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# Species Composition and Growth Pattern of a Multi-Species Grouper in Kwandang Bay, Sulawesi Sea, Indonesia

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## Abstract

Grouper fishery has been the source of income for 3,700 fishermen in Kwandang Bay. Since 2017, grouper populations in Kwandang have been depleting due to the absence of management. This research aimed to analyze species composition, length-weight relationship, and condition factor of the groupers. Samples were collected from fishers who caught the fish using traps, speargun, and handline. Samples were identified through a method by Heemstra and Randall, while the length-weight relationship was estimated using log-linear regression and t-test. The number of specimens identified during January - December 2021 was 1,571 individuals. Research showed that those samples consisted of 26 species under eight genera. Six species found in Kwandang Bay were showing trends of decreasing populations and two species were vulnerable based on the IUCN conservation list. Length-weight relationship analysis of 14 grouper species resulted in b value ranging from 1.6359 to 3.4417 and $R^2$ ranges from 0.7718 to 0.9858. A significant test at a 95% confident interval showed that 14 species had an isometric growth pattern. Fulton condition factors show that Kwandang Bay is an essential habitat for groupers, and the bay can support the fish growth due to the adequate food availability.

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## 1. Introduction

As the world population increases, the demand for food and nutrition, such as fish resources, also increases. One of the fish resources with steady demand increase over the years is groupers (Jefri *et al*., 2015). Groupers are economically important fish (Bawole *et al*., 2017; Nanami *et al*., 2017; Osman *et al*., 2018) and the most exploited group in the reef fish trade (RRF) due to their high price and meat quality (Tupper and Sheriff, 2008). Hongkong has been the largest export destination of groupers in the world (Palm *et al*., 2015). In 2009, groupers trading contributed to more than 275,000 tons of the total captured fishery production, which increased up to a quarter of the volume in the consecutive year (Sadovy and Erisman, 2012).

Indonesia is one of the largest producers of groupers in the world, and this sector has provided livelihood for coastal people (Khasanah *et al*., 2019). Grouper exports from Indonesia constitute 50% of total imports in Hongkong market (Palm *et al*., 2015). In Indonesia, Gorontalo is one of the provinces that produce groupers, wherein these fish are called *Goropa* by locals (Achmad *et al*., 2020). Most of the groupers in the province come from the wild fishery in Kwandang Bay. Trading volumes for groupers in Gorontalo steadily increased from 2010 to 2014, with the most significant volume of more than 62 tons in 2014. However, this trend did not last since the production declined in 2015 where the tonnage produced by grouper fishery only reached 25,851 tons in 2019 and fell even more to 18,809 tons in 2021 (Achmad *et al*., 2017; Gorontalo Utara Fisheries and Marine Service, 2022).

The declining trend of the catches in Kwandang Bay is consistent with the reports from some other fishing grounds in Indonesia, such as Bangka Island (Adibrata *et al*., 2018), Saleh Bay (Efendi *et al*., 2020), Takabonerate National Park Waters (Fatma *et al*., 2021), and Sumbawa (Hilyana *et al*., 2021). Other groupers producing countries also reported similar trends (Kaunda-Arara *et al*., 2003; McClenachan, 2009; Giglio *et al*., 2014; Mavruk, 2020).

Based on a supply and demand model, fishing pressure is identified as the major contributor to the grouper population decline. Other biological aspects are also suspected to be the leading cause of supply shortages, such as low reproductive biology, longevity which is embedded by the late maturation, and fish aggregation during spawning seasons (Sadovy and Erisman, 2012). The situation was not made any better by the previous research, which only focused on particular species in Kwandang Bay, such as orange-spotted groupers the *Epinephelus coioides* (Achmad *et al*., 2019a; 2020; 2021), while many other grouper species remain understudied. The lack of scientific baseline data for most grouper species makes monitoring to this group of fish becomes difficult. There is also evidence that the fishery is switching to the previously-unexploited species and fishing efforts have shifted to deeper waters and more remote areas (Sadovy *et al*., 2020; Sala *et al*., 2022).

As one of the main fishing grounds of groupers in Indonesia, where multispecies of groupers were often caught, it is essential to establish a well-investigated database for Kwandang Bay grouper populations to allow management effort and monitoring. In this context, the aims of the study are (i) to provide primary inventory data of grouper species inhabiting Kwandang Bay and their conservation status through identification and determination of the composition of the fish; (ii) to establish the growth pattern of grouper species which is crucial for further population study through length-weight relationship and Fulton Condition; (iii) to assess the fitness and the importance of Kwandang Bay as the habitat of groupers. The information provided in this study can help fishery scientists and managers to identify future research areas and determine management measures for grouper fishery in Kwandang Bay.

