Potency of reef fishes in Tuhaha bay waters, Central Maluku Regency, Maluku Province, Indonesia

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Abstract. The research aimed to provide data on taxa composition, density, standing stock and potency of reef fishes at Tuhaha bay waters in 2017. There were 35 families, 105 genera and 243 species of reef fishes found in Tuhaha bay. Four areas of coral reef at good until excellent categories and various habitat had high species richness of reef fishes. Species richness, density and standing stock of major reef fishes species were higher than target and indicator species. Potency (biomass) of economically food fish (target species) ranged from 1.65 - 5.59 tons ha\textsuperscript{-1} of coral reef (total 2.93 tons ha\textsuperscript{-1}). Total potency, Maximum Sustainable Yield and Allowable Total Catch of economically food fish in 389.70 ha of Tuhaha bay coral reef area were 1,141.82, 590.91 and 456.73 tons, respectively. The status of reef fishes in two coral reef areas belonged to a high category, while the other nine areas had a moderate category.

1. Introduction

The position of Maluku Province is very strategic because it is influenced by the Banda Sea, the Maluku Sea and Seram Sea, as well as experiencing sea water mass runoff from the Pacific and the Indian Ocean. The largest proportion of Maluku marine waters is the deep sea with a stretch of 1340 islands of which 1336 islands consist of small and very small islands, and the coastal area is occupied by three main ecosystems of tropical waters such as mangrove, seagrass and coral reef. Furthermore, coral reef ecosystem is one of very prominent in coastal waters. As a consequence of this situation, it is believed that Maluku Province has high biodiversity and high potential of marine resources, especially reef fish. This is supported by Bengen (2013)[1] that coral reefs are spread on the small islands of Indonesia which play an important role as a habitat for a variety of fish species, thus giving an impact on the high productivity of fisheries (reef fish) with high economic value.

Saparua Island which is located in the administrative area of Central Maluku Regency belongs to the Small Island category, where the area is only 207 km\textsuperscript{2}. The coastal area of Saparua Island has three bays namely Haria Bay, Saparua Bay and Tuhaha Bay where the latter is wider than the other two bays. Tuhaha Bay waters area with an area of 4,363.17 ha has three main coastal ecosystems of tropical waters, namely coral reefs with an area of 389.70 ha, mangrove forests 154.23 ha, and seagrass beds only around 12.60 ha. The waters of Tuhaha Bay are considered as unique bay because they have around 22 small to medium lagoon ecosystems, and the Gosong ecosystem. The wider interaction of coral reef ecosystems with lagoon and Gosong as well as mangrove and seagrass ecosystems should be suspected as habitat for the high potential of reef fish resources.
Several reef fish studies have been carried out on the coral reefs of coastal waters and small islands of Maluku Province such as Halford (2002) [2] on reef fish biodiversity of Banda Island, Eastern Indonesia, Muljadi and Rijoly (2013)[3] concerning the diversity of reef fish in the Banda Islands Central Maluku Regency, Limmon et al (2017a)[4] concerning reef fish in the southern coastal waters of Ambon Island, and species richness of reef food fishes in Ambon Island waters, Maluku Province [5]. Regarding reef fish research in the Tuhaha Bay, Hukom and Sutarna (1998)[6] have examined the reef fish community which is limited to three coral reef stations. Study on the estimation of total species and relative diversity of coral reef fishes has also been done in this area [7]. Based on the description mentioned before, this research was conducted with the aim to reveal data and information about reef fish potency in Tuhaha Bay waters.

2. Materials and Method
The research was conducted in 2017 at 11 stations in the coral reef habitat of Tuhaha Bay, Central Maluku Regency, Maluku Province (Figure 1). Data on reef fishes were collected using Underwater Visual Census according to [7-10] at 250 m$^2$ transect area (50 m length and 5 m width). Reef fishes found inside transect were identified to the species level based on [11-20].

![Figure 1. The map showing sampling sites](image)

Reef fish species identified were categorized into target species, major species and indicator species [8,10]. Density and standing stock of reef fishes were calculated according to [21], and converted into individual units of ha$^{-1}$ coral reefs, the potential of reef fish target species including economically food fish is calculated using individual density values and constant from the National Commission for Stock Study of Marine Fish Resources [22], which are then converted into tons ha$^{-1}$ coral reef.

