity within a given species or population, and the

proportion of mature individuals within a stock, as well as to improve understanding of the reproductive cycle of fish species or population (Sulistiono et al. 2001). Gonad maturity stage is very important in research on fish population biology because it can be used to determine the ratio between fish with ripe gonads and immature gonads within the population, spawning size, spawning seasons as well as spawning cycles and patterns (Effendie 2002). Recording changes in the level of maturity can indicate whether the fish will spawn, have just spawned or have finished spawning. Research of brown-marbled grouper populations on the Great Barrier Reef, Australia, has suggested that both gonad morphology and demographic data strongly indicated monandric protogynous hermaphroditism in this species (Pears et al. 2007). In particular, they have found that “younger age groups contained only immature and mature females, and all males were above the size and age of 100% female maturity, consistent with secondary males derived from mature females by adult sex change”. As protogynous hermaphrodites, at least some brown-marbled grouper under-go a gonadal differentiation process from the mature female phase to the mature male phase.

Male gonads (Testes)

Histological observations on the gonad maturity stage (GMS) of sampled male brown-marbled grouper were presented (Figures 8-11). Based on the histological characteristics (Pears et al. 2007), the histological examination of male brown-marbled grouper gonads (testes) showed that most fish were in the mature ripe male stage (Figure 8) with gonads contained proliferating testicular tissue, including the development of secondary spermatocytes, spermatids, and spermatozoa (Figure 9). In the tubule lumen, the tubules were lined with cells that would later develop into sperm cells (spermatozoa or male gametes). The developing sperm travel through the tubules (Figures 10 and 11). An empty peripheral sperm duct was seen, and histological examination of the level of testicular development shows that connective tissue was more dominant; spermatogonia are attached to the cell membrane and some have developed primary spermatocytes (Figure 10).

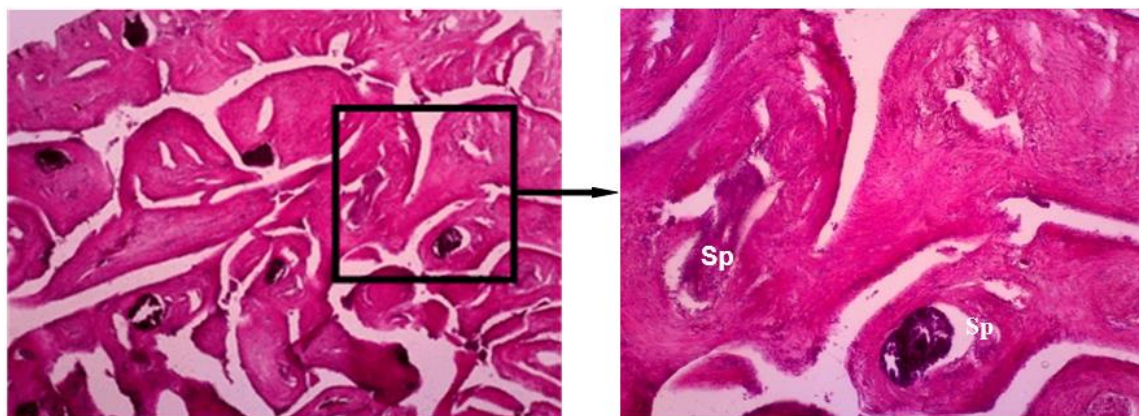


Figure 8. Testis of a mature ripe male brown-marbled grouper at 400 x magnification (TL: 78cm, W: 9.24 kg). Sp: spermatocytes

