Mortality and exploitation rate of some reef fish in Ternate Island Waters

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Abstract. Fish population dynamics are determined by the balance between population increase resulted from growth and addition of new individuals (recruitment), and population decrease due to fishing mortality and natural mortality. It is important to understand fish resources condition, including their change pattern caused by pressures on coral reef fisheries resource in coastal area of Ternate Island. This research aimed to analyze mortality and exploitation rate of several reef fishes that caught at coastal area of Ternate Island. Stock assessment method was used to determine the mortality and exploitation rate of some reef fishes. Study results showed that the fishing mortality of the sample species was lower than their natural mortality, while the exploitation rate results also showed the same condition those found in mortality rate, where the fish with high growth coefficient tended to have high mortality rates.

1. Introduction
Fish resources that have been exploited and have not received an assessment of their stock status will have an impact on the sustainability of these fish resources, both in the form of reduced catches and the availability of ecosystem services [1][2]. Failures in fishery activities are generally found in multi-species coral fisheries, where more than 100 million people are involved in small-scale fishing, where institutionally sometimes very weak or non-existent [3][4][5].

According to [6] that the increasing of development and human activity at the coastal area of Ternate Island, have an impact on coral reef fisheries, which resulting pressure for coral reef fisheries, both on the fishes and their ecosystem (coral reef ecosystem). The needs on resources information and their change pattern due to the pressure on the coral reef fisheries resource in the coastal area of Ternate Island, become an important thing to be done. That information will promote to the management process for sustainable development, regarding the structure changing processes of coral reef fisheries, both stock structure and distribution pattern.

Fisheries biology research is often directed at the species that are the target of fishing. In line with the current reduction in the number of catches, managers and users of fisheries resources are expected to have broad insight into the relationship between target species and other species and their ecosystems [7]. Fish stocks are generally seen in fishery activities that have an important economic component in maritime countries [8]. However, fisheries activities have also failed in several regions
of the world due to lack of efforts to maintain environmental sustainability, as well as efforts to maintain the diversity and biomass of fish resources [9].

Organisms generally experience growth in size (length and weight). Key factors that affect fish growth include the availability of food, the number of fish organisms that utilize food sources, water temperature, oxygen and other water quality factors, as well as the age and maturity level of spawning of the fish [10]. The length-weight relationship (LWR) is very important in fisheries biology to estimate the magnitude of the weight value at a certain length [10][11]. Fish population dynamics are determined by the balance between (1) population increase due to growth and the addition of new individuals (recruitment), and (2) population decrease due to fishing mortality (F) and natural mortality (M) [12]. This research aims to analyze the mortality and exploitation rate of several reef fishes that catch at the coastal area of Ternate Island.

2. Materials and methods

2.1. Data collection

The sample species are collected directly from the fisherman catches and from the catches that landed at the fishing port (PPI and PPN) at Ternate Island. Total sampled that have measured in this study was 3,316 fish, from five family with five sample species of reef fishes (Table 1). The length and weight measurement were done to each individual catches. The total length (Lt) was applied for the length measurement, and the weight was the wet weight of the total body of sampled fish.

| Family       | Species            | Number of sample |
|--------------|--------------------|------------------|
| Acanthuridae | Paracanthurus hepatus | 591              |
| Caesionidae  | Pterocaesio pisang  | 1,044            |
| Labridae     | Thalassoma lunare   | 367              |
| Lutjanidae   | Pinjalo pinjalo     | 722              |
| Siganidae    | Siganus guttatus    | 592              |
| **Total**    |                    | **3,316**        |

2.2. Data analysis

The mortality rate parameters consist of total mortality (Z), natural mortality (M), and fishing mortality (F). Total mortality rate can be determined by using several models. In this research, the Z value was estimated by linearized catch curve based on length composition data [13]. Natural mortality (M) rate was determined using Pauly empirical equation [7][13]:

\[
\ln M = -0.0152 - 0.279 \ln L_A - 0.6543 \ln K + 0.463 \ln T
\]

where \( T \) is average annual sea surface temperature (°C) which in this study used a value of 28 °C, \( L_A \) is asymptotic length and \( K \) is growth coefficient. Then from the results of the estimation of \( Z \) and \( M \) value, it can be determined the fishing mortality (F) rate, which are \( F = Z - M \), and the exploitation rate (E) was \( F/Z \). Gulland (1971) in [14] stated that the fishing mortality rate or optimum exploitation rate is 0.5 (\( E_{opt} = 0.5 \)).

