Stock estimation, species composition and biodiversity of target reef fishes in the lesser Sunda-Banda Seascape (East Flores, Alor and South West Maluku regencies), Indonesia

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Abstract. This study aimed to fill the gap of knowledge on this group of fishes by estimating the natural stock, species composition and biodiversity of target reef fishes from three regencies; Alor, East Flores (Flores Timur) and Southwest Maluku (Maluku Barat Daya/MBD) using underwater visual census method. A total of 176 species belong to 19 families of economically important target fish were recorded from 62 survey sites. The highest estimated stock is located in Southwest Maluku Regency – based on both abundance and biomass values, followed by Alor Regency and the lowest in East Flores Regency. Target fish species from the family of Caesionidae has the highest composition both based on abundance (74%) and biomass (40%). The highest species composition of target fish is from Pterocaesio tile (57.65%) which is more than 50% of the overall target fish. Community structure of target fish in the three regencies is still in a relatively good condition based on diversity index (H'), evenness (E) and no domination (C) of a single species occurs inside the target fish community, with exception in Alor Regency where the community of target fish is indicated to be under pressure. Biodiversity index by Bray-Curtis analysis in each location shows that most of the sites have the similarity of 67.51%, suggesting that there is not much difference in terms of target fish community structure between the three regencies.

Keywords: abundance, biomass, community structure, coral reef fisheries, underwater visual census

1. Introduction

Target fish is defined as fishes that are usually fished for consumption and have important economic value [1, 2]. The target fish consists of ten families i.e. Caesionidae, Holocentridae, Serranidae, Siganidae, Scaridae, Lethrinidae, Priacanthidae, Labridae, Lutjanidae, and Haemulidae [3]. However, The Ministry of Marine Affairs and Fisheries 2014 created a list of target fish to evaluate marine protected area effectiveness that consists of 16 families, which are Acanthuridae, Scaridae, Siganidae, Labridae, Serranidae, Haemulidae, Lutjanidae, Carangidae, Scombridae, Caesionidae, Nemipteridae, Sphyraenidae, Carcharhinidae, Dasyatidae, and Sphyridae. Meanwhile,
shortened the target fish into only four families, namely Serranidae, Lutjanidae, Lethrinidae and Haemulidae [4].

Coral reef ecosystems are complex and productive ecosystems that are predominantly scattered in small islands that act as habitats for various types of fishes [5]. Reef fishery - in this case, the target fish - is part of the coral reef ecosystem and is commonly related to small scale fisheries, as the small scale fishers undertake fishing in coastal areas using a boat with or without an engine, or even without a boat. Coral fish populations are declining due to these localized small-scale fisheries, and in case of targeted species, although their abundance can vary within one area to another, the high fishing pressure due to proximity to fishing villages [6-8], and the use of destructive fishing methods, i.e blast fishing, cyanide fishing, and speargun with hookah [9] can further threaten this particular fish group severely. Moreover, small scale fishers for live reef fish trade in Indonesia tend to increase their effort to double their catches due to the increase in demand, leading to overexploitation [10]. In addition, despite its importance for human well-being, reef fish data is often poorly recorded, under-appreciated, and less "used" in policy and management programs [11].

The target species diversity can reflect the coral diversity within the ecosystem. Therefore the problem of coral fisheries cannot be separated from the management of the coral reef ecosystem area. Target fish in Indonesia has a potential of around 0.08 million tons from 6.26 million tons of sustainable potential of Indonesian fisheries [12].

East Flores, Alor and Southwest Maluku regencies concerning fisheries management areas in Indonesia are included in The Fisheries Management Area of Indonesia (Wilayah Pengelolaan Perikanan Negara Republik Indonesia/WPPNRI) 573, 714 and 718, while the potential of their fisheries are 8,778, 164,165 and 30,555 tonnes respectively [13, 14]. Unfortunately, the level of utilization of WPPNRI 753 - located in the southern region of East Flores and Alor regencies - are overexploited while the rest (WPPNRI 714 and 718) are still moderately exploited. The purpose of this study was to estimate the natural stock of target fish in nature, measure the abundance of target species of fish and their biodiversity from Alor, East Flores and Southwest Maluku regencies in order to be used as a reference in managing the surrounding water area.