## 2. Materials and Methods

### *2.1 Study Area and Data Collection*

Kwandang Bay is situated in the Kwandang subdistrict of the Northern Gorontalo Regency, bordering with the Philippines to the north (Figure 1). The bay consists of nine islands (Aswandy, 2007) which sits within a 30,000 Ha bay area (Moore, 2017). It is a very busy water due to high economic activities in the area (Olii *et al*., 2015a). The bay hosts Pelabuhan Perikanan Nusantara (type B fish landing port) (Sugihartanto and Rahmat, 2018), which can accommodate fishing vessels with sizes of 15-60 GT. Then, fishing vessels that are operated nationally or within the exclusive economic zone (Ministry of Marine Affairs and Fisheries' regulation number: PER.16/MEN/2006) also functioned as an inter-island transportation hub in the region (Olii *et al*., 2015b).

Three types of habitats are found in the bay, i.e., mangrove, seagrass meadows, and coral reefs around the islands making the bay a unique ecosystem (Triyanti *et al*., 2017; Moore, 2017). Fishing ground for the groupers occurs in the coral reef habitats of Mohinggito Island, Malambe Island, Saronde Island, and Lampu Island (Achmad *et al*., 2019b).

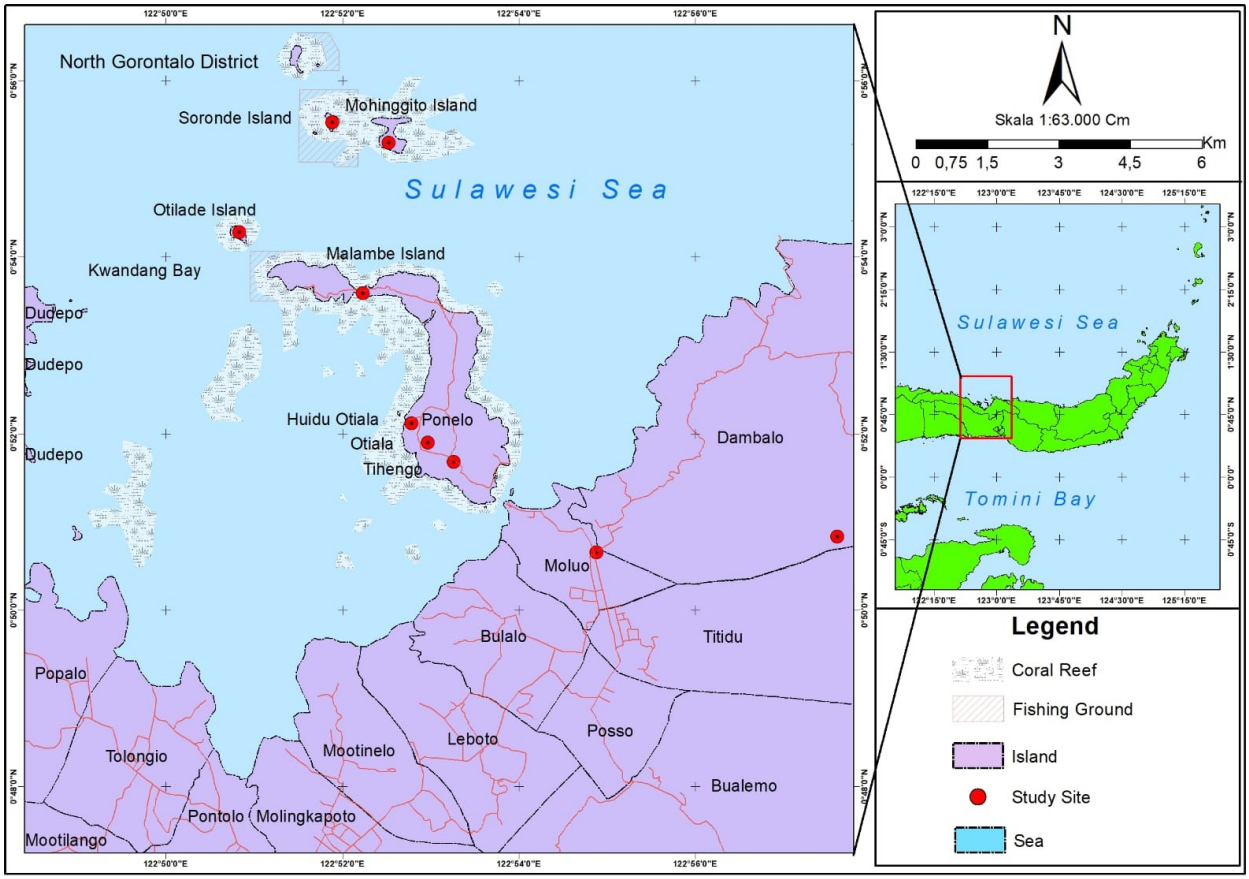


**Figure 1**. Study site showing fishing ground of groupers in Kwandang Bay

The research was conducted from January to December 2021. The sampling took place twice a month. Samples were collected from the fishers who caught the fish using traps, spearguns, and handlines. To amplify the data, fish were also collected from local middlemen (brokers). Samples were stored in an ice cool box and were transported to the Fish Biology Laboratory of Muhammadiyah University of Gorontalo.

