Long-Term Monitoring of Parrotfish Species Composition in the Catch of Fishermen from the Spermonde Islands, South Sulawesi, Indonesia

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Abstract. Parrotfishes, aside from playing an important ecological role in coral reef ecosystems, are an economically important fish group exploited for human consumption. Excessive exploitation of parrotfishes could cause ecological disturbances in the coral reef ecosystem. This study aimed to examine the species composition and population dynamics of parrotfishes caught by fishermen in the Spermonde Islands, South Sulawesi, Indonesia. Parrotfishes were collected from the catches landed in Makassar Fisheries Port. Monthly samples comprised all parrotfishes landed on the sampling day. Sampling was carried out throughout 2014 and from January 2018 to May 2019. The parameters observed were the name and the number of each species. The composition and dynamics of the Parrotfishes species were analysed using the Diversity Index, Evenness Index, Dominancy Index, and Similarity Index. During the study, 6,684 parrotfishes were collected belonging to 34 species, of which 10 species had a mean sampling presence over 90%, i.e. Chlorurus bleekeri, C. capistratoides, C. sordidus, Scarus chameleon, S. flavipectoralis, S. ghobban, S. niger, S. quoyi, S. rivulatus, and S. schlegeli. Long-term monitoring of parrotfish species composition indicate that parrotfish diversity was consistently at the moderate level, indicating moderate productivity, fairly balanced ecosystem conditions, and moderate ecological pressure. Over the study period, parrotfish species were evenly distributed, no one species was really dominant, and the high Similarity Index indicated little change in species composition. These results indicate that the fishing pressure from traditional capture of parrotfishes using nets and spears has not had a serious impact on the condition of parrotfish resources.

1. Introduction
Parrotfishes are members of the family Scaridae, and typically live in shallow tropical and subtropical seas, especially coral reef and seagrass ecosystems. There are around 90 species of herbivorous Scaridae associated with coral reef and seagrass ecosystems. Many parrotfishes have wide Indo-Pacific distributions, with habitat ranging from shallow and even intertidal waters to depths of up to 25 m. Parrotfishes are generally solitary fish, but when looking for food, parrotfishes can form nonspecific schools or join schools of other fish species [1].
Ecologically, parrotfishes have a very important role in the coral reef ecosystem. As herbivorous fish, parrotfishes play a role in maintaining ecosystem balance [2]. Parrotfishes play a particularly important role in maintaining the balance of marine aquatic plant community structures. Reduction of herbivorous fish in coral reef ecosystems can cause a shift in the community from coral to macroalgae because macroalgae can hinder recruitment and coral growth [3].

Parrotfishes as target fish that have important economic value must be managed by taking into account their ecological roles. Uncontrolled or excessive fishing pressure (overfishing) will reduce the ecological role of parrotfishes and their contribution to coral reef ecosystems [4]. Overfishing is a major threat faced by coral reef ecosystems today [5, 6]. In recent decades, overfishing has increased worldwide affecting many fishes, including reef fish. Based on archaeological data from the Pacific Islands, fishing pressures on reef fish populations can have very significant impacts [7, 8]. When there is overfishing of herbivores such as parrotfishes, the balance of the coral reef ecosystem will be disrupted. Overfishing can increase the vulnerability of coral reef communities [9], and can exacerbate or be exacerbated by other causes of imbalance, such as anthropogenic global warming which continues to increase [10].

Parrotfishes are one of the fish groups that are regularly caught in the waters of the Spermonde Islands, in South Sulawesi, Indonesia; this can be seen from the relatively high number of parrotfishes landed in the Makassar Fisheries Port. The Spermonde Islands form an archipelago consisting of 120 islands [11], comprising 50 vegetated islands and 70 non-vegetated sand bars [12], spread across an area of around 2,500 km² in the Makassar Strait region which is one of the main fishing grounds in South Sulawesi [13]. The vegetated islands are inhabited by around 50,000 people [14], whose lives depend directly or indirectly on the reef fish capture. The Spermonde fishermen generally land their catches at Makassar Fisheries Port. The capture of parrotfishes by a large number of fishermen in the Spermonde Islands could have an ecological impact on the coral ecosystems across the archipelago.

The dual role of Parrotfishes, firstly as a herbivore with a key role in maintaining the balance of coral reef ecosystems, and secondly as a food fish, consumed by coastal and island communities, even mountain-dwelling communities, places parrotfishes in a paradoxical situation. Parrotfishes are an important protein resource for upland communities, generally traded as dried fish in traditional markets in highland areas. Although not yet supported by published studies, parrotfishes are thought to contribute to reducing iodine deficits in highland communities. This socio-economic contribution can be overlooked, especially after recent calls not to eat parrotfishes in order to help maintain coral reefs [15]. This call needs to be carefully evaluated, because the management of parrotfishes, besides being based on ecological considerations, also needs to consider the socio-economic contributions of parrotfishes, especially in highland communities.