The exploitation rate of the stock can be determined using equation [15]:

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

If \( E = 0.5 \) shows optimum utilization ratio (\( E_{opt} \)). This is based on the assumption that a balanced result is optimal when \( F = M \) [15]. The analysis proceses were using the Ms. Excel and FiSAT II (FAO-ICLARM Stock Assessment)-ELEFAN.
3. Results and discussion

The growth parameters of reef fish measured in this study are as presented in Table 2.

Table 2. Growth parameters, age at maximum size, and growth performance index ($\sigma'$) used in the analysis.

| Family   | Species                  | $L_\infty$ (mm) | $K$ (per year) | $t_0$ (year) | $t_{max}$ (year) | $\sigma'$ |
|----------|--------------------------|-----------------|----------------|--------------|------------------|-----------|
| Acanthuridae | Paracanthurus hepatus     | 326.32          | 0.64           | -0.1478      | 4.54             | 4.833     |
| Caesionidae | Pterocaesio pisang        | 368.42          | 0.56           | -0.1702      | 5.19             | 4.881     |
| Labridae   | Thalassoma lunare         | 469.47          | 0.55           | -0.1630      | 5.29             | 5.084     |
| Lutjanidae | Pinjalo pinjalo           | 315.79          | 0.56           | -0.1776      | 5.18             | 4.747     |
| Siganidae | Siganus guttatus          | 421.05          | 0.71           | -0.1203      | 4.11             | 5.100     |

$L_\infty$ is asymptotic length; $K$ is growth coefficient; $t_0$ is theoretical age at zero length; $t_{max}$ is age at maximum length ($L_{max}$); $\sigma'$ is growth performance index.

The estimation of the mortality using length parameters from the sample species, resulting the higher value of total mortality ($Z \pm SD$) were found in the family of Siganidae ($Siganus guttatus$) with value of $0.99 \pm 0.171$ per year, while the lower value obtained by family of Labridae ($Thalassoma lunare$) with value of $0.62 \pm 0.151$ per year (Table 3). The natural mortality ($M$) at 28 °C of the average annual sea surface temperature was founded high in the family of Acanthuridae ($Paracanthurus hepatus$) and Siganidae ($Siganus guttatus$), within the value of 0.68 per year. Meanwhile, the lowest $M$ value was founded in the family of Labridae ($Thalassoma lunare$) with the value of 0.56 per year.

Table 3. The estimation of mortality and exploitation rate value on the sample fish.

| Family   | Species                  | $Z \pm SD$ (per year) | $M$ (per year) | $F$ (per year) | $E=F/Z$ (per year) | $M/K$   |
|----------|--------------------------|-----------------------|----------------|----------------|-------------------|---------|
| Acanthuridae | Paracanthurus hepatus     | 0.72 ± 0.051          | 0.68           | 0.03           | 0.05              | 1.07    |
| Caesionidae | Pterocaesio pisang        | 0.77 ± 0.023          | 0.61           | 0.16           | 0.21              | 1.08    |
| Labridae   | Thalassoma lunare         | 0.62 ± 0.151          | 0.56           | 0.06           | 0.10              | 1.02    |
| Lutjanidae | Pinjalo pinjalo           | 0.77 ± 0.016          | 0.63           | 0.14           | 0.18              | 1.13    |
| Siganidae | Siganus guttatus          | 0.99 ± 0.171          | 0.68           | 0.31           | 0.31              | 0.96    |

$Z$ is total mortality; $M$ is natural mortality; $F$ is fishing mortality, $E$ is exploitation rate, and $M/K$ is ratio of natural mortality to growth coefficient.