2. Materials and Methods

2.1. Time and study area
The study was conducted in 62 sites within three regencies which are comprised of 18 sites in East Flores, 24 sites in Alor, and 20 sites in Southwest Maluku. The survey was carried out in two periods, 13th March-1st April 2014 for both East Flores and Alor, and 1st-10th October 2014 for some parts of East Nusa Tenggara (Nusa Tenggara Timur/NTT) and Southwest Maluku. Determination of survey sites was based on locations that are representative to each coral reef habitat in these three regencies.
2.2. Target fish survey
The target fish data collection was conducted using a visual census method with 5 replications of 50 x 5-meter belt transect at depth of 10-12 meters [4, 9, 15-17]. Fish identification was based on [18-22]. We calculated the abundance and total area of transects to estimate fish stocks [23].

2.3. Data analysis
Reef fish analysis includes:

(1) An abundance of selected communities, calculated by the following equation [24]:

\[ X_i = \frac{n_i}{A} \] .......................... (1),

Where:
\( X_i \) = i-selected community abundance (individual/colony per square meter);
\( n_i \) = the total number of selected communities at the i-observation station;
\( A \) = Area of observation transect.

(2) Coral fish biomass: Fish length data (cm) was converted into weight (kg) using the following equation [25]:

\[ W = a \times L^b \] .......................... (2),

Where:
\( W \) = weight (gr);
\( L \) = total length (cm);
\( a \) & \( b \) = constant rate of growth per species [26-27]

(3) Target reef fish stock estimation is calculated using equation based on fish abundance and transect area used [28]:

\[ S = D \sum_{i=1}^{p} L_d \] .......................... (3)
Where:
S = total stock;
D = abundance of fish;
Ld = habitat area (ha).

Meanwhile, the (4) value of fish abundance was calculated using a number of individual fishes found and the area of transect, following the equation [23]:

$$D = \frac{\sum_{i=1}^{n_i} n_i}{L_d} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4),$$

Where:
D = fish abundance (ind/m² or ind/ha);
Ni = the number of fish to-i found (individual);
Ld = transect area (m²).

(5) Target fish biodiversity value, including the structure of the reef fish community, was calculated using Shanon-Weiner diversity index [29]:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5),$$

The value of $H' \leq 2$ was categorized as low diversity, the value of $2 \leq H' \leq 3$ as moderate diversity, and $H' \geq 3$ as high diversity [30].

(6) Similarity (Evenness) index was calculated [29]:

$$E = \frac{H'}{H \text{ maks}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6)$$

Evenness index value (E) shows the stability of a target fish community, where the E value closer to 1 indicates that the target fish community is more stable with an even number of species and if it approaches 0 then the target fish community is increasingly unstable [30].

(7) Dominance index (C) was calculated [29]:

$$C = \sum_{i=1}^{s} p_i^2 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

Dominance index value (C) ranged from 0 to 1, where value close to 1 indicates the dominance of particular species within the target fish community, and value close to 0 means no dominance by any species [30].

(8) To find out the level of classification based on the similarity of reef fish species, the Bray-Curtis similarity index is used [31] with an equation as follows:

$$B = \frac{\Sigma(X_{ij} - X_{ik})^2}{\Sigma(X_{ij} - X_{ik})^2} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

Where:
B = measurement of the dissimilarity of Bray-Curtis,
Xij, Xik = no. Individuals in species I in each sample,
I, j = row and column 1,2,3 ... x.

Measurement of the Bray-Curtis similarity index can further be used to generate the Bray-Curtis measurement index, namely 1.0 - B [31]. The results of the calculation of the Bray Curtis index are
displayed in the form of a dendrogram cluster analysis. The analysis of data was conducted using PRIMER 7 and R statistical programming language [32].