Assessment of the status (condition) of reef fish in each area of coral reefs in the waters of the bay of Tuhaha used methods and followed the assessment categories from [23, 24, 25]. Parameters and categories for assessing the status (condition) of reef fish as presented in Table 1.
3. Results and Discussion

3.1. Taxa composition of reef fishes
A total of 35 families, 105 genera and 243 species of reef fishes were identified inhabit coral reefs of Tuhaha Bay waters (Table 2). Species richness of reef fish were higher than Luang Island, West-Southeast Maluku Regency [26], small island coral reefs of Eastern Part of Seram Regency, Maluku Province [27] and coral reefs of Kendari Waters, Southeast Sulawesi [28], with the species number of 172, 222, 111 species respectively. However, the species richness of reef fishes in this study was lower than 355 species of reef fish in Ambon Island waters [4], 300 species in Wakatobi waters, Southeast Sulawesi Province [10] and 264 species in coral reef area of Papua Province outermost islands [6].

The total number of reef fish species predicted through the Reef fish Diversity Index of 6 fish families as a key indicator [28,29] of 434 species [7]. Therefore, Sahetapy et al (2018)[7] says that more species of reef fish can be found at Tuhaha bay coral reefs if repeated data collection is carried out.

Families of reef fishes that have high species richness are Pomacentridae (36 species), Labridae (36 species) and Cahetodontidae (23 species). These three reef fish families are permanent coral reef inhabitants [27, 28, 31] and are included in the ten most-speciose reef fish families in Indonesian coral reefs [29]. According to [31], as many as 123 species of Pomacentridae inhabit coral reefs in Eastern Indonesia. Thus, 29.3% species of family Pomacentridae in Eastern Indonesia occupy the coral reef ecosystem of Tuhaha Bay. Other reef fish families that permanently inhabit coral reefs with prominent species of richness are Serranidae (19 species), Scaridae (13 species), Acanthuridae (12 species) and Pomacanthidae (11 species). Also, reef fish families with low species of richness are Aulostomidae, Bleniidae, Carangidae, Cirrhitidae, Dasyatidae, Ptereleotridae, Spyraeniidae, Synodontidae and Zanclidae. The genera of reef fish that have a large number of species are Chaetodon (19 species), Pomacentrus and Scarus (9 species), Chromis, Lutjanus and Siganus (8 species).

Data in Table 2 shows that species richness of major reef fish species is higher (143 species) than the target species (77 species) and indicator species (23 species). This fact is commonly found in coral reef ecosystems [10, 26, 32]. Moreover, the species richness of reef fishes from major, target and indicator species found in this study was higher than coral reefs in Kendari waters [30] i.e. 63, 31 and 17 species respectively. Furthermore, the species richness of target and indicator species is lower than that of small islands coral reefs in Eastern Part of Seram, Maluku Province [27], which was 92 and 27 species, but, species richness of major species is higher (143 species).

Tuhaha Bay coral reef has 23 indicator species or 39% of 59 species from the Chaetodontidae family on Indonesian coral reefs [29]. Its presence is very important to assess the condition of coral reefs [8,10]. Coral reef which has some species from the Chetodontidae family indicates that the coral reefs are healthy. It can be seen in Table 2 that coral reef of Station 1 with excellent coral reefs and high coral species richness [33]. In contrast, Station 2 coral reefs with fair coral reefs have relatively large indicators of fish species richness, but conditions Station 5 coral reefs are in the excellent category, and low coral species richness has low indicator fish species richness.
The condition of coral reefs in the excellent category does not have significant indicators of high fish species richness and the condition of coral reefs in the fair category is also insignificant with low indicator fish species richness. Station 5 coral reefs with reef of excellent condition because only the coral species *Anacropora forbesi* contributes a large percent coverage, but the constituent components of reefs and coral species are not varied [33] so that they do not support the presence of reef fish species. Coral reefs station 2 with low percentages of coral coverage and a low number of coral species, but the composition of varied coral reefs provide suitable habitat for the presence of relatively large indicators of fish species.