The total length of samples was measured using a ruler with 1 mm accuracy and weighted using a digital scale with 0.1 grams accuracy. Fish was identified based on measurements provided by Heemstra and Randall (1993). Conservation status was verified with International Union for the Conservation of Nature and Natural Resources (IUCN) Red List.

*2.2 Data Analysis*

The length-weight relationship was calculated using log-linear regression formula of Le Cren (1951):

$$W = aL^b$$

The formula above was linearized using log linear transformation into the following formula (Jisr *et al.*, 2018):

$$\log(W) = \log(a) + b\log(L)$$

where:
W : weight
L : total length
a : intercept (regression coefficient)
b : the slope

The value of b was compared with the value of b as a hypothesis (b=3) using the t-student test to identify growth pattern. Fish follows an isometric growth pattern when b=3 and follows an allometric growth pattern when b≠3.

Condition factor was computed with the following formula (Froese, 2006):

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

where:
K : the Fulton condition factor
W : the weight (gram)
L : the total length (mm) and 100 is a rounding coefficient in order to bring the value to unity

**Table 1**. Species composition of grouper in Kwandang Bay

| Species | Common Name | n | Total Length (cm) | Maximum Length (cm)[a] | Status in IUCN Red List |
|---|---|---|---|---|---|
| *Aethaloperca rogaa* | Redmouth Grouper | 21 | 13.4 – 37 | 60 | LC[c] |
| *Anyperodon leucogrammicus* | Slender Grouper | 50 | 26 – 40 | 52 | LC[d] |
| *Cephalopholis argus* | Peacock Grouper | 31 | 19 – 40 | 55 | LC[e] |
| *Cephalopholis cyanostigma* | Blue Spotted Hind | 47 | 26 – 43 | 30 | LC[f] |
| *Cephalopholis miniata* | Coral Hind | 36 | 17 – 65 | 40 | LC[g] |
| *Cephalopholis sexmaculata* | Six-blotch Hind | 46 | 15 – 50 | 48 | LC[h] |
| *Cephalopholis sonnerati* | Tomato Hind | 47 | 28 – 45 | 57 | LC[i] |
| *Cephalopholis urodeta* | Darkfin Hind | 10 | 16 – 20 | 28 | LC[j] |
| *Cromileptes altivelis* | Humpback Grouper | 62 | 18.7 – 53 | 70 | DD[k] |
| *Epinephelus areolatus* | Areolate Grouper | 85 | 21.5 – 43.5 | 40 | LC[l] |
| *Epinephelus bleekeri* | Duskytail Grouper | 13 | 25 – 45 | 76 | DD[m] |
| *Epinephelus corallicola* | Coral Grouper | 46 | 18 – 48 | 49 | LC[n] |
| *Epinephelus coioides* | Orange-spotted Grouper | 170 | 20.1 – 71.5 | 95 | LC[o] |
| *Epinephelus caeruleopunctatus* | Whitespotted Grouper | 49 | 26 – 47 | 59 | LC[p] |
| *Epinephelus fasciatus* | Blacktip Grouper | 86 | 15 – 36 | 40 | LC[q] |
| *Epinephelus fuscoguttatus* | Brown-marbled Grouper | 27 | 15 – 72 | 95 | VU[r] |
| *Epinephelus faveatus* | Barred-chest Grouper | 95 | 14 – 50.8 | 32 | LC[s] |
| *Epinephelus maculatus* | Highfin Grouper | 53 | 18 – 49 | 50[b] | LC[t] |
| *Epinephelus morrhua* | Comet Grouper | 26 | 28 – 43 | 73 | LC[u] |
| *Epinephelus ongus* | Specklefin Grouper | 64 | 14.9 – 49 | 40 | LC[v] |
| *Gracila albomarginata* | Masked Grouper | 50 | 27 – 40 | 38 | LC[w] |
| *Plectropomus areolatus* | Squaretail Coralgrouper | 48 | 27 – 70 | 60[b] | VU[x] |
| *Plectropomus leopardus* | Leopard Coral Grouper | 73 | 17.9 – 60 | 70 | LC[y] |
| *Plectropomus oligacanthus* | Highfin Coral Grouper | 44 | 16.5 – 41 | 75 | LC[z] |
| *Variola albimarginata* | White-edged Lyre Tail | 222 | 18 – 53 | 47 | LC[aa] |
| *Variola louti* | Yellow-edged Lyretail | 70 | 17 – 46 | 81 | LC[ab] |