3. Results and Discussion

3.1. Stock estimation of target fish
A total of 176 species from 19 families of target fish were recorded during the study. The location with the highest abundance of target fish is located at the Buffalo Reef in the Southwest Maluku Regency with 37,216 individuals (ind.) ha\(^{-1}\) (±18,557.45 SE) and the lowest is at Tanjung Soyang in Alor Regency with 186.67 ind. ha\(^{-1}\) (± 74.23 SE). Meanwhile, the highest biomass was found at Buffalo Reef as well, which consisted of 33,943.77 kg.ha\(^{-1}\) (±18,078.97 SE) biomass while the lowest biomass was found at Waybalun B in East Flores Regency with 15,033 kg.ha\(^{-1}\) (± 6.63 SE; figure 2).

![Figure 2](image)

Figure 2. The mean of target fish abundance (ind.ha\(^{-1}\); bottom) from 62 dive sites in three regencies.

The results of the analysis of the three regencies showed that the Southwest Maluku Regency has the highest abundance with an average of 13,668.4 ind.ha\(^{-1}\) (±2,854.27 SE) and also the highest average biomass of 13,079.18 kg.ha\(^{-1}\) (±2,367.03 SE), whereas East Flores Regency was the lowest with abundance of 1,502.23 ind.ha\(^{-1}\) (±342.84 SE) and biomass of 652.83 kg.ha\(^{-1}\) (±173.42 SE; figure 3). It was clear that there were significant differences in both abundance (\(F_{8,212} = 0.000118\), p-value < 0.001) and biomass (\(F_{17,17} = 0.000392\); p-value < 0.001) of target fish in Southwest Maluku Regency compared to Alor and East Flores Regencies.
The highest abundance of target fish in Southwest Maluku is with Caesionidae family at 4,654 ind.ha\(^{-1}\) (±1,351.76 SE), Carangidae at 3,028 ind.ha\(^{-1}\) (±2,322.52 SE), and Scombridae at 2,928 ind.ha\(^{-1}\) (± 2,888 SE). The highest abundance of target fish in Alor waters based on the family is Scombridae 9,240 ind.ha\(^{-1}\) (± 8,760 SE), Caesionidae 3,350 ind.ha\(^{-1}\) (± 1,055.02 SE), and Acanthuridae 290 ind.ha\(^{-1}\) (± 106.06 SE). The highest abundance of target fish in East Flores waters based on the family is Scombridae 6,080 ind.ha\(^{-1}\), Caesionidae 1,413 ind.ha\(^{-1}\) (± 387.49 SE), and Acanthuridae at 257 ind.ha\(^{-1}\) (± 77.38 SE; figure 4).

The calculation of fish stocks based on [28] is carried out based on two assumptions; the pattern of dispersion and composition of homogeneous fish within a fishing ground area [33]. This approach does not use biomass (B) value which is expressed in units of kg or tons, but using fish abundance (D) value expressed in the number of individuals per unit area (ind.ha\(^{-1}\)) [34].
Using geographic information systems (GIS) analysis, the area of coral reefs for the Southwest Maluku, Alor, and East Flores are 35,240.14 ha, 4,437.19 ha, and 11,497.82 ha respectively. The highest average number of fish stocks in the waters of Southwest Maluku, Alor, and East Flores waters are as many as 314,813,058, 42,359,361, and 46,449,031 individuals respectively (figure 5). The waters of Southwest Maluku was dominated by (1) Caesionidae family which consisted of Pterocaesio tile and Caesio caerulaurea, (2) Carangidae family which consisted of Elagatis bipinnulata and Seriola lalandi, (3) Scombridae family which consisted of Selaroides leptolepis and Scomberomorus commersoni. The number of target fish stocks in Alor waters is dominated by Selaroides leptolepis from Scombridae family, Pterocaesio tile and P. pisang from Caesionidae family, and Naso hexacanthus and Naso lopesi from Acanthuridae family. The target fish stocks in the waters of East Flores is dominated by Rastreliger kanagurta from Scombridae family, Pterocaesio trilineata and the Pterocaesio digramma from Caesionidae family.

Figure 5. The mean of target fish stock (ind ±SE) is based on fish families in three regencies.