The richness of reef fish species in four coral reef locations is high compared to 7 other stations (Table 2). The difference in fish species richness between coral reef areas is related to differences in coral reef conditions and variations in coral species, as well as due to variations in habitat in coral reef ecosystems [34]. The richness of coral species in the coral reef area of stations 1, 3, 9 and 10 are classified as high, with good to excellent coral reefs [33], and the habitat of the four reef areas are more varied. This condition causes the high richness of reef fish species in the four reef stations.

During the study period, nine species of reef fish namely *Ctenochaetus striatus*, *Zebrasoma scopas*, *Balistapus undulatus*, *Diproctacanthus xanthurus*, *Chlorurus bleekerii*, *Chlorurus sordidus*, *Siganus vulpinus*, *Zanclus cornutus* were found to distribute widely and able to adapt to the biophysical environment of coral reefs in the waters of Tuhaha Bay. On the contrary, 64 species of reef fish have limited distribution because they only occupy one of the coral reef stations. Regarding bioecology, 64 species of reef fish are only able to adapt to micro-specific coral reef habitats and are very sensitive to environmental stresses and uses that change the structure and function of microhabitats. Reef fish species with a limited distribution of coral reefs in Station 1 are more numerous (11 species). This fact shows that Station 1 of coral habitat is more varied and very suitable for the presence of most reef fish species with limited distribution.

| Taxon of Coral Reef Fishes | Observation Station | Tuhaha Bay |
|---------------------------|---------------------|------------|
| Species: |
| Target | ST1 | ST2 | ST3 | ST4 | ST5 | ST6 | ST7 | ST8 | ST9 | ST10 | ST11 | Total |
| 99 | 56 | 99 | 81 | 56 | 77 | 67 | 81 | 101 | 104 | 60 | 243 |
| Major | 30 | 15 | 30 | 32 | 20 | 18 | 22 | 18 | 30 | 30 | 16 | 77 |
| Indicator | 54 | 32 | 59 | 39 | 31 | 54 | 39 | 54 | 62 | 65 | 37 | 143 |
| Genera | 15 | 9 | 10 | 10 | 5 | 5 | 6 | 9 | 9 | 7 | 23 |
| Family | 61 | 35 | 54 | 52 | 40 | 49 | 47 | 50 | 60 | 61 | 40 | 105 |

The contradictory fact proves that the condition of coral reefs in the excellent category does not have significant indicators of high fish species richness and the condition of coral reefs in the fair category is also insignificant with low indicator fish species richness. Station 5 coral reefs with reef of excellent condition because only the coral species *Anacropora forbesi* contributes a large percent coverage, but the constituent components of reefs and coral species are not varied [33] so that they do not support the presence of reef fish species. Coral reefs station 2 with low percentages of coral coverage and a low number of coral species, but the composition of varied coral reefs provide suitable habitat for the presence of relatively large indicators of fish species.

3.2. Density, standing stock and potency of reef fishes

The density of reef fish in the coral reef area of Tuahaha bay ranges from 1.5 individuals m⁻² at Station 2 to 4.0 individuals m⁻² at Stations 3, 9 and 10, with individual densities of all coral reef areas reaching 2.9 individuals m⁻². The density of reef fish is relatively lower compared to the outermost islands of Papua Province waters which are about 2.99-10.14 individuals m⁻² [24] and Padaido Islands; West Papua Province are about 5.7 - 6.2 individuals m⁻² [9]. The distribution of data in Figure 2 indicates a higher individual density of reef fish in the major species category (1.1 - 3.0 individuals m⁻²) than the target species (0.4-1.3 individuals m⁻²) and indicator species (0.1 - 0.2 individuals m⁻²).