[a]Heemstra and Randall (1993); [b]standard length, LC = Least Concern; DD = Data Deficient; VU = Vulnerable; [c]Rhodes *et al.* (2018b); [d]Rhodes (2018a); [e]Choat *et al.* (2018b); [f]Choat (2018); [g]Rocha (2018); [h]Sadovy and Boon (2018a); [i]Sadovy and Boon (2018b); [j]Cabanban (2018); [k]Sadovy *et al.* (2018a); [l]Nair and To (2018); [m]Law *et al.* (2018a); [n]Rhodes *et al.* (2018a); [o]Amorim *et al.* (2018); [p]Fennessy (2018); [q]Law (2018); [r]Rhodes *et al.* (2018c); [s]Russell (2018); [t]Rhodes and Sadovy (2018); [u]Barreiros (2018); [v]Rhodes (2018b); [w]Choat *et al.* (2018a); [x]Rhodes (2018c); [y]Choat and Samoilys (2018); [z]Law *et al.* (2018b); [aa]Sadovy *et al.* (2018b); [ab]Nair *et al.* (2018)

**Table 2.** Grouper species in several study locations in Indonesia

| Location | Number of Grouper Species | References |
|---|---|---|
| Kwandang Bay | 26 | This study |
| A Thousand Island Marine Park, Jakarta | 4 | Jimmi *et al.* (2011) |
| Berau Waters, East Kalimantan | 25 | Nuraini (2007) |
| Peukan Bada, Aceh | 21 | Astuti *et al.* (2016) |
| Raja Ampat, Papua | 8 | Kusuma *et al.* (2021) |
| Tanjung Tuing, Bangka Regency | 7 | Guchita (2020) |

## 3. Results and Discussion

### *3.1 Species Composition and the Importance of Kwandang Bay*

The total number of grouper specimens identified during the study period was 1,571 (Table 1). These samples were distributed into eight genera and 26 species. Among the 14 species which was measured for their total length, four groups (*Cephalopholis cyanostigma*, *Cephalopholis miniata*, *Epinephelus faveatus*, and *Gracilla albomarginata*) contain specimens with size larger than the maximum length of those species recorded by Heemstra and Randall (1993).