3.2. Species composition of target fish
This study reveals the largest 10 fish species from the whole target fish community in the three regencies. They are Pterocaesio tile (57.65%), Caesio lunaris (4.18%), Caesio teres (3.27%), Selaroides leptolepis (3.12%), Pterocaesio pisang (2.84%), Selar crumenopthalmus (2.83%), Naso hexacanthus (2.13%), Caesio caerulaurea (1.86%), Lutjanus gibbus (1.84%), and Pterocaesio chrysozona (1.51%). Caesionidae family is the most abundant (74%) with the highest biomass (51%) compared to other target fish families. Meanwhile, the lowest abundance and biomass values were from family Sphyraenidae or barracuda fishes with 0.0038% in abundance and 0.0016% in biomass (figure 6).
Target fish composition in East Flores Regency is dominated by Caesionidae family that comprised of 47% of total abundance, followed by Scaridae family with 19% of total biomass. Meanwhile, the lowest composition in abundance and biomass is from family Dasyatidae (stingray) with 0.058% and 0.16%, respectively. In Southwest Maluku Regency, the highest abundance composition of target fish is from Caesionidae family (76%) and the lowest is from Carcharhinidae (sharks) family (0.0055%). The highest composition of biomass in Southwest Maluku is from the Caesionidae family with 53% and the lowest is from the Nemipteridae family which consisted of only 0.000099% of total biomass.

### 3.3. Biodiversity of target fish

Community structure of target fish is assessed based on Shannon-Weiner diversity index. The average value from the three regencies is 2.1, with the highest value in Southwest Maluku (2.264) and the lowest in Alor (1.854). This diversity index value indicates that the overall location has moderate diversity level (<3). The greater diversity (H’) values indicate higher species diversity or species richness [24, 35]. The diversity index value depends on the number of target fish species found in habitat and affected by species abundance distribution. The highest diversity value is 3.34 found at Pulau Laut in Southwest Maluku Regency, and the lowest is 0.34 at Pulau Pura B (table 2). The diversity index values in Alor and East Flores are slightly higher than the diversity index in the Anambas Islands [36] with an average of 1.451.

Among the three regencies, the highest evenness index (E) is 0.635 from East Flores and the lowest is 0.368 from Southwest Maluku, with average from the three regencies is 0.490. Within the site level, the highest evenness index value is 0.82 in Balaweling B Village which can be categorized as stable, meanwhile, the lowest is 0.06 in Pulau Pura B which can be categorized as enduring stress. Evenness index (E) is used to describe the number of individuals within each species in a target fish community [24].

The average value of dominance index from the three regencies is 0.251. The lowest value is 0.0315 in Alor and the highest is 0.159 in East Flores. The dominance index in all regencies showed low values indicating no domination of single target fish species in the region. In site level, the highest dominance value is 0.89 in Pulau Pura B-Alor Regency, and the lowest is 0.05 in Pulau Laut-Southwest Maluku (table 2).
Table 2. Diversity Index (H’), Evenness (E), Dominance (C), Number of individuals and Number of target fish species in the three regencies in the Lesser Sunda Banda seascape.