The total density of reef fish found on four coral reef stations (Figure 2) is higher than seven other coral reef stations. This is because the total number of individual reef fishes that are counted on the 250 m² coral reefs of the four stations is high. Reef fish species with a high number of individuals at Station 9 were *Naso thynoides*, *Caesio cuning*, *Cirrhilabrus cyanopleura*, *Chromis atripectoralis*, *Amblyglyphidodon curacao* and *Siganus fuscens*. Reef fish species that have high numbers of individuals in Station 10 are *Cirrhilabrus cyanopleura*, *Naso thynoides*, *Caesio teres*, *Pomacanthus...*
moluccensis, Abudefduf vaigiensis, and Chromis viridis. Only four species of reef fish were found with high numbers of individuals at Station 3, namely Cirrhilabrus cyanopleura, Rastrelliger kanagurta, Amblyglyphidodon curacao, and Ctenochaetus striatus. Furthermore, reef fish species with high numbers of individuals in the coral reef area of Station 1 were Mullloidichthys vanicolensis, Pterocaesio tile, P. banana, Gnathodentex aorofasciatus, and Ctenochaetus striatus.

![Density of reef fish based on Monev categories in coral reef station](image)

**Figure 2.** The density of reef fish based on Monev categories in coral reef station

Total standing stock, maximum sustainable yield and total allowable catch of reef fishes in the Tuhaha Bay coral reef are 29,016; 14,508 and 11,606 individuals ha⁻¹ respectively. Of all reef fisher species found, six species of reef fish are found with high standing stock (Table 3). Four major species form aggregation and large schools [15, 17] so that they have a high standing stock. Also, two target forms of groups and as the most abundant reef fishes [17], hence the standing stock values of these two major species become high.

**Table 3. Six species of reef fishes with highest standing stock**

| No. | Species                              | Standing Stock (Ind. ha⁻¹) | Category of Monev Coral Reefs |
|-----|-------------------------------------|-----------------------------|--------------------------------|
| 1.  | Cirrhilabrus cyanopleura            | 1,233                       | Major species                  |
| 2.  | Chromis atripectoralis              | 1,116                       | Major species                  |
| 3.  | Ctenochaetus striatus               | 1,051                       | Target species                 |
| 4.  | Naso thynonides                     | 1,011                       | Target species                 |
| 5.  | Amblyglyphidodon curacao            | 1,009                       | Major species                  |
| 6.  | Pomacentrus moluccensis             | 1,004                       | Major species                  |

Standing stock of reef fish of major species category is higher than the standing stock of target species and indicator species (Table 4). This is a fact that commonly found in a coral reef ecosystem [10] because the number of individuals of major species is more than other reef fish categories.

The analysis results according to the coral reef monitoring and evaluation (Monev) criteria shows the comparison of the standing stock value of reef fish for the target species, major species and indicator species is 11: 17: 1 respectively. This means that if there are one individual indicator species, then there are 17 individual major species and 11 individual target species. The value of this comparison ratio is higher than that of [10] in Wakatobi waters, Southeast Sulawesi Province (2: 5: 1). Therefore, it is concluded that the abundance ratio of individual indicator species with major species and target species is too large and can be called in unbalanced conditions.
Total Standing Stock (SS), Maximum Sustainable Yield (MSY) and Total Allowable Catch (TAC) of target species category at five coral reef stations (Table 4) and major species at three station are more than others coral reef station due to the condition of coral reefs which is in good to excellent category. Reef fish species of indicator category with high standing stock was found at the coral reef in Station 1 with excellent corals condition, and low standing stock at coral reefs in Station 5, even though the coral reef conditions in Station 5 are in the excellent category. This difference in standing stock is not only caused by low species, genus and family richness but also by dominated coral cover from *Anacropora forbesi*, a coral species which is not an ideal habitat for reef fish from indicator species.

Standing stock of major species of reef fish is greater than the target species in 91% of the coral reef area is caused the presence of 1-3 major species with a large number of individuals, namely *Cirrhilabrus cyanopleura*, *Chrysiptera springeri*, *Ostichthys compressus*, *Chromis weberi*, *C. atripectoralis*, *C. viridis*, *Amblyglyphidodon curacao*, *Pomacentrus moluccensis*, *Zanclus cornutus*. In contrast, standing stock of reef fish of the target species category is greater than the major species category at Station 1 is due to the abundance of individual fish from the six target species namely *Mulloidichthys vanicolensis*, *M. flavolineatus*, *Pterocaesio tile*, *P. banana*, *Gnathodentex aorofasciatus*, and *Ctenochaetus striatus*. Target species with large potential among coral reef areas are *Mulloidichthys vanicolensis*, *M. flavolineatus*, *P. tile*, *P. banana*, *C. striatus*, *Rastrelliger kanagurta*, *Naso thynnoides*, *Odonus niger* and *Chlorurus sordidus*.

