Population parameters of several groupers (Famili Serranidae) in Labuan Bajo waters, East Nusa Tenggara

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Abstract. Labuan Bajo has a fertile aquatic ecosystem, one of them is the coral reef ecosystem. This condition happened because of the supply of nutrients that are carried through Indonesia Through Flow and the local upwelling phenomena. Various species of reef fish of various sizes have been caught in Labuan Bajo waters. In general, the type of reef fish that dominates is grouper fish catches by using handline fishing gear. Furthermore, there is damage that occurs in the coastal ecosystem causes changes in ecological functions and disrupted ecosystem benefits. In addition, pressure from overuse did not provide opportunities for resources to carry out recovery makes the condition of resource stocks threatened. This study aims to determine the parameter aspects of the population of several types of grouper fish in Labuan Bajo waters. The types of grouper studied included Plectropomus leopardus, P. maculatus, P. oligacanthus, and Variola albimarginata. Data collection was carried out by enumerators from April to August 2019 which included the daily data on the length and weight distribution of groupers. Length-frequency distribution data is analyzed by estimating fish population parameters using the Electronic Length Frequency Analysis (ELEFAN I) program which is packaged in the FAO-ICLARM Stock Assessment Tool II (FiSAT II) software. The results of the analysis showed the equation of growth parameters for Von Bartalanffy for P. leopardus is \( L_t = 89.06(1 - e^{-0.24(t+0.52)}) \); P. maculatus is \( L_t = 76(1 - e^{-0.54(t+0.23)}) \); P. oligacanthus is \( L_t = 72.32(1 - e^{-0.66(t+0.19)}) \); and V. albimarginata is \( L_t = 45(1 - e^{-0.51(t+0.29)}) \). The length at first birth of each species is \( L_{t=0} \) P. leopardus = 10.45 cm, \( L_{t=0} \) P. maculatus = 8.88 cm, \( L_{t=0} \) P. oligacanthus = 8.52 cm, and \( L_{t=0} \) V. albimarginata = 6.19 cm. Meanwhile, the exploitation rate (E) of P. leopardus, P. maculatus, P. oligacanthus, and V. albimarginata were 0.81; 0.53; 0.45; and 0.70.

1. Introduction

Labuan Bajo waters mostly have coral reef ecosystems. The major fisheries activities that develop in that area are coral reef fisheries. As an ecosystem that is directly connected to the Indian Ocean, Labuan Bajo has more or less the same oceanographic conditions. The geographical location of the Indian Ocean waters has a very high dynamics of water mass variability because it's influenced by water mass intrusion from other regions such as the Indonesian Through Flow (ITF) and is also influenced by global climate anomalies such as El-Nino Southern Oscillation (ENSO) [1]. In addition, the occurrence of an upwelling phenomenon that occurs in the east monsoon brings a supply of nutrients from the deep layers to the surface [2;3;4]. This condition also brings the supply of nutrients to Labuan Bajo so that this area has very fertile water conditions. Based on the statistical data of West Manggarai District in 2018, coral reef...
fishes, which consisted of several types of groupers catch by using handline, contributed 18-21% of the total production. Furthermore, several environmental problems that have become the attention include climate change issues, shoreline changes, land-used shifting, and overfishing will affect the sustainability of fisheries resources. Afterward, the occurrence of degradation of coastal and marine ecosystems such as mangroves, coral reefs, and seagrasses also affects the dynamics of the population of fish resources and the environment. This event has been indicated by several general problem trends, such as catch declining, longer distances to the fishing ground, and smaller length of first catch and maturity in several types of economically important fish species, like groupers. The damage that occurs to coastal and marine ecosystems, in this case, causes the ecological functions and economic benefits of these ecosystems to be disrupted, while excessive use pressures and do not provide opportunities for resources to self-recover, make the condition of resource stocks threatened from sustainability [5]. This study aims to determine the aspects of population parameters of several types of groupers in the waters of Labuan Bajo.

2. Materials and Methods

2.1. Location
The data was collected with the locations around Labuan Bajo waters, East Nusa Tenggara in April - August 2019. Daily length-weight data was obtained from the handline fishing boat that landed on Selayar Island, Labuan Bajo. Data recording is carried out by enumerators who have been previously appointed.

2.2. Data Collection
Data collection was carried out randomly following standard sampling procedures in the field [6]. Measurement aspects include total length (cm), fork length (cm), and individual weight (grams). The type of fish taken was focused on the type of grouper (Family Serranidae), which are Plectropomus leopardus, P. maculatus, P. oligacanthus, and Variola albimarginata.