| Regency   | Location                  | H’   | E    | C    | No. individuals | No. species |
|-----------|---------------------------|------|------|------|-----------------|-------------|
| Babylon   |                           | 2.18 | 0.32 | 0.62 | 671             | 33          |
| Bangkalan/Desa Ombay B |                         | 0.51 | 0.08 | 0.8  | 3292            | 34          |
| Baulaung B |                          | 2.65 | 0.75 | 0.08 | 384             | 27          |
| Clownfish valley |                      | 2.4  | 0.42 | 0.15 | 70              | 25          |
| Desa Aimole B |                        | 2.88 | 0.61 | 0.11 | 1125            | 47          |
| Desa Pandai B |                        | 0.9  | 0.16 | 0.72 | 925             | 36          |
| Karang Le B |                         | 2.15 | 0.58 | 0.13 | 30              | 9           |
| Kolana Utara B |                       | 1.88 | 0.39 | 0.26 | 185             | 30          |
| Lemma     |                          | 1.06 | 0.18 | 0.57 | 407             | 30          |
| Mademang B |                          | 2.23 | 0.76 | 0.13 | 37              | 17          |
| Mahi B    |                          | 1.96 | 0.68 | 0.18 | 18              | 11          |
| Marutaing 2 |                        | 2.34 | 0.63 | 0.13 | 427             | 33          |
| Mausamang B |                       | 0.5  | 0.08 | 0.84 | 594             | 24          |
| Pulau Batang B |                      | 2.73 | 0.7  | 0.08 | 1278            | 38          |
| Pulau Kambing B |                    | 1.79 | 0.56 | 0.2  | 932             | 14          |
| Pulau Kangge B |                    | 2.31 | 0.6  | 0.12 | 54              | 17          |
| Pulau Pura B |                        | 0.3  | 0.06 | 0.89 | 568             | 14          |
| Pulau Rusa B |                       | 2.32 | 0.8  | 0.1  | 59              | 21          |
| Pulau Ternate B |                     | 2.19 | 0.56 | 0.16 | 1177            | 21          |
| Sawarana B |                            | 0.94 | 0.2  | 0.57 | 228             | 29          |
| Tanjung Ikara B |                      | 2.37 | 0.74 | 0.1  | 49              | 24          |
| Tanjung Soyang |                     | 1.48 | 0.76 | 0.27 | 14              | 8           |
| Taramana B |                          | 2.23 | 0.76 | 0.13 | 158             | 23          |
| The Boardroom |                        | 2.21 | 0.35 | 0.21 | 112             | 29          |
| Adonara B  |                          | 2.61 | 0.73 | 0.09 | 112             | 29          |
| Aran B     |                          | 2.36 | 0.62 | 0.12 | 123             | 26          |
| Batu Payung B |                        | 2.61 | 0.74 | 0.1  | 257             | 45          |
| Desa Balaweling B |                  | 1.89 | 0.82 | 0.16 | 118             | 26          |
| Hurung B   |                          | 2.71 | 0.8  | 0.07 | 38              | 19          |
| Ile Padung B |                        | 2.4  | 0.69 | 0.13 | 428             | 27          |
| Karang Sarbete |                       | 2.53 | 0.45 | 0.14 | 141             | 27          |
| Kolidateng B |                       | 2.01 | 0.67 | 0.18 | 78              | 18          |
| Koten B    |                          | 2.51 | 0.75 | 0.1  | 99              | 34          |
| Lamawalang B |                      | 2.24 | 0.62 | 0.12 | 82              | 20          |
| Lato B     |                          | 2.48 | 0.75 | 0.1  | 135             | 28          |
| Lowoingu B |                           | 2.42 | 0.61 | 0.15 | 757             | 38          |
| Pulau Tiga B |                        | 1.87 | 0.43 | 0.27 | 432             | 35          |
| Pulo Mas B |                           | 1.99 | 0.78 | 0.15 | 176             | 10          |
Target fish from the three regencies were grouped based on the similarity of species in all observation locations (62 sites). At the setting level, the dendrogram is 0.3248 or 32.48% which is the average value of the Bray-Curtis dissimilarity index between locations. The target group of fish communities was then grouped based on this setting level, and we found 8 target fish groups with grouping independent from the grouping based on the regencies (figure 8).

The clusters created by the Bray-Curtis analysis indicated the similarity of habitat features within each site group, including the contour type and oceanographic hydrodynamic conditions such as currents and tides. The first site cluster was characterized by the flat slope contour, consisted of the Pulau Mas B, Karang Le B, and Tanjung Soyang. The second site cluster was characterized by a gentle slope with weak currents consisted of Lowoingu B, Balaweling Village, Aran B, Hurung B, Ile Padung B, Adonara B and Lato B. The third site cluster was grouped by a steep slope contour type and weak currents, which includes 60% of sites in the three regencies ranging from Clownfish Valley to Pulau Laut. The fourth site cluster was grouped by sloping types; they are Mademang B, Kambing B Island, Lamawalang, Rusa Island, Kolidateng and Kangge Island. The next site cluster was grouped by a steep slope and strong currents consisted of Pura Island and Tanjung Naga. Meanwhile, Pulau Tiga and Waybalun were not included in any cluster due to having totally different characteristics of habitats and they were grouped into the last site cluster (figure 8).
Figure 7. Dendrogram of cluster analysis using Bray-Curtis dissimilarity index based on target fish communities in three regencies in the Lesser Sunda Banda seascapes.