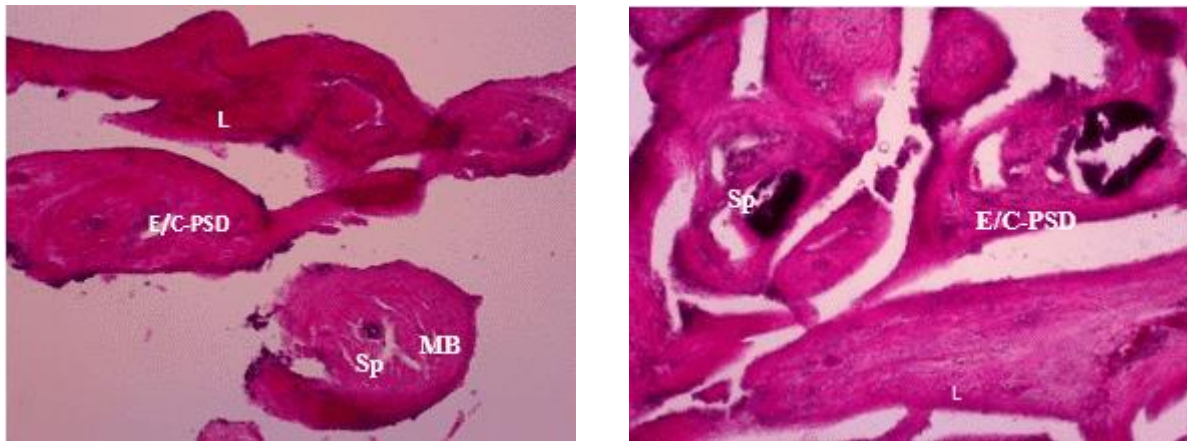


Figure 9. Testis of a mature ripe male stage male brown-marbled grouper at 100x magnification. Sp: spermatocytes; L: lobules; E/C-PSD: empty peripheral sperm duct; MB: muscle and connective tissue bundle

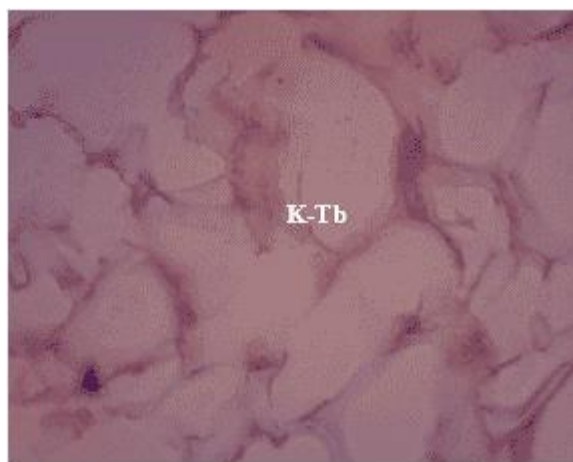


Figure 10. Testis of a ripening male stage male brown-marbled grouper at 100x magnification (TL: 37cm; W: 1.03kg). K-Tb: tubule lumen

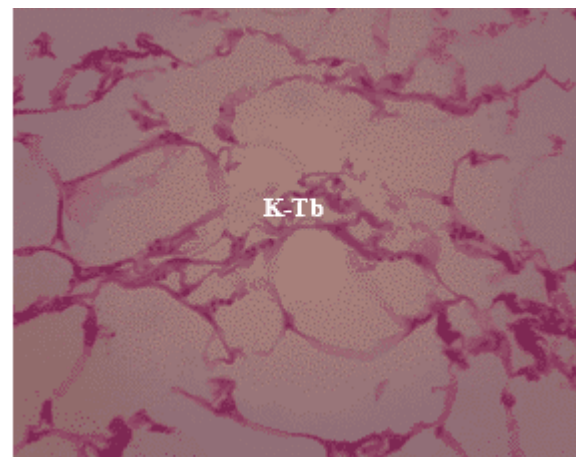


Figure 11. Testis of a ripening male stage male brown-marbled grouper at 100x magnification (TL: 56cm; W: 3.20kg). K-Tb: tubule lumen

Female Gonads (Ovaries)

Based on the histological characteristics (Pears et al. 2007), the histological examination of female brown-marbled grouper gonads (ovaries) showed that the female groupers had ovaries in several stages of gonadal development (Figures 12-19). The gonad maturity stages observed included immature females with small ovaries, lamellae well-enclosed with previtellogenic gonio and oocytes (chromatin-nucleolar and perinucleolar stages) and oocytes in stage 1 or stages 1 and 2 (Figures 12 and 18) through to mature ripe females with oocytes in stages 1 to 4 (Figure 16) or 1 to 5 (Figures 13 and 19). In the mature ripening female stage, the most advanced oocytes were in stage 3 (Figures 15 and 17). The mature ripe female stage was characterized by ovaries with active vitellogenesis, usually dominated by stage 3 and 4 oocytes. Some gonads showed signs of spawning, such as atretic vitellogenic oocytes (AVO) and muscle and connective tissue bundles (MB) (Figure 19).

Size at first maturity and spawning

The length at first maturity is very important in fish stock management because it can be used to determine the size of the mesh used to catch the fish. However, factors such as the availability of food can affect the length at which fish gonads mature and vary between species, populations, between males and females of the same species/population, and between individuals (Dahlan et al. 2015). The mean size at first maturity for brown-marbled grouper in Taka Bonerate National Park was calculated using the formula in King (1995) for male brown-marbled grouper (Figure 21) and female brown-marbled grouper (Figure 22).

