Uncontrolled fishing of dusky parrotfish *Scarus niger* (Forsskal, 1775) Spermonde Islands, Makassar Strait, Indonesia

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Abstract. Reef fish is one of the abundant communities in coral reef ecosystems. This fish community is an important component in the food web of the coral reef ecosystem. As a herbivorous fish, Dusky Parrotfish *Scarus niger* has an important role in balancing the energy flow in the coral ecosystem because it can control the turf algae growth. Uncontrolled growth of turf algae will inhibit the recruitment of corals juveniles. The ecological role of the Dusky Parrotfish can be disturbed if fishing activities are not regulated. The Dusky Parrotfish is an economically important fish caught in the Spermonde Islands waters. Dusky Parrotfish is a consumption fish that is exported fresh to Hong Kong, Taiwan and Singapore. High economic value causing the Dusky Parrotfish increase progressively. Until the present, the fishing status of Dusky Parrotfish in the Spermonde Islands waters have never been studied. This study aims to assess the exploitation rate of Dusky Parrotfish in Spermonde Islands, Makassar Strait, Indonesia. Dusky parrotfish samples were collected from the catch landed at Fish Landing Port, Makassar City. Growth was estimated using the von Bertalanffy equation. Total mortality (Z) was estimated using the Beverton and Holt equations. The natural mortality rate (M) was estimated using the Pauly empirical formula. Fishing mortality rate (F) was estimated using the equation \( F = Z - M \). The exploitation rate (E) was estimated using the Beverton and Holt equations, \( E = \frac{F}{Z} \). The growth rate was \( L_t = 40[1-\exp^{-0.24(t-0.646)}] \). The total mortality rate was 3.19, the natural mortality rate was 0.66, the fishing mortality rate was 2.53, and the exploitation rate was 0.79. This exploitation rate indicated that the Dusky Parrotfish fishing in Spermonde Islands was uncontrolled.

1. Introduction

The waters of Spermonde are the waters surrounding small islands in the Makassar Strait, to be precise, to the southwest of South Sulawesi. The waters of Spermonde from the Sunda Shelf are located across the Makassar Strait. The Spermonde Archipelago consists of hundreds of small islands with varying environmental conditions and human activities [1]. The Spermonde Islands are part of the State Fisheries Management Area of the Republic of Indonesia, number 713 [2,3].

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The Spermonde Islands have a high diversity of reef fish species. Artisanal fishers catch at least 64 types of landed reef fish at Fish Landing Port, Makassar City [4-10]. Reef fish are essential organisms in the flow of energy in coral reef ecosystems [11]. Various types of reef fish have a high dependence on coral reefs as their habitat. Coral fish use coral reefs directly or indirectly for their livelihood interests [12]. Several types of coral fish make coral reefs as shelter or nursery ground, feeding ground, breeding ground, and nursery ground [11].

One type of reef fish caught in the waters of Spermonde is the Dusky Parrotfish *Scarus niger*. Male Dusky Parrotfish has a dark reddish-brown color, along with the dorsal area to the back of the body a greenish color, and darker in color as adults. There is a black line around the mouth and behind the eyes. Whereas in the female Dusky Parrotfish, the body is dark red with many black and white lines around the mouth. Female Dusky Parrotfish has a reddish head and dark spots near the eyes and a rounded tail fin [13].

Dusky Parrotfish is a shallow water dweller found on coral reefs at a depth of 2 - 20 meters. The Dusky Parrotfish has a wide distribution, from the Red Sea and East Africa to Micronesia and Tuamotu Sea; from Australia to Ryukyu and Ogasawara islands; ranges out to the east Indian region and Indonesia [13,14]. Dusky Parrotfish inhabit clean areas in coral reef areas. When relatively small or juvenile, Dusky Parrotfish tend to live in groups and prefer seagrass beds as a nursery ground. As an adult, Dusky Parrotfish will migrate to coral waters. Dusky Parrotfish like to live in groups; the size of the group can reach hundreds of fish [15]. The feeding activity of Dusky Parrotfish has an essential role for coral reef ecosystems because it feeds on algal turf that attaches itself to dead coral. Algal turf can inhibit the growth and recruitment of new corals [16].