2.3. Data Analysis
The length-frequency distribution data were analyzed using fish population parameter estimation analysis consisting of \( L_\infty \), \( K \), \( t_0 \), \( Z \), \( M \), \( F \), and \( E \) values using the Electronic Length Frequency Analysis (ELEFAN I) program which is packaged in the FAO-ICLARM Stock Assessment Tool II (FiSAT II) software [7]. In general, the theory regarding the analysis is:

2.3.1. Growth Estimation. Estimation of growth parameters was carried out using the growth formula Von Bertalanffy \( L_t = L_\infty \left( 1 - e^{-k(t-t_0)} \right) \) [8]. From Von Bertalanffy's growth equation, the formula can be manipulated into \( a = L_\infty \times (1 - b) \), with \( K \) and \( L_\infty \) are constants, \( a \) and \( b \) are constants if \( t \) is a constant. The growth parameters \( k \) and \( L_\infty \) are derived from:

\[
k = \frac{-1}{\Delta t} \ln b
\]

\[
L_\infty = \frac{a}{1-b}
\]

Furthermore, to determine \( t_0 \) use Pauly formula [9]:

\[
\log (-t_0) = -0.3922 - 0.2752 (\log L_\infty) - 1.038 (\log K)
\]

with:

\( L_\infty \) : length asymptotic (cm)  \( K \) : growth rate coefficient (year)
\( t_0 \) : the theoretical age of the fish when the length is equal to zero (year)

2.3.2. Mortality Estimation. According to [9], fish natural mortality is also influenced by environmental temperature. Various relationships can be seen from the length growth data with multiple
regression:

\[
\log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T
\]

with:

- \(M\): natural mortality rate (year)
- \(L_{\infty}\): length asymptotic (cm)
- \(K\): growth coefficient
- \(T\): average sea surface temperature (°C)

According to [8], information on mortality rates is very important in analyzing the dynamics of an exploited population and stock size. The mortality rate can be estimated using the equations proposed by Beverton and Holt. Total mortality can be estimated by the average length (L) of the catch of a fish population, with the following equation:

\[
b = \exp (-k \times \Delta t)
\]

\[
Z = \frac{L_{\infty} - L}{L - L^1}
\]

with:

- \(Z\): total mortality rate (year)
- \(K\): growth coefficient
- \(L_{\infty}\): length asymptotic (cm)
- \(L\): average length of fish caught
- \(L^1\): the minimum size of fish caught

According to [9], to calculate the rate of exploitation (exploitation ratio) the following formula is used:

\[
E = \frac{F}{F + M}
\]

\[
Z = M + F
\]

with:

- \(E\): exploitation rate
- \(F\): fishing mortality rate
- \(M\): natural mortality rate
- \(Z\): total mortality rate

3. Results

3.1. Size Distribution

The size distribution of *Plectropomus leopardus* or known as leopard coral grouper (Figure 1) ranges from 31 - 75 cm with an average of 46.1 cm. The dominant size ranged from 36 - 40 cm as many as 342 individuals. During April – August 2019, the highest catch number was caught in May (236 individuals) with a size range of 33 – 68 cm, while the lowest number was caught in August (57 individuals) with a range of 33 – 63 cm. The smallest size (31 cm) was caught in August and the largest size (75 cm) was caught in June.

![Figure 1. Length frequency distribution of *Plectropomus leopardus*.

\[
\text{Figure 1. Length frequency distribution of *Plectropomus leopardus*.
}
The size distribution of *Plectropomus maculatus* (spotted coral grouper) (Figure 2) ranged from 26 – 75 cm with an average of 42.8 cm. The dominant size catch ranged from 36 – 40 cm as many as 168 individuals. During April – September 2019, the highest catch number was caught in May (162 individuals) with a size range of 28 – 63 cm. The lowest catch was caught in August (59 individuals) with a range of 28 – 73 cm. The smallest size (26 cm) was caught in April and the largest (75 cm) was caught in August.

![Figure 2. Length frequency distribution of *Plectropomus maculatus.*](image)

The size distribution of *Plectropomus oligacanthus* (high fin coral grouper) (Figure 3) ranged from 32 – 67 cm with an average of 48.2 cm. The dominant catch ranged from 37 – 41 cm as many as 15 individuals. During April – September 2019, mostly *P. oligacanthus* were caught in May (18 individuals) with a size range of 34 – 64 cm, while the lowest number was caught in August (2 individuals) with a range of 34 – 64 cm. The smallest size (32 cm) was caught in May and the largest (67 cm) was caught in June.