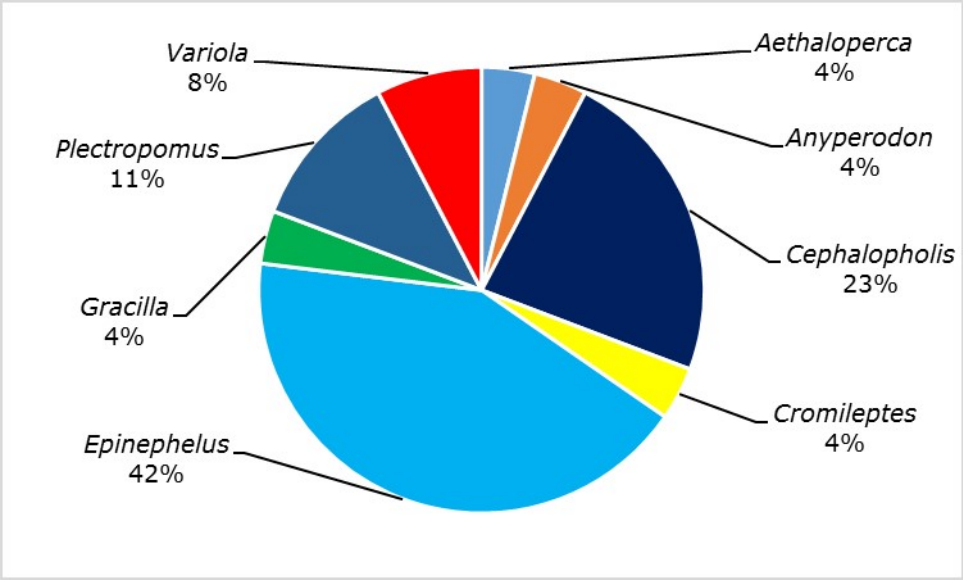


**Figure 2**. Composition of groupers total sample caught in Kwandang Bay.

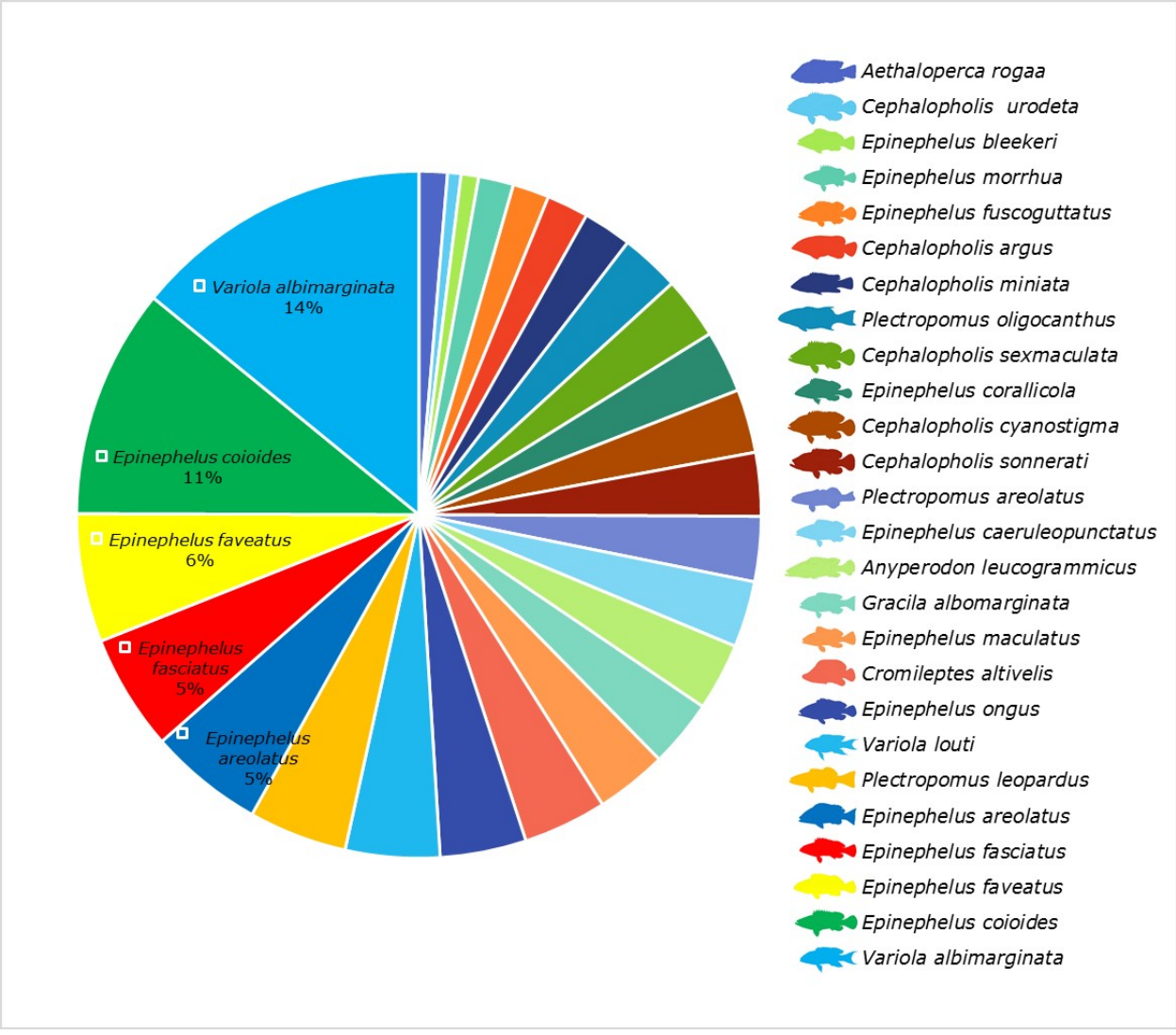


**Figure 3.** Species level composition of grouper samples collected from the Kwandang Bay

**Table 3.** Length-weight relationship of grouper in Kwandang Bay

| Spesies | Growth Model | $R^2$ | Growth Pattern |
|---|---|---|---|
| *Aethaloperca rogaa* | $W = 0.0351L^{2.7547}$ | 0.9398 | Isometric |
| *Cephalopholis argus* | $W = 0.0057L^{3.2975}$ | 0.9837 | Isometric |
| *Cromileptes altivelis* | $W = 0.0302L^{2.8232}$ | 0.9760 | Isometric |
| *Epinephelus areolatus* | $W = 0.0139L^{2.9537}$ | 0.8005 | Isometric |
| *Epinephelus corallicola* | $W = 0.0040L^{3.3256}$ | 0.9761 | Isometric |
| *Epinephelus coioides* | $W = 0.0065L^{3.1572}$ | 0.9444 | Isometric |
| *Epinephelus fuscoguttatus* | $W = 0.0035L^{3.3677}$ | 0.9821 | Isometric |
| *Epinephelus faveatus* | $W = 0.0042L^{3.3747}$ | 0.9855 | Isometric |
| *Epinephelus maculatus* | $W = 0.0063L^{3.2255}$ | 0.8984 | Isometric |
| *Epinephelus ongus* | $W = 0.0517L^{2.6359}$ | 0.9858 | Isometric |
| *Plectropomus leopardus* | $W = 0.0223L^{2.8315}$ | 0.8975 | Isometric |
| *Plectropomus oligocanthus* | $W = 0.0212L^{2.8699}$ | 0.8926 | Isometric |
| *Variola albimarginata* | $W = 0.0270L^{2.7543}$ | 0.7718 | Isometric |
| *Variola louti* | $W = 0.0023L^{3.4417}$ | 0.8619 | Isometric |

**Table 4.** Summary of several grouper species that follow allometric growth model

| Species | Location | Growth Model | References |
|---|---|---|---|
| *E. fuscoguttatus* | Wakatobi Waters | Negative allometry | Setiawan *et al.* (2019) |
| *E. costae* | Mediterranean, Lebanon | Negative allometry | Jisr *et al.* (2018) |
| *E. marginatus* | | Negative allometry | |
| *E. coeruleopunctatus* | Padang Waters | Negative allometry | Bulanin *et al.* (2017) |
| *E. diacanthus* | Arab Sea, Oman | Positive allometry | Al-Marzouqi *et al.* (2015) |
| *E. diacanthus* | Ponnani, India | Negative allometry | Ranjeet *et al.* (2015) |
| *V. albimarginata* | Northern coast of Aceh | Negative allometry | Damora *et al.* (2021) |
| *E. coioides* | | Negative allometry | Fadli *et al.* (2021) |
| *E. diacanthus* | Karachi, Pakistan | Positive allometry | Saleem *et al.* (2015) |