With total of 176 species from 19 families of target fish recorded in this study, this shows that the number of fish species within our study area is much higher than in Bunaken National Park where the target fish were 100 species from 15 families [37] and in Teluk Perigi, Trenggalek in East Java where 32 species from 9 families were found [38].

Meanwhile, the Southwest Maluku regency showed the highest fish abundance and the highest fish biomass compared to the other two regencies. The high potential of coral fisheries in Southwest Maluku is known to be highly influenced by the existence of local tenure system called Sasi. The available fishing period and accessibility to the fishing ground are so limited that it creates a natural barrier and helps to maintain the sustainability of the resources. Other locations in Alor and East Flores are already overexploited where abundance and biomass are very low.

Similar to the condition of the reef fishes, habitat coverage in Alor and East Flores regencies are also lower than Southwest Maluku Regency. Habitat degradation will cause a double effect: one, increasing fisheries pressure; and two, reducing large-sized target fish so that smaller fish are prone to be targeted as well and finally resulted in degraded fish stocks [39]. However, conservation effort to restore fish stocks and coral reef ecosystem, in general, is developed in each regency. Pantar Strait Aquatic Conservation Area in Alor Regency was established based on previous research [40], and Natural Reserve of East Flores in East Flores Regency was established based on previous research [41].

The most abundant fish family from the three regencies is from Caesionidae family which resembles the previous research [42] where the Caesionidae family has the highest abundance in Bunaken National Park. This is also similar to the results of La Tanda study [18] in Raja Ampat Regency, where the Caesionidae family has the highest abundance and biomass compared to other target fish family. Caesionidae family is not as highly-targeted as groupers (Serranidae) and jacks/trevallies (Carangidae), therefore the exploitation rate is relatively low and they are still found in high abundance and biomass.

The target fish stock ranged from 314,813,058 individuals in Southwest Maluku as the highest and 46,449,031 individuals in East Flores Regency as the lowest and dominated by Caesionidae and
Scombridae families. Target fish species from the member of Caesionidae family is the biggest species composition with 74% of total abundance and 51% of total biomass, valid in all three regencies. According to the biodiversity indices of $H'$, $E$ and $C$, species diversity in the three regencies are categorized as moderate, with a level of evenness ranged from stable (Southwest Maluku and East Flores) to stress (Alor), and no domination of a single species. There is no strong difference observed from all three regencies. However, based on Bray-Curtis analysis, there are 8 clusters of sites with an average of 32.48% dissimilarity index between locations, which can be relatively predicted based on the similarity of substrate contour type and oceanographic hydrodynamic features in each site cluster. The rationale of this grouping is still very weak and yet to be tested using the effect of slope height or coral topography with the presence of the associated target fish. The results obtained are slightly strengthened by the results of a study [2] where hydrodynamic conditions play a role in the formation of site clusters. In conclusion, each site cluster may represent a unique habitat characteristic that should be managed differently in order to maintain the target fish resources in all three regencies.

4. Conclusion

Target fish species from the family of Caesionidae has the highest composition both based on abundance (74%) and biomass (40%). The highest species composition of target fish is from *Pterocaesio tile* (57.65%) which is more than 50% of the overall target fish. Community structure of target fish in the three regencies is still in a relatively good condition based on diversity index ($H'$), evenness ($E$) and no domination ($C$) of a single species occurs inside the target fish community, with exception in Alor Regency where the community of target fish is indicated to be under pressure. Biodiversity index by Bray-Curtis analysis in each location shows that most of the sites have the similarity of 67.51%, suggesting that there is not much difference in terms of target fish community structure between the three regencies. However, there are 8 groups of site cluster identified, suggesting that each site cluster represents one specific habitat type that may need to be managed differently in order to maintain the resources of this important fisheries target.

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