The distribution of reef fish in Ternate Island, North Maluku, Indonesia

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Abstract. Reef fish is a constituent component for coral reef ecosystems, so it is very important to identify the distribution of reef fish species. This study aims to assess the number of reef fish species, diversity, abundance, recruitment, and frequency of size. The results showed that the number of reef fish species on Ternate Island was 42 families, 109 genera, and 265 species. The high level of diversity is 3.57 - 4.79 with an abundance of 8 - 28 ind.m⁻². The addition of new individuals to the population both due to reproduction and migration of 16.26 - 51.72%, the size-frequency of reef fish based on the size of the first time the gonads mature (Lₘ) is 45.00 - 70.00% of the total population of reef fish.

1. Introduction
Ternate Island's coastal waters have an area of 70% of coral reef ecosystems and 30% of seagrass, sand, and rock ecosystems resulting from the eruption of Gamalama. Coral reef ecosystems are coastal ecosystems that have high productivity, these ecosystems have organisms from a low level (producer) to high-level organisms (top-level), mostly from carnivorous fish species. Organisms that make up the coral reef ecosystem include reef-producing coral animals, determinants of water fertility plankton, macroalgae, macrobenthos, and reef fish [1, 2, 3].

Reef fish is a group of fish that are in the tropics and their life is closely related to coral reefs which are an important resource for protein supply for people's lives. The fish use coral reefs directly or indirectly for the benefit of their lives. Reef fish are grouped into target fish, indicator fish, and major fish. Information on the whereabouts and distribution of reef fishes on Ternate Island has not been finalized so it is necessary to conduct periodic studies to refine the addition of species. This study aims to assess the number of reef fish species, diversity, abundance, recruitment, and frequency of size.

2. Material and method
This study was conducted in Ternate Island, North Maluku, at 13 research locations spread in the southern, central, and northern parts of the Ternate Island, over a research period between November 2017 and November 2018 (Figure 1).
Data collection methods used are Belt Transect, Coral Reef Fish Visual Census, Underwater Photo Transect (UPT), and Underwater Video Transect (UVT). Each method has advantages and disadvantages so that a combination of methods is carried out to cover each other's deficiencies to obtain maximum data. Belt Transect is a method that is often integrated with visual census methods to identify reef fish. The monitoring process uses line transects with monitoring distance left and right of 1-2 meters each [4, 5].

Coral reef fish visual census is a method that is fast, accurate, effective, and environmentally friendly. The ideal time is when the water starts to tide where the fish come out to look for food, ranging from 09:00 - 16:00. This method is combined with the Belt Transect method [4, 6, 7, 8, 9, 10, 11, 12, 13].

UPT and UVT methods are methods that take advantage of technological developments, the images taken are then analyzed using computer software to obtain quantitative data [8, 14].

Analysis of reef fishes includes the number of reef fish species, diversity, abundance, recruitment, and size-frequency. Reef fish diversity was analyzed using a formulation of Shannon-Wiener [15], namely:

\[ H' = \sum_{i=1}^{s} P_i \ln P_i \]

Where, \( H' \) is diversity index, \( P_i \) is species chance of the total individual, \( s \) is number of species, \( n_i \) is number of individual species, \( N \) is total number of individual species. Analysis of the abundance of reef fish species in coral reef areas is calculated using the formula proposed as follows [15]:

\[ X = \frac{X_i}{A} \]
Where, \( X \) is abundance of fish (ind. m\(^{-2}\)), \( X_i \) is number of fish in the observation station (ind). \( A \) is area of coral reef observed (m\(^2\)). Recruitment was analyzed using the Beverton & Holt approach, which is the relationship between the size of reef fish juveniles and adult reef fish [16], with the following formula:

\[
R = S(\alpha + \beta S) \tag{3}
\]

\[
\frac{R}{S} = \alpha + \beta S \tag{4}
\]

Where, \( R \) is recruitment of reef fish juveniles (%), \( S \) is spawning stock of adult reef fish, \( \alpha \) and \( \beta \) is constant. The frequency of fish size is the process of grouping reef fish species based on the size of each species, genus, and family.