Dusky Parrotfish is one of the target fish groups caught in the waters of the Spermonde Islands. Dusky Parrotfish is classified as a prevalent food fish because it has a compact and white meat texture. Dusky Parrotfish is an essential economic commodity exported fresh to Hong Kong, Taiwan, and Singapore [15]. The high economic value can lead to the uncontrolled fishing stock of Dusky Parrotfish. If exploitation continues to increase, it will have an impact on the Dusky Parrotfish population. Stock management is needed to preserve the Dusky Parrotfish. One of the crucial parameters in stock management is the exploitation rate. Previous research results indicate that there have been many studies on aspects of the reproductive biology of parrotfish in the Spermonde Islands [10], including Dusky Parrotfish [17]. However, there is no study on the exploitation rate of Dusky Parrotfish in the waters of the Spermonde Islands. Therefore, it is necessary to study the exploitation rate of Dusky Parrotfish in the waters of the Spermonde Islands to support efforts for sustainable use. The study aims to assess the exploitation rate of Dusky Parrotfish in Spermonde Islands, Makassar Strait, Indonesia. The study is expected to be used as a reference in the use of Dusky Parrotfish resources, especially in the waters of the Spermonde Islands.

2. Materials and Methods
The sample of Dusky Parrotfish is the catch of fishermen in the waters of the Spermonde Islands, South Sulawesi Province, who landed at Fish Landing Port, Makassar City. During the fish length measurement, the Dusky Parrotfish sample was stored in a coolbox containing ice crystals. The total length of the Dusky Parrotfish was measured using a measuring ruler with an accuracy of 1.0 mm.

The age group of Dusky Parrotfish was determined using the Bhattacharya method by dividing the length of the Dusky Parrotfish into several long ranges, then mapped using the class middle value as the x-axis and the difference in the natural logarithm of the cumulative frequency as the y-axis. The number of lines formed indicates the number of age groups of the Dusky Parrotfish. Estimation of the number of age groups in Dusky Parrotfish using the help of the FISAT II program [18].

The growth rate of Dusky Parrotfish based on the total length was estimated using the Von Bertalanffy growth equation [19, 20]: \( L_t = L_\infty \left[1 - e^{-K(t - t_0)}\right] \), where: \( L_t \) was the length of the Dusky Parrotfish at age \( t \) (cm), \( L_\infty \) was the asymptote length of the Dusky Parrotfish (cm), \( K \) was the growth rate coefficient of the Dusky Parrotfish (year\(^{-1}\)), \( t_0 \) was the theoretical age of the Dusky Parrotfish at the time length was equal to zero (year), \( t \) was the age of the Dusky Parrotfish at time \( t \) (years).
The response Surface Analysis was used in ELEFAN I in the FISAT II program to obtain the estimated value of the asymptote length and growth rate coefficient of Dusky Parrotfish. Estimation of theoretical age when the length of the Dusky Parrotfish was equal to zero \( t_0 \), estimated using empirical formulas (Pauly, 1983): \( \log (-t_0) = -0.3922 - 0.2752 (\log L_\infty) - 1.038 (\log K) \), where \( L_\infty \) was the asymptote length of the Dusky Parrotfish (cm), K was the growth rate coefficient of the Dusky Parrotfish (year\(^{-1}\)), the theoretical lifespan of the Dusky Parrotfish when the fish length was zero (year). The total mortality of Dusky Parrotfish was estimated using the Beverton and Holt equations [19, 21]: 
\[
Z = \frac{K (L_\infty - L)}{L - L'},
\]
where \( Z \) was the total mortality rate of the Dusky Parrotfish (year\(^{-1}\)), \( K \) was the growth rate coefficient of the Dusky Parrotfish (year\(^{-1}\)), \( L_\infty \) was the asymptote length of the Dusky Parrotfish (mm), \( L' \) was the smallest length of the fully caught Dusky Parrotfish.