The mean size at first maturity (L_m) is a key parameter for determining the smallest allowable catch size for a given species or population. Furthermore, estimating size at first maturity is one way to determine stock condition. Fish stock abundance and size may decline if the fish caught are about to spawn or are immature fish that have not yet spawned, so preventive measures are needed, such as the

use of selective fishing gear such as mesh size adjusted to the target fish allowable catch size (Dahlan et al. 2015). The analysis results showed that, on average, brown-marbled grouper in Taka Bonerate National Park reach

maturity as females at 45.43 cm TL and as males at 66.34 cm TL. These values were compared to length at first maturity for other brown-marbled grouper populations and other grouper species in Table 4.

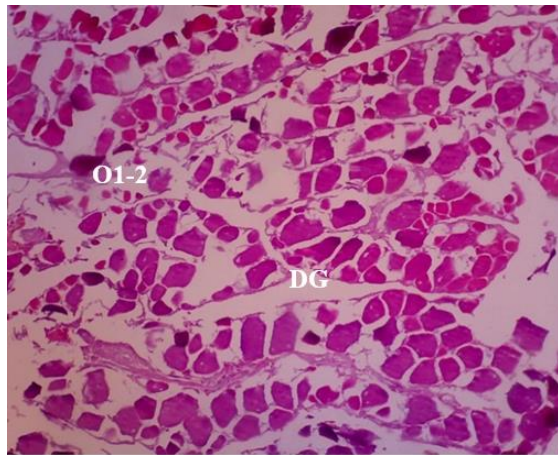