| Coral Reef Station (ST) | Target Species | Major Species | Indicator Species |
|------------------------|----------------|---------------|------------------|
|                        | SS (ha⁻¹) MSY TAC | SS (ha⁻¹) MSY TAC | SS (ha⁻¹) MSY TAC |
| ST1                    | 22,360 11,180 8,944 | 11,960 5,980 4,784 | 2,360 1,180 944 |
| ST2                    | 6,600 3,300 2,640 | 6,560 3,280 2,624 | 1,720 860 688 |
| ST3                    | 15,400 7,700 6,160 | 22,960 11,480 9,184 | 1,440 720 576 |
| ST4                    | 8,800 4,400 3,520 | 15,160 7,580 6,064 | 960 480 384 |
| ST5                    | 11,920 5,960 4,768 | 12,160 6,080 4,864 | 960 480 384 |
| ST6                    | 7,928 3,964 3,171 | 14,440 7,220 5,776 | 880 440 352 |
| ST7                    | 6,320 3,160 2,528 | 12,440 6,220 4,976 | 1,080 540 432 |
| ST8                    | 6,250 3,125 2,500 | 18,000 9,000 7,200 | 1,600 800 640 |
| ST9                    | 20,840 10,420 8,336 | 20,960 10,480 8,384 | 1,120 360 448 |
| ST10                   | 15,640 7,820 6,256 | 25,280 12,660 10,112 | 1,080 540 432 |
| ST11                   | 7,080 3,320 2,656 | 9,920 4,960 3,964 | 1,240 620 466 |
| Tuhaha Bay             | 11,707 5,854 4,683 | 15,957 7,979 6,383 | 1,354 677 542 |

The total potency, maximum sustainable yield and total allowable catch of target species (economically food fish) in this area was 2.93, 1.47, and 1.17 ton ha⁻¹ respectively (Figure 3), and this lower than the coral reefs fish of the small islands of Eastern Part of Seram Regency [27], which was 6.61, 3.83, 2.64 tons ha⁻¹. Reef fish species of economically food fish with high biomass potential are *Ctenochaetus striatus*, *Naso thynnoides*, *Pterocaesio tile*, *Mulloidichthys vanicolensis*, *Chlorurus sordidus*, and *Rastrelliger kanagurta*.

Data on Figure 3 shows the potential of economically food fish in the study site. This figure shows that there are four coral reef areas with a high potency of economically important food fish i.e., Station 1 and 9 with excellent coral reef conditions, and Stations 3 and 10 with good reef condition [33]. Economic important of food fish with relatively high potency from the four coral reef station are *Mulloidichthys vanicolensis*, *Pterocaesio banana* and *Mulloidichthys flavolineatus* (Station 1), *Naso thynnoides*, *Ctenochaetus*
striatus and Naso thynoides (Station 3) and Naso thynoides, Caesio teres and Odonus niger (Station 10).

![Figure 3. Total potency, MSY, and ATC of economically food fish based on coral reef stations](image)

Total coral reef area of Tuhaha Bay amounted to 389.70 ha with total potency, sustainable yield and total allowable catch of economically food fish of 4,562,218, 2,881,109, and 1,824,887 individual respectively\(^5\) (1,141.82, 590.91, 456.73 ton yr\(^{-1}\) respectively). Based on the estimation, the biomass potency of economically food fish (target species) of Tuhaha Bay was 29.3 tons km\(^{-2}\). This potential is greater than [36,37] which stated that the coral reef ecosystem with a depth of fewer than 30 m has a fish potential of 15 tons km\(^{-2}\). Reef fish resources from economically food fish have long been utilized by local fishermen from this area, therefore, it is necessary to be managed properly to maintain its sustainability.