3. Result

The number of reef fishes in the waters of Ternate Island was 265 species 109 genera from 42 families spread over 13 research sites with 143.5 Ha of water. The highest types of Pomacentridae are 50 species and 26 species of the Chaetodontidae family (Table 1). The highest number of reef fish species is found in the north (Tobololo) and the south (Fitu) (Figure 2).

| No. | Family         | Genus | Species | No. | Family         | Genus | Species |
|-----|----------------|-------|---------|-----|----------------|-------|---------|
| 1   | Acanthuridae   | 5     | 19      | 22  | Monacanthidae  | 1     | 1       |
| 2   | Apogonidae     | 3     | 11      | 23  | Mullidae       | 1     | 5       |
| 3   | Aulostomidae   | 1     | 1       | 24  | Muraenidae     | 2     | 2       |
| 4   | Balistidae     | 5     | 9       | 25  | Nemipteridae   | 1     | 3       |
| 5   | Blenniidae     | 1     | 1       | 26  | Orectolobidae  | 1     | 1       |
| 6   | Caesionidae    | 2     | 8       | 27  | Ophichthidae   | 1     | 1       |
| 7   | Callionymidae  | 1     | 1       | 28  | Ostraciidae    | 2     | 3       |
| 8   | Carangidae     | 2     | 3       | 29  | Pempheridae    | 2     | 4       |
| 9   | Centriscidae   | 1     | 1       | 30  | Pinguipedidae  | 1     | 1       |
| 10  | Chaetodontidae | 5     | 26      | 31  | Plotosidae     | 2     | 2       |
| 11  | Diodontidae    | 3     | 4       | 32  | Pomacanthidae  | 4     | 7       |
| 12  | Ephippidae     | 1     | 2       | 33  | Pomacentridae  | 15    | 50      |
| 13  | Fistulariidae  | 2     | 2       | 34  | Priacanthidae  | 1     | 3       |
| 14  | Gobiidae       | 1     | 1       | 35  | Scaridae       | 4     | 11      |
| 15  | Haemulidae     | 1     | 7       | 36  | Scorpaenidae   | 2     | 5       |
| 16  | Hemiscyllidae  | 1     | 1       | 37  | Serranidae     | 7     | 19      |
| 17  | Holocentridae  | 3     | 5       | 38  | Siganidae      | 1     | 5       |
| 18  | Labridae       | 7     | 14      | 39  | Soleidae       | 1     | 1       |
| 19  | Lethrinidae    | 2     | 3       | 40  | Synodontidae   | 2     | 2       |
| 20  | Lutjanidae     | 6     | 14      | 41  | Tetraodontidae | 3     | 4       |
| 21  | Microdesmidae  | 1     | 1       | 42  | Zanclidae      | 1     | 1       |

|              | Total      | 54 | 134 | 55 | 131 |
|--------------|------------|----|-----|----|-----|
| Total number of genera | 109 |    |     |    |     |
| Total number of species  | 265 |    |     |    |     |
The level of diversity of coral fish in Ternate Island is relatively high with a value of 3.57 - 4.79 (Figure 3). The highest diversity of reef fishes in Tobololo with 186 species of reef fish species, and the lowest diversity of reef fish in Kalumata with the lowest number of reef fish species, 55 species.

The abundance value is the number of individual reef fish found in the area of research in the coral reef ecosystem. The abundance of Ternate Island reef fish ranges from 8-28 ind.m$^{-2}$, the highest abundance in the northern part (Tobololo, Sulamadaha, Talaga Nita, and Jikomalamo), the central part (Gamalama and Daulasi), and the southern part (Gambesi and Fitu). The range of abundance of reef fish is 23-28 ind.m$^{-2}$ (Figure 4).
Coral fish recruitment is the entry of new individuals into the population due to reproduction or migration. Coral fish recruitment occurs to defend themselves from predators and maintain balance in the population. The recruitment value is obtained from the size of the juvenile fish and migration from other locations. The recruitment value of reef fish in Ternate Island ranges between 16.26 - 51.72%. Recruitment of reef fish is highest in the north (Sulamadaha and Jikomalamo) and the south (Fitu) (Figure 5).