![Figure 3. Length frequency distribution of *Plectropomus oligacanthus.*](image)

The size distribution of *Variola albimarginata* (white-edge lyretail) (Figure 4) ranged from 28 – 40 cm with an average of 34.2 cm. The size that dominates the catch ranges from 34 – 35 cm. During April – August 2019, mostly *V. albimarginata* was caught in April (27 individuals) with a size range of 28.5
– 40.5 cm, while the lowest number was caught in August (1 fish) with a range of 34 – 35 cm. The smallest and largest size was caught in July.

![Graph showing length frequency distribution](image)

**Figure 4.** Length frequency distribution of *Variola albimarginata.*

### 3.2. Population Parameter Estimation

Estimation of population parameter calculations was carried out using the FiSAT II software. The parameters analyzed include $L_{\infty}$ (asymptote length), $K$ (growth coefficient), $t_0$ (theoretical age), $Z$ (total mortality rate), $M$ (natural mortality rate), $F$ (fishing mortality rate), and $E$ (exploitation rate). The results of the analysis of growth parameters following the Von Bertalanffy (VB) growth formula (Table 1) describe the relationship between length increase ($L_t$) over time ($t$). Based on the results of the analysis, it is known that $L_{t=0}$ (length of first birth) of each species is $L_{t=0} P. leopardus = 10.45 $ cm, $L_{t=0} P. maculatus = 8.88 $ cm, $L_{t=0} P. oligacanthus = 8.52 $ cm, and $L_{t=0} V. albimarginata = 6.19 $ cm (Figure 5).

| No | Species                      | $L_{\infty}$ (cm) | $K$ (year$^{-1}$) | $t_0$ (year) | VB growth formula's                              |
|----|-------------------------------|-------------------|-------------------|--------------|--------------------------------------------------|
| 1  | *Plectropomus leopardus*      | 89.06             | 0.24              | -0.52        | $L_t = 89.06(1-e^{-0.24(t+0.52)})$               |
| 2  | *Plectropomus maculatus*      | 76.00             | 0.54              | -0.23        | $L_t = 76(1-e^{-0.54(t+0.23)})$                  |
| 3  | *Plectropomus oligacanthus*   | 72.32             | 0.66              | -0.19        | $L_t = 72.32(1-e^{-0.66(t+0.19)})$               |
| 4  | *Variola albimarginata*       | 45.00             | 0.51              | -0.29        | $L_t = 45(1-e^{-0.51(t+0.29)})$                  |
**Figure 5.** Von Bartalanffy growth curve of each grouper species.

Furthermore, based on satellite data, the average sea surface temperature of Labuan Bajo waters is 28.27 °C with a standard deviation of 0.95 °C [10]. Thus, the results of the analysis regarding the mortality rate and exploitation rate are attached in Table 2. Based on the comparison of M and F values, it can be seen that the exploitation rate (E) for *P. leopardus*, *P. maculatus*, and *V. albimarginata* exceed the $E_{opt} = 0.5$, so their status is in a fully exploited condition. Meanwhile, the value of the exploitation rate of *P. oligacanthus* is $E = 0.45$, or almost in a fully exploited condition if not managed properly.

Table 2. Mortality and exploitation rate of groupers.

| No | Species                     | Z (year⁻¹) | M (year⁻¹) | F (year⁻¹) | E (year⁻¹) |
|----|-----------------------------|------------|------------|------------|------------|
| 1  | *Plectropomus leopardus*    | 2.70       | 0.52       | 2.18       | 0.81       |
| 2  | *Plectropomus maculatus*    | 1.96       | 0.92       | 1.04       | 0.53       |
| 3  | *Plectropomus oligacanthus* | 1.95       | 1.07       | 0.89       | 0.45       |
| 4  | *Variola albimarginata*     | 2.92       | 0.89       | 2.03       | 0.70       |