*Epinephelus* followed by *Cephalopolis* were the two largest genera being caught during the sampling period. The two groups constituted more than 65% of the total catch. On the other hand, *Gracilla*, *Aethaloperca*, *Anyperodon*, and *Cromileptes* shared similar contribution (4%) to the total catch which was the lowest among the eight genera identified (Figure 2). Similar information was also reported by Razi *et al.* (2022) that 54% of groupers caught in Simeulue and Banyak Island, Aceh comes from the genus *Epinephelus*.

Even though *Epinephelus* shared the highest contribution to the total catch at the genus level, *Variola albimarginata* from the genus *Variola* represented the highest catch at the species level (14%) followed by *Epinephelus coioides* (11%). Other species contributed to less than 10% of the total samples collected (Figure 3).

Groupers identification from Kwandang Bay resulted in 26 species of groupers. This means that out of 76 grouper species known to exist in Indonesia (Razi *et al.*, 2021), more than one-third of them are present in Kwandang Bay. Compared to other study locations, the number of species that occur in Kwandang Bay are the highest among other places that have been studied in Indonesia (Table 2). These results suggest that Kwandang Bay is an important habitat for groupers as it can serve as genetic resources for grouper species in the country.

The high number of grouper species occurring in the bay may indicate the highly diverse underwater life of Kwandang Bay. Reports from studies of grouper research from various locations have consistently shown that groupers are highly associated with diverse habitats, where different species inhabit different coral reef communities (zones) (Sluka *et al.*, 2001). Therefore, the highly diverse groupers in Kwandang Bay identified in this study may reflect the rich condition of the habitat below the water. However, unfriendly fishing practices have contributed to the degradation of coral reefs in Kwandang Bay. The hard coral cover condition in the bay ranges from 11.8% (bad) to 77.2% (good) with an average of 48% (moderate condition) (Olii *et al.*, 2015b).

Genus *Epinephelus* was found the most in Kwandang Bay. Eleven out of 28 species from *Epinephelus* distributed in Indonesia, were found in Kwandang Bay. The species include *Epinephelus areolatus*, *E. argus*, *E. bleekeri*, *E. bontoides*, *E.*