Figure 12. Immature female with oocytes in stages 1-2, DG: Gonad Wall

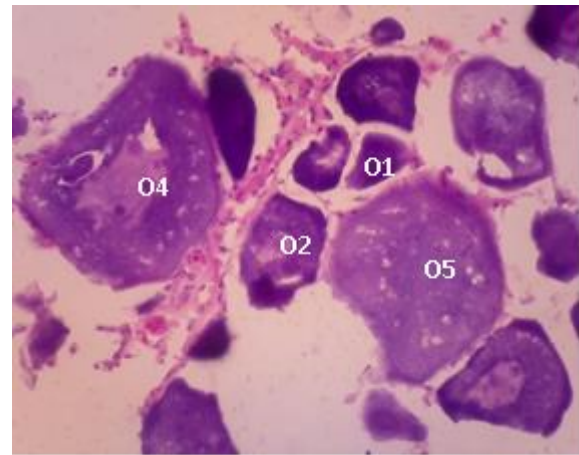


Figure 13. Mature ripe female with oocytes in stages 1-5. DG: Gonad wall

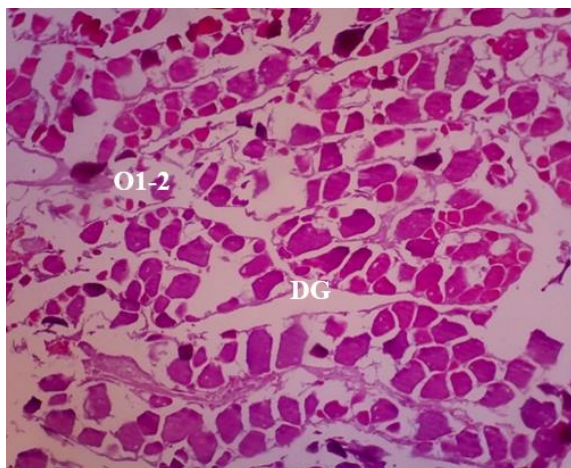


Figure 14. Mature ripe female with oocytes in stages 1-4

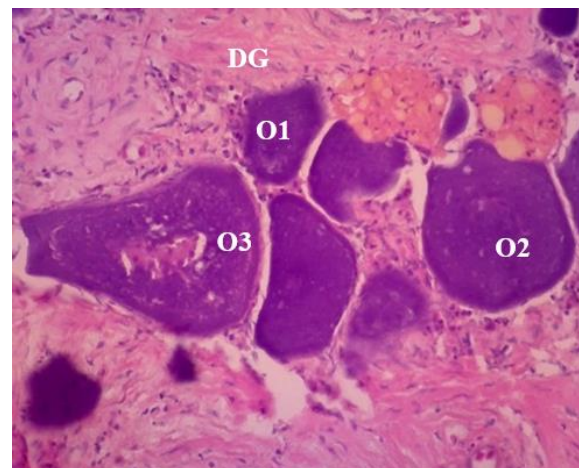


Figure 15. Mature ripening female with oocytes in stages 1-3

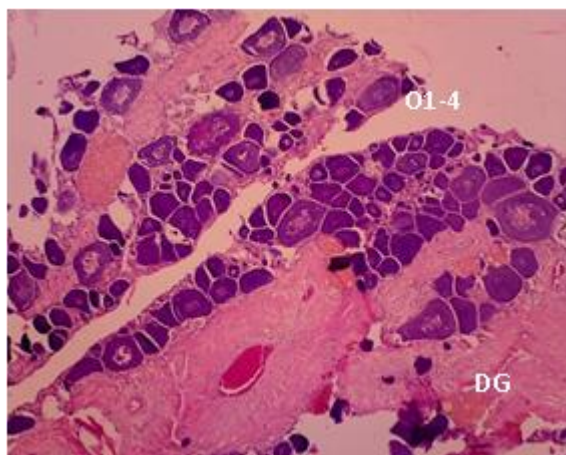


Figure 16. Mature ripe female with oocytes in stages 1-4. DG: gonad wall

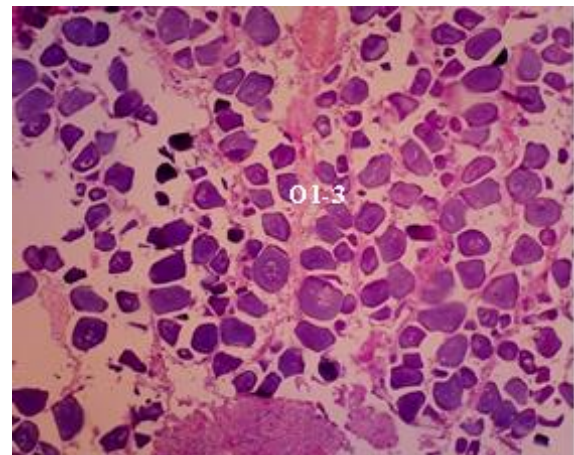


Figure 17. Mature ripening female with oocytes in stages 1-3

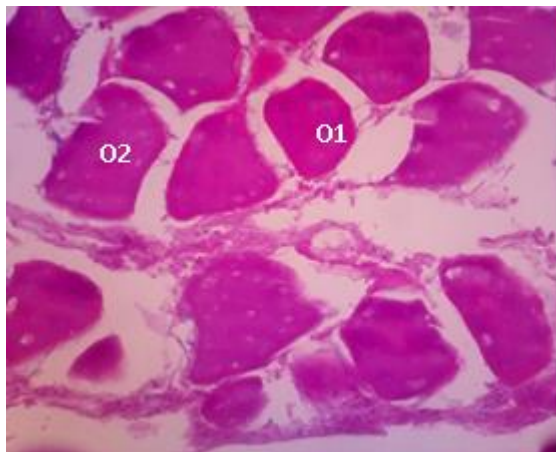


Figure 18. Immature female with oocytes in stages 1-2

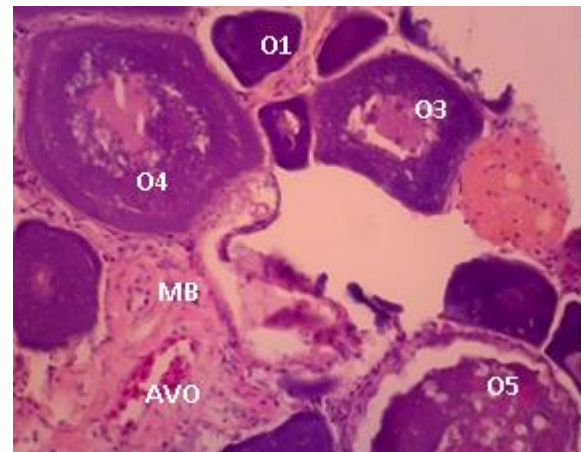


Figure 19. Mature ripe female with oocytes in stages 1-5. AVO: atretic vitellogenic oocytes; MB: muscle and connective tissue bundles