In this situation there is a need to analyse whether fishing has actually disturbed the balance of the species composition and population dynamics of parrotfish species. This study aimed to analyse the species composition and population dynamics of Parrotfishes caught by fishermen in Spermonde Islands. Long-term sampling was intended to obtain an overview of the species composition and population diversity as well as the population dynamics of parrotfishes caught in Spermonde Islands in response to fishing pressure.

2. Materials and Methods
Parrotfishes were sampled every month by taking all the parrotfishes landed by fishermen on the sampling day in that month at the Makassar Fisheries Port, South Sulawesi, Indonesia (Figure 1). Parrotfishes were sampled throughout 2014 and from January 2018 to May 2019.
The parameters observed were species names and number of each species. Identification of species names refers to Allen, Swainston and Ruse [17], Kuiter and Tonozuka [18], and Allen and Erdmann [19]. Based on the results of the species identification, the diversity index, evenness index, domination index, and similarity index are calculated. The Shannon Diversity Index (H') was calculated based on the Shannon-Wiener equation [20]:

\[
H' = \sum (p_i \ln p_i)
\]

where

- \( p_i = (n_i/n) \)
- \( n_i = \) number of individuals for species \( i \)
- \( n = \) total number of sampled individuals in a sampling period

Diversity status was determined based on the range criteria of diversity index values: (1) low species diversity if \( H' < 1 \); (2) moderate species diversity if \( 1 < H' < 3 \); and (3) high \( H' \) diversity if \( H' > 3 \).

Evenness index (E) was calculated using the evenness index formula [20]:

\[
E = H'/\ln(S)
\]

where

- \( H' = \) Shannon Diversity Index
- \( S = \) the number of species found in a sampling period

Evenness status was determined based on range values of evenness index, namely: (1) population evenness was low if \( E < 0.3 \); (2) population evenness was moderate if \( 0.3 < E < 0.6 \); and (3) population evenness was high if \( E > 0.6 \).
The Dominance Index ($C$) was calculated based on the Simpson dominance index formula [20], as follows:

$$C = \sum_{i=1}^{s} (pi)^2$$

where

- $pi = (ni/N)$
- $ni =$ number of individuals of species i
- $N =$ total number of individuals in a sampling period
- $s =$ number of species identified in the sampling period

Dominance was determined based on the following criteria: (1) low dominance if $0.01 < C \leq 0.30$; (2) moderate dominance if $0.31 < C \leq 0.60$; (3) high dominance if $0.61 < C \leq 1.00$. The greater the value of the dominance index, the greater the tendency for certain species to dominate the other species.

The Similarity Index ($Si$) was calculated based on the similarity index formula with reference to Izsak and Price [21] and Yue and Clayton [22] as follows:

$$Si = \frac{a}{a + b + c}$$

where

- $a =$ the number of species found only in Year A
- $b =$ the number of species found only in Year B
- $c =$ the number of species found in both Year A and Year B.

3. Results

The total number of parrotfishes found during the study was 6,684, with 2,459 in 2014, 2,580 in 2018, and 1,645 in 2019. The number of parrotfishes collected varied between sampling years (Table 1) and between months within each year (Figure 2). Likewise, the number of species varied considerably between sampling years (Table 1), as well as between sampling months (Figure 3).

### Table 1. Monthly parrotfish samples by volume and species in each sampling year

|                | Number of specimens collected | Number of species identified |
|----------------|-----------------------------|----------------------------|
|                | 2014 | 2018 | 2019 | 2014 | 2018 | 2019 |
| Mean           | 205  | 215  | 329  | 18   | 20   | 20   |
| SD             | 40   | 80   | 71   | 2    | 3    | 1    |
| Minimum        | 134  | 106  | 228  | 14   | 17   | 19   |
| Maximum        | 303  | 379  | 427  | 20   | 26   | 21   |
During the study, 34 species of Parrotfishes were found, namely *Bolbometopon muricatum*; *Calotomus carolinus*; *C. spinidens*; *Cetoscarus ocellatus*; *C. bleekeri*; *C. capistratoides*; *C. frontalis*; *C. japanensis*; *C. microrhinos*; *C. sordidus*; *Hipposcarus longiceps*; *Leptoscarus vaigiensis*; *Scarus altipinnis*; *S. caudofasciatus*; *S. chameleon*; *S. dimidiatus*; *S. festivus*; *S. flavipectoralis*; *S. forsteni*; *S. frenatus*; *S. ghobban*; *S. hypselopterus*; *S. niger*; *S. oviceps*; *S. prasiognatos*; *S. psittacus*; *S. quoyi*; *S. rivulatus*; *S. rubroviolaceus*; *S. scaber*; *S. schlegeli*; *Scarus sp*; *S. spinus*; and *S. tricolor*. The number of individuals of each species in the samples collected varied considerably over the research period (Figure 4).
Of the 34 species identified, there were ten parrotfish species with an average presence above 90%. These were: *C. bleekeri*, *C. capistratoides*, *C. sordidus*, *S. chameleon*, *S. flavpectoralis*, *S. ghobban*, *S. niger*, *S. quoyi*, *S. rivulatus*, and *S. schlegeli* (Figure 5).