Natural mortality was estimated using an empirical formula [22]: 
\[
\ln M = 0.8 \times \exp (-0.152 - 0.279 \ln L_\infty + 0.6534 \ln K + 0.4634 \ln T),
\]
where \( L_\infty \) was the asymptote length of the Dusky Parrotfish (mm), \( K \) was the growth rate coefficient of the Dusky Parrotfish (year\(^{-1}\)), \( T \) was the annual average temperature of the water surface (°C) as measured by the Makassar Meteorological and Geophysical Agency Station, namely 28.92°C. The arrest mortality rate (F) was estimated using the equation [19, 23]: 
\[
F = Z - M,
\]
where \( Z \) was the total mortality rate of Dusky Parrotfish (year\(^{-1}\)), \( M \) was the natural mortality of Dusky Parrotfish (year\(^{-1}\)).

The exploitation rate of Dusky Parrotfish was estimated by comparing the fishing mortality rate to the total mortality rate using the Beverton and Holt formulas [22]: 
\[
E = \frac{F}{Z},
\]
where \( E \) was the exploitation rate of Dusky Parrotfish (year\(^{-1}\)), \( Z \) was the total mortality rate of Dusky Parrotfish (year\(^{-1}\)).

3. Results
The number of samples of Dusky Parrotfish (Figure 1) was 334, with a length range of 13.0 - 30.5 cm. The length of the Dusky Parrotfish was grouped into 18 classes, using 1.0 cm intervals. The distribution of total length measures consisted of three age groups or cohorts, with a separation index greater than two (Table 1). The catch of the Dusky Parrotfish is dominated by the first cohort (Figure 2).

![Figure 1. Dusky Parrotfish *Scarus niger* captured in Spermonde Islands, Makassar Strait, Indonesia](image)

![Figure 2. Histogram total length of Dusky Parrotfish *Scarus niger* in Spermonde Islands, Makassar Strait, Indonesia](image)
Table 1. Average length and standard deviation of each age group or cohort of Dusky Parrotfish *Scarus niger* in Spermonde Islands, Makassar Strait, Indonesia

| Age Group or Cohorts | Average Length (cm) | Standard Deviation (cm) | Population (individual) | Separation Index |
|----------------------|---------------------|-------------------------|-------------------------|------------------|
| 1                    | 20.46               | 2.51                    | 175.20                  | n.a              |
| 2                    | 24.41               | 1.23                    | 83.42                   | 2.02             |
| 3                    | 27.71               | 1.26                    | 81.36                   | 2.06             |

Table 2. Estimation of growth parameters of Dusky Parrotfish *Scarus niger* in Spermonde Islands, Makassar Strait, Indonesia

| Parameters       | Estimated Value |
|------------------|-----------------|
| L∞ (cm)          | 40.0            |
| K (year⁻¹)       | 0.24            |
| t₀ (year)        | -0.646          |

The growth parameter analysis indicates that the growth of Dusky Parrotfish was slow (Table 2). Growth is relatively rapid at a young age, with 75% of the asymptote length being achieved in the first five cohorts (Figure 3).

Figure 3. Growth curve of Dusky Parrotfish *Scarus niger* in Spermonde Islands, Makassar Strait, Indonesia

The total mortality rate of Dusky Parrotfish was almost four times that of its natural mortality, and the exploitation rate of Dusky Parrotfish was 0.79 (Table 3). The high exploitation rates indicate the uncontrolled fishing condition of Dusky Parrotfish in Spermonde Islands, Makassar Strait.

Table 3. Estimated value of Dusky Parrotfish *Scarus niger* in Spermonde Islands, Makassar Strait, Indonesia

| Parameters                  | Estimated Value (year⁻¹) |
|-----------------------------|--------------------------|
| Total mortality rate (Z)    | 3.19                     |
| Natural mortality rate (M)  | 0.66                     |
| Fishing mortality rate (F)  | 2.53                     |
| Exploitation rate (E)       | 0.79                     |
4. Discussion

Dusky Parrotfish has a slightly flattened and oval body shape, a slightly rounded snout, and a blunt head [13, 24]. Dusky Parrotfish male has a dark reddish-brown color, along the dorsal area to the back of the body is greenish, and will be darker when adult. There is a black line around the mouth and behind the eyes, and the caudal fin has elongated lobes. The female Dusky Parrotfish has a dark red body with many black and white lines around the mouth, has a reddish head and dark spots near the eyes, and a rounded tail fin.