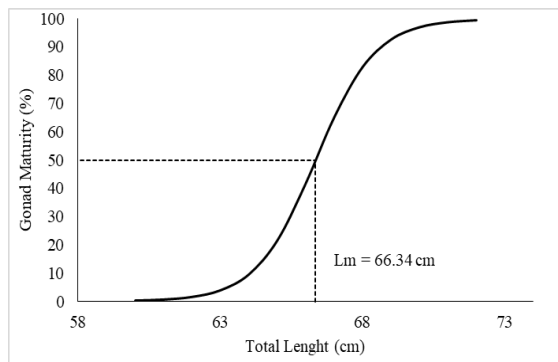


Figure 20. Mean size at first maturity for male brown-marbled grouper in Taka Bonerate National Park, Selayar Islands, Indonesia

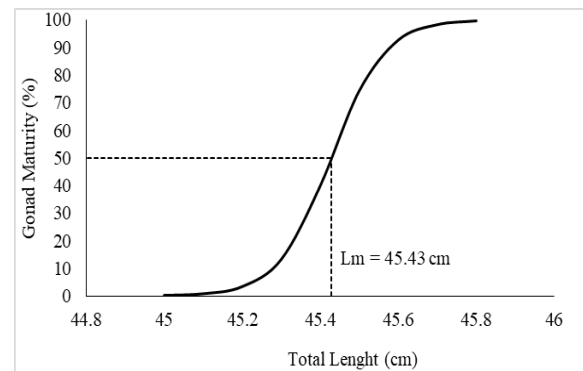


Figure 21. Mean size at first maturity for female brown-marbled grouper in Taka Bonerate National Park, Selayar Islands, Indonesia

Table 4. Mean length at first maturity for brown-marbled grouper populations and other grouper species in Indonesia

| Location | Species | Mean length at first maturity (cm) | | Reference |
|--|----------------------------------|------------------------------------|---------------|------------------------|
| | | Female | Male | |
| Taka Bonerate National Park Indonesia (unknown sites) | <i>Epinephelus fuscoguttatus</i> | 45.43 | 66.34 | This study |
| | <i>E. fuscoguttatus</i> | 51 (3 kg) | 60 (7 kg) | Slamet et al. (2001) |
| | <i>E. coioides</i> | 55 (4 kg) | 72 (10 kg) | |
| | <i>Cromileptes altivelis</i> | 36 (1 kg) | 48 (2.5 kg) | |
| Indonesia (unknown sites) | <i>C. altivelis</i> | 42 (1 kg) | 48 (1.8 kg) | Slamet et al. (2004); |
| | <i>E. fuscoguttatus</i> | 51 (2.1 kg) | 60 (7 kg) | Slamet et al. (2010) |
| | <i>E. tauvina</i> | 55 (4 kg) | 72 (10 kg) | |
| | <i>E. polyphkadion</i> | 38 (1.5 kg) | 42 (2 kg) | |
| | <i>E. fasciatus</i> | 26 (0.3 kg) | 35 (0.8 kg) | |
| Takalar District | <i>E. areolatus</i> | 23 (0.223 kg) | 29 (0.284 kg) | Sitepu (2014) |
| Taka Bonerate National Park | <i>E. polyphkadion</i> | 885.9 (g) | | Khasanah et al. (2019) |
| Wakatobi National Park | <i>E. polyphkadion</i> | 1058.4 (g) | | Khasanah et al. (2019) |

Feeding habit

The food items identified in the guts of brown-marbled groupers from Taka Bonerate National Park were described in Table 5. The Index of Preponderance (IP) indicates which food items predominate in the diet of the fish sampled (Nikolsky 1963). The Index of Preponderance

values for each of the food items identified in the guts of brown-marbled grouper from Taka Bonerate National Park were shown in Figure 22. The parameters and values from which the index of preponderance for brown-marbled grouper (*E. fuscoguttatus*) from Taka Bonerate National Park were shown Table 6.

Table 5. Food items found in the guts of brown-marbled grouper from Taka Bonerate National Park, South Sulawesi Province, Indonesia