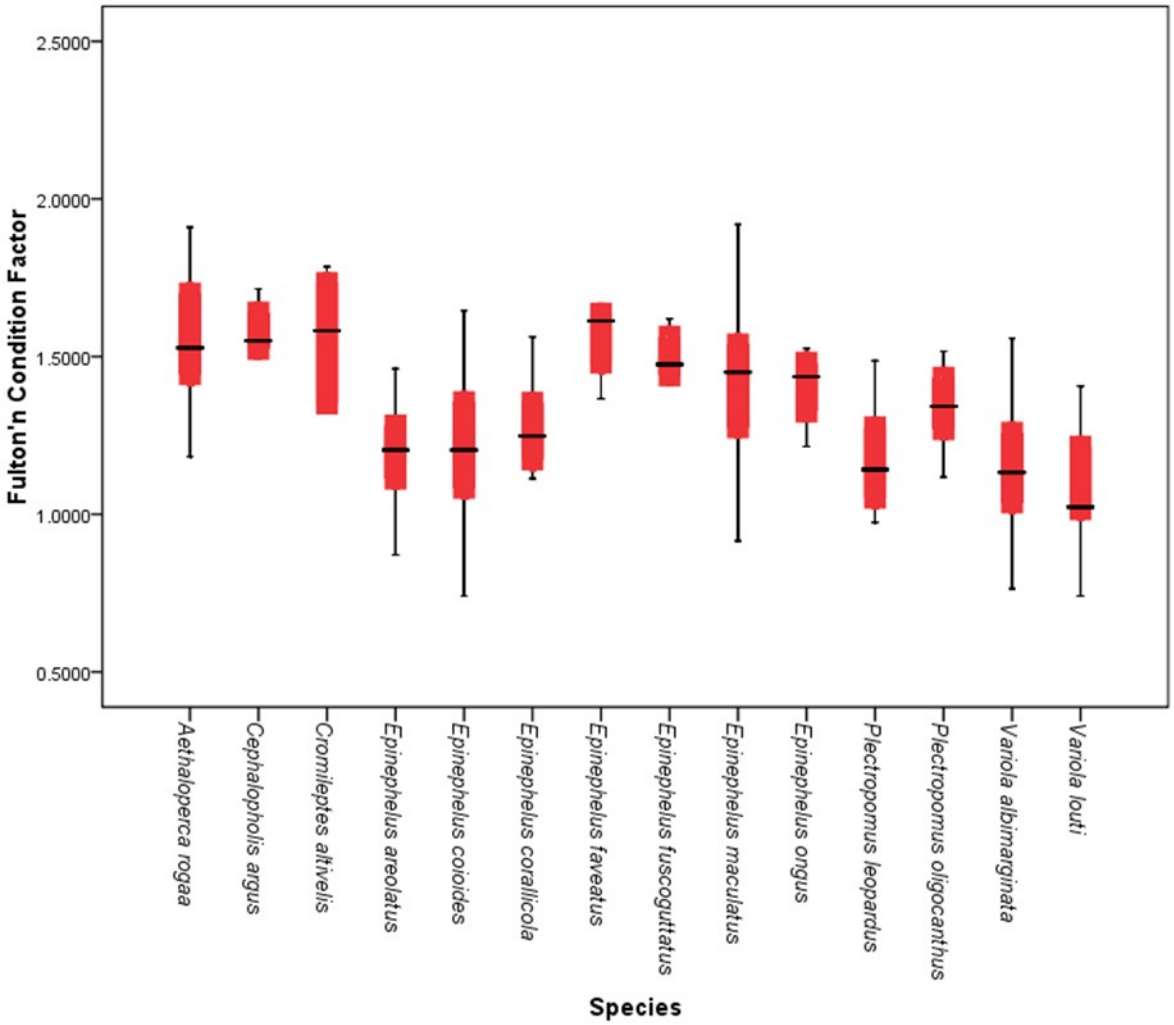


**Figure 4**. Fulton condition factor for the 14 grouper species found in Kwandang Bay

*aeruleopunctatus*, *E. coioides*, *E. cyanostigma*, *E. corallicola*, *E. fasciatus*, *E. fuscoguttatus*, *E. faveatus*, *E. hexagonatus*, *E. lanceolatus*, *E. longispinis*, *E. melanostigma*, *E. miliaris*, *E. malabaricus*, *E. merra*, *E. macropilos*, *E. maculatus*, *E. microdon*, *E. ongus*, *E. polyphekadion*, *E. sexfasciatus*, *E. spilotoceps*, *E. suillus*, *E. tauvina*, and *E. quayanus* (Hartati and Pralampita, 1994; Pirzan *et al*., 1998; Bulanin, 2010; Jimmi *et al*., 2011; Jefri *et al*., 2015; Astuti *et al*., 2016).