The results of the research shows the natural mortality ($M$) from all sample species was higher than fishing mortality ($F$). This condition may accrue due to fishing gear that been use in fishing activity at the coastal area of Ternate Island. There is only a handline gear that used as fishing gear. The result also shows that fishes with high growth coefficient such as family Siganidae tend to have high mortality rates, which indicated that the high predations was occur in the food webs on coral reefs ecosystem at Ternate Island.

Fishing activities will have an influence on the size of the exploited community structure. This change can be seen from the differences that occur in size-based indicators (e.g., length and weight), which have a direct or indirect impact on changes in the size structure of a population [16][17]. In capture fisheries, fishing activities are simultaneously targeting on several fish, such as in reef fisheries. When fishermen target certain fish in their catch, they will use certain fishing methods for the target fish, and become suboptimal for other fish. Therefore, the catch coefficient will depend on the type of fishing target [18]. According to [19], selective fishing activities where fishermen target large-sized fish as their fishing targets, as well as the vulnerability of each individual fish in avoiding fishing gear, will affect the low population growth of the target fish species.
Figure 1. Mortality of sample fishes of reef fishes that found in Ternate Island waters.

For the fishing mortality (F), the higher value was from the family of Siganidae (*Siganus guttatus*) with the value of 0.31 per year, and the lowest value was from Acanthuridae (*Paracanthurus hepatus*) with the value of 0.03 per year, where it resulting the exploitation rate (E) for those two species was 0.31 and 0.05 per year, respectively (Table 3).

The exploitation rate (E) results also shows the same condition those found in mortality rate, where the fish with high K value, tend to have high mortality rates. The dynamics of a fish population are determined by a balance between (1) increases due to growth and recruitment, and (2) losses due to fishing mortality (F) and natural mortality (M) [12].

The natural mortality ratio to growth coefficient (M/K) values, show that the highest ratio of M/K was from the family of Lutjanidae (*Pinjalo pinjalo*) with M/K = 1.13, while the lowest value was from the family of Siganidae (*Siganus guttatus*) with M/K = 0.96 (Table 3). The estimation result for the mortality of the sample species was presented in Figure 1, while the estimation of fishing mortality, number of population, and number of catch based on the length size using FiSAT II-ELEFAN routine was presented in Figure 2.

The value of the natural mortality ratio to the growth coefficient (M/K) of the sample fishes indicates that there are environmental factors that play a significant role in the development of target fish populations in coral reef ecosystems in the coastal area of Ternate Island. Many ecological factors affect natural mortality (M), including biotic influences such as changes in environmental carrying capacity, foraging pressures (top-down) or increased productivity (bottom-up), and abiotic influences such as physical stress due to changes in temperature, salinity and other parameters [20]. It further explained that many aspects of a species' life cycle are related to natural mortality (M), including growth rate, maximum age and size, and fecundity, and all aspects related to population dynamics of a stock. Failure to predict and respond to changes in natural mortality will affect the level of sustainable use of these stocks.
Figure 2. The estimation of fishing mortality, number of population, and number of catch based on the length size using FiSAT II-ELEFAN routine.

According to [7] that fishing that has not reached its maximum size will result in overfishing. The most important thing in capture fisheries management is to maintain the number of adult fish that have matured at a level that can ensure the survival of the fish population. It was further explained that the life span and growth rate were different for each type of organism. Organisms with low growth rates do not require a large amount of energy and are able to spawn rapidly and repeatedly, while the advantage of organisms with high growth rates (fast growth) is that they can quickly reach the initial size of their life span, so they are able to avoid predators. In environmental conditions with a high
level of predation, a high growth rate allows some individual organisms to reach a size that is able to regenerate to maintain their population in the nature.

4. Conclusion
The fishing mortality (F) of reef fishes is lower than then their natural mortality (M). Low exploitation rate (E) for reef fishes indicated that reef fish resource exploitation at coastal area of Ternate Island was under-exploited. However, there were several things to be considered in reef fishing activity, such as catch of small size (or under size) fishes. If it continues, it may affect recruitment pattern of reef fish populations and lead to disturbing abundance and structure of the reef fish population.

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