4. Discussion

*Plectropomus leopardus*. The $L_{max}$ value of the research results is the same as the size ever found in East Indian waters of 75 cm [11], but smaller than have been found in Asia Pacific waters, which is 120 cm [12]. Based on the Von Bartalanffy equation, the $L_{\infty}$ value of the research results is greater than [13], which is 62.16 cm in Karimun Jawa, Indonesia; and [14] namely 63.01 cm and 50.5 cm in Coron and Guiuan waters, Philippines. K values is bigger (0.10 and 0.0088) than research results. The value of K can illustrate that *Plectropomus* sp. has a slow growth rate compared to other types of groupers. The speed of fish growth can show the condition of the waters and the abundance of food in there [15]. Furthermore, the $t_0$ value of the research results is greater when compared to the case study [13;14], which is -1.37 years and -4.41 years. The characteristics of coral grouper are slow growth, long lifespan, and slow natural mortality rate [16;17]. Therefore, coral grouper has a high mortality rate and susceptibility to fishing pressure so that the possibility of overfishing conditions is increasing. Fish mortality is divided into natural mortality (M) or mortality due to age, competition, predation, and disease; and fishing mortality (F) or mortality due to fishing activities. Fishing mortality (F) is a function of fishing effort. If we compare the natural mortality rate and the fishing mortality rate, it's shown that $F>M$ so that $E>E_{opt}=0.5$ so that the condition is already in fully exploited status. The results of the study [13;14] have values of $E = 0.13$ and $E = 0.78 – 0.81$. From both cases, it can be seen that there are
differences in exploitation status that are influenced by environmental conditions of the waters and market demand for grouper consumption needs in the area.

*Plectropomus maculatus.* The Lmax research value comparison of *P. maculatus* with the case study [11] in East Indian waters, which is 125 cm, has a smaller value. Meanwhile, when compared with [18] in the waters of Cendrawasih Bay, Papua, 48.5 cm, has a greater value. The differences were caused by the geographic location and environmental condition. Furthermore, the L∞ in Karimun Jawa [13] is 92.56 cm with K = 0.10/year and t0 = -1.21 years. Then the L∞ in Saleh Bay waters, West Nusa Tenggara [19] was 76.55 cm with K = 0.10/year and t0 of -1.34 years. As a comparison, it can be seen that the value of L∞ is varying while the values of K and t0 are lower than the results. This condition was occurred due to differences in the latitude of geographical location, environmental factors, and food availability [20;8]. Then, based on the results of the analysis, E = 0.53 indicates overfishing pressure. This condition also occurs in several other places [13;19]. Excessive fishing pressure can cause growth and recruitment overfishing [21;22].

*Plectropomus oligacanthus.* As we compared the result with case studies in Cendrawasih Bay waters [18] and East India waters [11], the Lmax value of *P. oligacanthus* varied with the Lmax values in both locations were 48.5 cm and 75 cm. The difference in size caught often occurs because of differences in fishing gear and fishing locations. Furthermore, based on the case study [13], the parameter values for the population of *P. oligacanthus* were L∞ = 67.93 cm, K = 0.13, and t0 = -1.05 years. This value is greater when compared to the results of the study. Meanwhile, the value of the exploitation rate is not much different, E= 0.51 (slightly exceeds Eopt). If we have good management, these conditions can be recovered at the optimum point of exploitation so that the resource can be sustainable. Where possible, a combination of no-take marine reserves, market-based management approaches, and allocation or resurrection of property rights system is recommended to complement conventional fishery management actions that limit catch and effort. Additional investment in aquaculture propagation is also needed to reduce fishing pressure on wild stocks and support management initiatives. This global

5. Conclusion

The results of the analysis showed the equation of growth parameters for Von Bartalanffy for *P. leopardus* L\(_t\) = 89.06(1-e\(^{-0.24(t+0.52)}\)) ; *P. maculatus* L\(_t\) = 76(1-e\(^{-0.54(t+0.23)}\)) ; *P. oligacanthus* L\(_t\) = 72.32(1-e\(^{0.66(t+0.19)}\)) ; and *Variola albin marginata* L\(_t\) = 45(1-e\(^{-0.51(t+0.29)}\)) with L\(_{m0}\) *P. leopardus* = 10.45 cm, L\(_{m0}\) *P. maculatus* = 8.88 cm, L\(_{m0}\) *P. oligacanthus* = 8.52 cm, and L\(_{m0}\) *V. albin marginata* = 6.19 cm. Meanwhile, the exploitation rate (E) of *P. leopardus, P. maculatus, P. oligacanthus,* and *V. albin marginata* were 0.81; 0.53; 0.45; and 0.70. For management, a combination of no-take marine reserves, market-based management approaches, open-closed season, community knowledge and awareness, and allocation or resurrection of property rights systems are recommended to complement conventional fishery management actions that limit catch and effort. Additional investment in aquaculture propagation is also needed to reduce fishing pressure on wild stocks and support management initiatives. This global
synthesis of information about the biology, fisheries, and management of *Plectropomus* will assist in guiding future management actions that are attempting to address a range of stressors including fishing, reef habitat degradation, and the escalating effects of climate change.

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