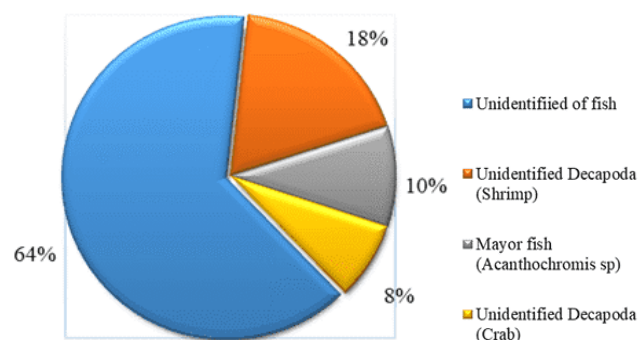
| No | Category and description | Example |
|----|---|---|
| 1 | Unidentified fish Unidentified fish or fish body parts such as heads, parts of the body, tails or bones |  |
| 2 | Unidentified decapods (shrimps) Whole shrimp or shrimp body parts such as heads, parts of the body or carapace which could be identified | |
| 3 | Major group fish Fish (<i>Acanthochromis</i> sp) identified as belonging to the major group |  |
| 4 | Unidentified decapods (crabs) Crab carapace or body parts |  |

Table 6. Index of Preponderance (IP) for each food type identified in the guts of brown-marbled grouper from Taka Bonerate National Park, Kepulauan Selayar District, South Sulawesi Province, Indonesia

| Food type | Vi | Oi | Vi x Oi | IP | Food category |
|---|--------|-----|---------|---------|---------------|
| Unidentified fish | 4.6981 | 100 | 469.81 | 63.955 | Main |
| Unidentified Decapods (shrimp) | 1.3424 | 100 | 134.24 | 18.275 | Complementary |
| Major group fish (<i>Acanthochromis</i> sp.) | 0.7366 | 100 | 73.66 | 10.028 | Complementary |
| Unidentified Decapods (crabs) | 0.5687 | 100 | 56.87 | 7.742 | Complementary |
| Total | | | 787.48 | 100.000 | |

**Figure 22.** Index of preponderance of food items found in the guts of brown-marbled grouper from Taka Bonerate National Park, Kepulauan Selayar District, South Sulawesi Province, Indonesia

Based on the Index of Preponderance, the brown-marbled grouper in Taka Bonerate National Park were carnivorous and predominantly piscivorous, with a prevalence of 100% for all four food types identified. Overall, unidentified fish comprise more than half of their diet (64%), with a further 10% of a single major fish group genus, the spiny chromis *Acanthochromis* sp. According to Fish Base (Froese and Pauly 2021), this genus is comprised of just one species *A. polyacanthus* and is a reef-associated fish with a wide distribution in Western Pacific, from Indonesia and the Philippines to northeastern Australia and Melanesia. The remaining two food types were both decapod crustaceans, with shrimp contributing more than twice as much as crabs to brown-marbled grouper gut contents. However, like the spiny chromis *Acanthochromis* sp., with reference to Nikolsky (1963) both types of

decapods contributed more than 4% and were thus classified as complimentary food items, with no additional food items identified. Non-food items or entrained matter found in the brown-marbled grouper guts included fragments of coral fragments and of the seagrass *Enhalus acoroides*.

The feeding habit of brown-marbled grouper in Taka Bonerate National Park is similar to that reported for other groupers. Research on the Malabar grouper (*Epinephelus malabaricus*) by Badhul et al. (2015) in the bays of Palk and Mannar found this grouper to be carnivorous while also reporting macro plankton in the gut contents; the Malabar grouper diet was dominated by fish, with other types of food including crabs, shrimp and squid (*Sepia* sp.). These prey items tend to be available or abundant throughout all seasons. In addition, microplankton such as juvenile copepods, zoea stage larvae, *Lucifer* sp., the larvae of *Alima* sp., and other crustaceans were also found.

In conclusion, the length-weight relationship of brown-marbled grouper in the waters of Taka Bonerate National Park, Selayar Islands District, South Sulawesi Province, shows a negative allometric growth pattern, where an increase in length is faster than weight gain. The condition factor (K) was in the range of ≈ 0.55 to 2.37 overall, ≈ 0.56 to 0.37 for male brown-marbled grouper and ≈ 0.55 to 2.17 for female brown-marbled grouper. The gonad maturity stage (GMS) of male brown-marbled grouper was dominated by the mature ripe male stage; female brown-marbled grouper GMS ranged from immature to fully mature, with the majority of gonads sampled in the mature ripe female category. Size at first maturity for brown-marbled grouper in Taka Bonerate National Park was 45.43 cm for females and 66.34 cm for males of this protogynous hermaphrodite. Brown-marbled grouper eating habit is carnivorous, predominantly piscivorous (74%), with the main food item being unidentified fish (64%). Some management and monitoring strategies for grouper fisheries were needed, such as limited groupers fishing activities so that fish have not spawned are not caught. This will be useful for further fisheries management of grouper.

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