Apart from being an important habitat for groupers, Kwandang Bay must also be subjected to conservation actions. Among the 26 grouper species that occur in the area, there are two species (*E. fuscoguttatus* and *P. areolatus*) that are categorized as vulnerable under the IUCN species conservation list (Rhodes *et al.*, 2018c; Rhodes, 2018c). Besides the two species, six other species (*C. altivelis*, *E. bleekeri*, *E. coioides*, *E. maculatus*, *P. leopardus* and *V. albimarginata*) are listed as having population decline (Sadovy *et al*., 2018a; Law *et al*., 2018a; Amorim *et al*., 2018; Rhodes and Sadovy, 2018; Choat and Samoilys, 2018; Sadovy *et al*., 2018b). Two species are listed as data deficient and the remaining 20 species are listed as least concern (Rhodes *et al*., 2018b; Rhodes, 2018a; Choat *et al*., 2018b; Choat, 2018; Rocha, 2018; Sadovy and Boon, 2018a; 2018b; Cabanban, 2018; Nair and To, 2018; Rhodes *et al*., 2018a; Amorim *et al*., 2018; Fennessy, 2018; Law, 2018; Russell, 2018; Rhodes and Sadovy, 2018; Barreiros, 2018; Rhodes, 2018b; Choat *et al*., 2018a; Choat and Samoilys, 2018; Law *et al*., 2018b; Sadovy *et al*., 2018b; Nair *et al*., 2018). The conservation status of the eight species mentioned above in the IUCN red list prompt further studies are required in this field to help fishery management to regulate fishing activities in the area and to determine the safe level of fishery exploitation for the respective species. Finally, the current study can be valuable as a baseline data for future grouper studies in Kwandang Bay, Sulawesi Sea.

*3.2 Grouper Wellbeing in Kwandang Bay*

Among 26 species identified from the total samples, only 14 species can be assessed for their length-weight relationship due to an inadequate number of samples required for the analysis of the remaining species. All the 14 species have an exponent-b values which are not significantly different from the reference value of 3 (Table 3). None of the exponent-b values from the grouper species were found to be b < 2.5 or b>3.5.

It can be seen that all determinant coefficients for the models showed high values (mostly above 90%) which reflects that the models are adequate to represent the relationship between the length and weight of groupers caught in Kwandang Bay (Table 3). The LWR analysis results showed that all grouper species captured in Kwandang Bay followed the isometric growth model (as t-student tests were insignificant). The exponent-b values of the 14 species fell between the range of 2.5 and 3.5 which indicates that the species grow normally as other fish species, where 90% of fishes have the exponent-b value fall within this range of 2.7 and 3.4 (Carlander, 1969).

However, the exponent-b value does not remain constant. The value normally fluctuates in accordance with the changes in the environment (such as food availability) or physiological factors of the fish, for example, fish that has spawned tend to have smaller exponent-b values (Froese, 2006). The value of exponent-b is sampling time-dependent. Therefore, some other studies can have different exponent-b values for the same species (Table 4).

The results of data analysis showed that the average of condition factor ranged from 1.0927 to 1.5738. Generally, the condition factor obtained is the same as the condition factor for grouper caught in Aceh waters (Ramadhani *et al*., 2017). The highest condition factor was found in *Cephalopholis argus* and the lowest was in *Variola louti* (Figure 4). The Fulton condition factor, of which all mean values are > 1 indicates that the groupers in Kwandang Bay is in a good state of wellbeing (good nutritional status) (Froese, 2006; Haser *et al*., 2022). The value also reflects the fitness of the Kwandang Bay as a habitat for groupers since it provides the fish with adequate food (nutrition).

## 4. Conclusion

This research is the first study that establishes biological data for multi-species of groupers that occur in Kwandang Bay. There are 26 species identified to be originated from the bay, which has the highest diversity in Indonesia. The growth model and Fulton condition factor determined for 14 species indicate that they live in a good state of well beings in the bay. The models and condition factors also reflect the adequate food resources required for grouper growth which makes Kwandang Bay a good habitat for groupers. Both metrics (LWR and Fulton condition factor) can also serve as the basic data for future monitoring on the grouper population. The highly diverse species found and the fitness of the bay as a grouper habitat make Kwandang Bay become an important area for grouper conservation. However, due to the high economic activities in the area, together with continuous unfriendly fishing practices has been the cause of environmental degradation in the bay. Therefore, it is important for the stakeholders to manage activities that occur in Kwandang Bay and its surroundings.

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## Authors' Contributions

The contribution of each author is as follow, DSA and MSN; conceptualized the research. DSA, MSN, and FA; conducted the methodology. DSA, MSN, MAI, EH, JJ, and NA; conducted the research. DSA, MSN, TFH and FA; analyzed data and wrote the original draft. MAI, EH, JJ, and NA; helped in manuscript preparation. All authors discussed the results and contributed to the final manuscript.

## Conflict of Interest

The authors declare that they have no competing interests.

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