Assessment of the size of reef fish based on the size of the first mature gonad (L_{m}) or adult fish, assuming that fish with the size of Lm have the opportunity to produce new individuals (juveniles) more quickly. The frequency of coral fish size on Ternate Island ranged from 45.00 - 70.00%, the highest value in the north (Daulasi, Tobololo, and Sulamadaha) and the south (Rua, Kastela, Fitu, and Ngade) (Figure 6).
4. Discussion

Coral fish is a resource that has a close relationship with the coral reef ecosystem, spending part or all of its life in the area of coral reefs. Fish serves to maintain the stability of coral reefs to stay healthy, fish have levels in the food chain category, namely planktivores fish, herbivore fish, omnivore fish, and carnivore fish. The parameters of reef fish as an indicator of ecosystem health are diversity, abundance, recruitment, frequency of size, and abundance of herbivorous fish.

When compared with West Papua bird's head cages, there are 1511 species of 451 genera from 111 families with an area of 50 000 km$^2$ [17], so reef fish on Ternate Island are classified as high because of the small island and relatively low water area. Ternate Island has one endemic reef fish species, the Walking Shark (Hemiscyllium halmahera) which is spread in the south (Fitu) and the central (Falajawa and Gamalama).

The highest number of individuals was found from the reef fish species Pomacentridae in all study sites, the Chaetodontidae family in the northern part of Ternate Island. Pomacentridae is a major fish or ornamental fish species of small size 5 - 25 cm, diverse color characteristics, found to be abundant from the number of individuals and species, tend to be territorial. This fish throughout his life in the waters of coral reefs. Chaetodontidae is an indicator of fish, a typical reef fish species inhabiting the area of coral reefs and an indicator of ecosystem fertility.

Recruitment of reef fish in the south is found juvenile fish with a size of 2 - 5 cm, settled in coral holes, and between coral colonies. The most common types of coral found juvenile fish, namely Acropora Branching and Acropora Tabulate, the aim is to avoid predators and easy to obtain algae and plankton food. Most juvenile reef fish are found at depths of 2-4 meters. In the north (Sulamadaha) besides juvenile reef fish, coral fish migration is found from the family Chaetodontidae namely Chaetodon lunula and Hemitaurichthys polylepis. From 2011 to 2012 the results of identification of reef fish in the waters of Sulamadaha were not found by both types of reef fish [18] but were found in the waters of Talaga Nita a distance of 1.5 km, this migration occurred because the Talaga Nita area is now used as a tourist site so it feels interrupted migrating to safer reefs.

The level of frequency of reef fish is classified as medium, with an average of 55.92% fish groups with the size of the first gonad ripe, so it has a chance to spawn to produce new juveniles. Sulamadaha has a high value of the size of reef fish that is 70% the size of the Lm fish from the existing coral fish hordes. It was concluded that Sulamadaha is the highest reef fish spawning site because this area is protected, both for the spawning and enlargement process. After all, many juvenile fish sizes are found.

The highest abundance of reef fish in the south (Kastela), because these waters are directly associated with seagrass ecosystems. The highest number of individuals is found in Siganus canaliculatus. In the central and northern parts of Ternate Island found herbivorous fish from the
family Siganidae, Achanturidae, Scaridae, and Pomacentridae. The average abundance of herbivorous reef fish is relatively low at 6 ind.m\(^{-2}\), a high category if it has a fish abundance value > 10 ind.m\(^{-2}\).

The role of herbivorous fish in coral reef ecosystems is as a consumer from producers, connecting energy flow between producers to the next level of consumers (carnivores), and controlling algal growth. Herbivorous fish abundance is negatively correlated with the percentage of macroalgae cover but positively correlated with the addition of individual/coral colonies [19, 20, 21].

5. Conclusions
The distribution of reef fish in Ternate Island is evenly evidenced by the high level of diversity. The highest number of species in the waters of Tobololo in the north and Kastela in the south. The most common type is found in the family Chaetodontidae and Pomacentridae which are indicators and major fish with an abundance of 8-28 ind.m\(^{-2}\). Coral fish recruitment occurs to defend themselves from predators and maintain balance in the population, coral fish recruitment is 16.26 - 51.72% of the total population. Reproductive opportunities are generated from the frequency of first-time gonad fish (L\(_m\)) which is 45.00 - 70.00% of the total population.

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Acknowledgements
We are grateful for the diving team from Coastal Ecosystem Research Center (M-JIKO Pesisir) for their participation along the research.