Age group or Cohort is a group of individual fish in waters born at the same time and come from the same stock. The determination of the age group using the Bhattacharya method must pay attention to the value of the separation index. The distribution of the total length of the Dusky Parrotfish does not show a clear enough peak, but the separation index value obtained is more than 2.0, so the separation of the three cohorts is quite valid. The separation index is a measure of the quantity of cohort splitting. If the separation index value is less than 2.0, cohort separation should not be performed because there is considerable overlap between two adjacent cohorts [19]. The results of this cohort separation indicate that the catch of Dusky Parrotfish in Spermonde Islands, Makassar Strait consists of three age groups that live together at one time. The age group structure in an exploited population or stock is vital because of the production and recruitment success [25]. From the distribution of total length, it is known that the Dusky Parrotfish recruitment was quite successful because there were three consecutive recruitment results.

Fish growth is influenced by several factors, such as the amount and size of food available, temperature, water quality, age, organism size, and gonad maturity [26, 27]. Fish with a high growth rate coefficient takes a short time to reach their asymptote length, and conversely, organisms with a low growth rate coefficient take a long time to reach their asymptote length. The reference value for determining whether a growth rate is fast or slow is 0.5. If the growth rate coefficient value is less than 0.5, then the fish is categorized as having slow growth. Conversely, if the value of the growth rate coefficient is more than 0.5, then the fish is categorized as having fast growth [19]. Based on the growth curve analysis results, it appears that the Dusky Parrotfish in Spermonde Islands, Makassar Strait has a slow growth rate because it is far from the value of 0.5. The growth rate of Dusky Parrotfish is lower than other herbivorous fish caught in the Spermonde Islands waters [28]. Generally, fish grow faster at a young age, then slow down when getting older. Apart from being caused by biological factors, the slowdown in the growth rate of old fish is also caused by reduced energy allocation for growth and reproduction. The Bertalanffy growth coefficient is proportional to reproductive effort [29]. Old fish use some of the energy obtained from food for body maintenance and movement [30]. The growth of Dusky Parrotfish is relatively rapid at a young age because 75% of its asymptote length is achieved in the first five cohorts.

Mortality is a description of the number of fish that have died during a one-time interval. In fisheries, the causes of mortality in the population are divided into natural and catch mortality. The fishing mortality rate, which is almost four times the natural mortality rate, shows that the population structure of Dusky Parrotfish in Spermonde Islands, Makassar Strait is determined by fishing effort.

The rate of exploitation is the share of the age group captured in a population or stock. The fishing mortality rate strongly influences the rate of exploitation. The higher the fishing mortality rate, the higher the rate of exploitation [22]. The ideal rate of exploitation is 0.50 year-1. The total mortality rate of 0.79 indicates that the population or stock of Dusky Parrotfish in Spermonde Islands, Makassar Strait, is suffering from overfishing. If this uncontrolled fishing condition continues, then the Dusky Parrotfish in Spermonde Islands, Makassar Strait could become extinct because overexploitation will impact reducing adult fish that can reproduce so that no recruits will enter the stock [31]. Overfishing will cause fish to be caught before spawning at least once in their life [32]. Fishing pressure on a fish population can cause a decrease in reproductive ability, which begins with a decrease in the size at first maturity of the fish stock caught [33, 34], then continues to decrease the number of recruits who enter the stock, and at will eventually lead to a reduction in stock size.
5. Conclusion
Dusky Parrotfish in Spermonde Islands, Makassar Strait, consists of three cohorts. The growth rate of Dusky Parrotfish is slow; it takes 30 cohorts to reach its asymptote length; however, the growth of Dusky Parrotfish is quite fast at a young age because 75% of its asymptote length is achieved in the first five cohorts. The fishing and exploitation mortality rate because 75% of the asymptote length achieved in the first five cohorts is so high that it appears that there is an uncontrolled fishing condition of Dusky Parrotfish Scarus niger in Spermonde Islands water, Makassar Strait, Indonesia. This uncontrolled fishing condition needs to be addressed with better management efforts, such as selective fishing gear and limiting fishing efforts so that the Dusky Parrotfish resource in Spermonde Islands, Makassar Strait, can be used sustainably.

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