### 3.3. Status of reef fishes

Based on the cumulative value of assessment parameters in Table 5, the status of reef fish with high categorize was found in two coral reef areas (Station 1 and Station9), while the rest haveing moderate conditions. High condition of reef fish in Station 1 mainly due to total abundance of Chaetodon fish (TACF), total abundance of target species (TATS), total number of reef fish species (TNRFs) and species number of Chaetodontidae (SNC) which all high, although having moderate of total fish abundance (TFA) and total abundance of major species (TAMS). Station 9 had a high category of reef fish, but species number of Chaetodontidae (SNC), total abundance of major species (TAMS), and total abundance of target species (TATS) were moderate. On the other hand, the remaining 9 was in the moderate category since it only had a high total target species (TATS) abundance, while five other assessment parameters fluctuated from moderate to low.

| Parameter | ST1 | ST2 | ST3 | ST4 | ST5 | ST6 | ST7 | ST8 | ST9 | ST10 | ST11 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|-------|
| TFA       | 920(4) | 382(4) | 999(4) | 639(4) | 626(4) | 588(4) | 502(4) | 661(4) | 1073(6) | 1062(6) | 463(4) |
| TACF      | 59(6) | 41(6) | 40(6) | 32(6) | 22(4) | 16(4) | 28(4) | 36(6) | 28(4) | 30(4) |  |
| TATS      | 518(6) | 165(6) | 387(6) | 239(6) | 289(6) | 199(6) | 148(6) | 157(6) | 498(6) | 393(6) | 177(6) |
| TAMS      | 337(4) | 174(2) | 565(4) | 363(4) | 299(4) | 369(4) | 306(4) | 458(4) | 513(4) | 537(4) | 254(4) |
| TNRFs     | 99(6) | 56(4) | 99(6) | 82(6) | 56(4) | 77(6) | 67(6) | 81(6) | 101(6) | 104(6) | 60(4) |
| SNC       | 15(6) | 9(4) | 10(4) | 10(4) | 5(4) | 5(4) | 6(4) | 9(4) | 9(4) | 9(4) | 7(4) |
| **Cumulative values** | H | M | M | M | M | M | M | M | H | M | M |

Notes: H means high, M means moderate, and L means Low

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Although the status of reef fish in stations 2, 3, 4 and 6 is categorized as moderate, it has a high total abundance of Chaetodontidae fish (TACF) and total abundance of target species (TATS). Also, reef fish status was moderate in five other reef stations because it had a high total abundance target specimen (TATS) but a total abundance of Chaetodon fish (TACF) was moderate.

High and low species richness and abundance of individual reef fish depend on the condition of coral reefs as their habitat. The high condition of reef fish in two coral reef areas is influenced by the complexity of coral reef habitats [24], the condition of coral reefs is good to excellent [35], and variations in high coral species [33]. Furthermore, nine other coral reef areas with reef fishes were categorized as moderate because the coral reefs were categorized as good and fair, and low species richness of corals [33]. From these findings, the two areas of coral reefs with high-status reef fish status should be conserved, while the condition of the coral reef in the fair category with the status of reef fish in the moderate category should be rehabilitated.

4. Conclusion
A total of 243 reef fish species which consists of 105 genera and 35 families were identified inhabit the coral reef of Tuhaha Bay. Reef fishes of family Pomacentridae, Labridae and Chaetodontidae have high richness species. Four areas of coral reefs have high species richness of reef fish. Species richness, density and standing stock of major reef fish species are higher than targets and indicator species. Potential (biomass) of economically food fish (target species) ranged from 1.65 - 5.59 tons ha$^{-1}$ (total 2.93 tons ha$^{-1}$, more or less 29.3 tons km$^{-2}$ of coral reefs). Total potency, maximum sustainable yield and total allowable catch of economical food fish in 389.70 ha of coral reef areas were 1,141.82, 590.91, 456.73 tons, respectively. Status (condition) of reef fishes at two coral reefs belonged to high category areas, while nine coral reef areas in the moderate category. Two coral reef areas with high reef fish status are conserved, and the condition of the coral reefs in the fair category is rehabilitated to improve the status of reef fish and ensure their sustainability.

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