The average values of the Diversity Index in 2014, 2018 and 2019 were similar (Table 2). The monthly diversity index values were in the range 1.79 to 2.85 (Figure 6).

| Table 2. Parrotfish Diversity Index values for each year of sampling |
|---------------------------------------------------------------|
| Diversity Index  | Year 2014 | Year 2018 | Year 2019 |
|------------------|-----------|-----------|-----------|
| Average          | 2.23      | 2.49      | 2.47      |
| STD              | 0.20      | 0.19      | 0.19      |
| Minimum          | 1.79      | 2.15      | 2.15      |
| Maximum          | 2.51      | 2.85      | 2.66      |
Figure 6. Parrotfish Diversity Index by sampling month and year

The average values of evenness index in 2014, 2018 and 2019 were 0.78, 0.84 and 0.84, respectively (Table 3). The monthly Evenness Index values ranged from 0.62 to 0.9 (Figure 7)

Table 3. Evenness index of Parrotfishes for each year of sampling

| Diversity Index | Year 2014 | Year 2018 | Year 2019 |
|-----------------|-----------|-----------|-----------|
| Average         | 0.78      | 0.84      | 0.84      |
| STD             | 0.07      | 0.04      | 0.03      |
| Minimum         | 0.62      | 0.76      | 0.80      |
| Maximum         | 0.86      | 0.90      | 0.87      |

Figure 7. Parrotfish Evenness Index by sampling month and year

The mean monthly values of the dominance index in 2014, 2018 and 2019 were 0.13, 0.12 and 0.10, respectively (Table 4). The monthly dominance index ranged from 0.05 to 0.23 (Figure 8). The
Similarity Index values were 0.912 (between 2014 and 2018), 0.969 (between 2014 and 2019), and 0.941 (between 2018 and 2019).

**Table 4.** Parrotfish Evenness Index values during each year of sampling

| Diversity Index | Year 2014 | Year 2018 | Year 2019 |
|-----------------|-----------|-----------|-----------|
| Average         | 0.13      | 0.12      | 0.10      |
| STD             | 0.04      | 0.03      | 0.02      |
| Minimum         | 0.05      | 0.08      | 0.09      |
| Maximum         | 0.23      | 0.19      | 0.13      |

**Figure 8.** Parrotfish Dominance Index by sampling month and year

4. Discussion

The diversity index values in the moderate range (1< $H'$ > 3) indicate that the exploited parrotfish populations have a moderate level of diversity. This indicates a situation where productivity is reasonably high, the ecosystem conditions are fairly balanced, and ecological pressures are moderate. The 34 species of parrotfishes found in the study is higher than the number of species found by Choat, Johnson, Taylor, Robbins, Franklin, Toonen and Bowen [23] in the Northern Great Barrier Reef. The relatively high parrotfish diversity, with a large number of species, and a fairly constant diversity index value over the period of study, indicates that the capture of parrotfishes in the Spermonde Islands does not seem to have endangered the diversity of the parrotfish community in this area.

The Evenness Index was quite high, with $E > 0.6$. This indicates that the parrotfish populations were relatively evenly distributed. Although the results of this study are difficult to compare directly to studies elsewhere, it could be concluded that the parrotfishes caught during the study had a fairly good distribution. This was despite the fact that parrotfishes in the Spermonde Islands do suffer anthropogenic pressures similar to those affecting parrotfish populations in other Indo-Pacific regions [24].

The dominance index was in the range of 0.01< $C <$0.30, which means that dominance was low and no one species really dominated the catch. The lack of dominance of certain species in the parrotfish community can be considered as a favourable result, because it means that each parrotfish species is likely to have an opportunity to carry out its ecological role in the local ecosystem. As herbivorous fish, parrotfishes are a key functional group in the coral reef ecosystem. Parrotfishes play an important role in the balance system of coral reef ecosystems, especially when facing periods of disturbance (increasing resistance) and during recovery periods (promoting resilience) [25].
The similarity index was close to one, which means that most of the 34 species of parrotfishes were found in each year during the study. High similarity index values indicate that fishing pressure on the parrotfish populations in the Spermonde Islands does not appear to give cause for alarm. Nonetheless, as parrotfishes are intrinsically vulnerable to overfishing [26], there is a need for caution and continued monitoring of the situation. Fishermen in the Spermonde Islands use two fishing main gears for catching parrotfishes, namely spears for large fish, and nets for medium and small fish. The consistently relatively high diversity of parrotfishes throughout the study may be related to the fishing gear used by these fishermen.

5. Conclusion
Long-term monitoring of parrotfishes species composition indicates that parrotfish diversity remained consistently at the moderate level, indicating reasonably productive and balanced ecosystem conditions, and moderate levels of ecological pressure. Over the study period, the parrotfishes species were evenly distributed, no one species really dominated the catch, and the similarity of species between the three sampling years was close to perfect. Based on the results of this research, it could be concluded that, in the Spermonde Islands, the capture of parrotfishes by traditional fishermen using nets and spears has not as yet resulted in fishing pressure heavy enough to have a serious impact on the condition of the resource.

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