The condition of economical important coral reef fishes in eastern and western small outer island Indonesia

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Abstract. More than three months of cumulative comprehensive studied we conducted to evaluate coral reef fishes composition in Eastern Indonesia Region (Liki Island) and Western Indonesia Region (Natuna Island) of small outer Island (SOI) Indonesia. There is a fundamental problem in the ecological function of the coral reef ecosystem and the potential of economically important reef fishes in small outer Island Indonesia. Several obstructions become an essential problem, including the location of SOI, which is far from the mainland with a lack of surveillance and monitoring; consequently, the coral ecosystem and its coral reef fishes are threatened. Overfishing and destructive fishing are the major problems reported in several locations on the outermost island. Both anthropogenic stressors cause degraded coral ecosystems and give the loss specific species of marine species, especially in economically important coral reef fishes that primary target for fisheries. The latest and continuous time series data is essential as necessary information to arrange the appropriate and sustainable policies in Small outer islands, especially in protected the ecosystem from ecological extinction. The main goal of our study is to evaluate the potential of economic coral reef fishes with analysis of two families of fundamental economic and targeted fisheries: groupers (Serranidae) and snapper (Lutjanidae) in eastern and western small outer island Indonesia. The data were collected in each six site location in both eastern and western region SOI using Underwater Visual Census (UVC) technique. Four parameters, including species richness, abundance, biomass, and indices of economic coral reef fishes (Shannon, Evenness, Simpson, and ENS), were compared between the eastern region (Liki) to the Western region (Natuna) with Kruskal-Wallis non-parametric statistical analysis and internal Pairwise Wilcoxon analysis. The eastern region (Liki) recorded higher fish richness, abundance, and biomass than the western region (Natuna) (p< 0.05). Comparisons with ecological indices shown in the eastern region SOI (Liki) had a more diverse economic important coral reef fishes than western region SOI (Natuna). Understanding the composition of economically important coral reef fish in SOI will reveal more about the condition of the ecological function of the coral ecosystem and their vulnerability to future changes.
1. Introduction
Coral Triangle Region (CT) is a highly productive region in terms of species diversity, including coral reef fish. The diversity of coral reef fish in the Coral Triangle area is an attraction for fishing activities. In recent decades, severe threats have begun to emerge in the Coral Triangle region associated with environmentally non-friendly and over-exploitation fishing activities. Practically in most area of CT has become a place to effect this destructive fishing. Several economically important reef fishes fish families that contribute significantly to fishing [1–3], including Lutjanidae, Serranidae, and Lethrinidae, are interesting in fishing activities with high catching frequencies especially by using trawler catches [4]. Consequently, several locations in the CT region had high intensity found Lutjanidae and Serranidae with trawler catches than discovered under the sea, especially in diving activities [5,6]. In particular, according to [7], the economically important fish most frequently caught by recreational fishermen came from the families of Lutjanidae and Serranidae is becoming more challenging to find in recent years.

The consequence of damaging fishing is the high degradation of marine biota populations, mainly target fish as a source of economic commodities. Most coral-based fisheries tend to target large fish species from Serranidae and Lutjanidae species as the main fishery targets [8] and are preferred in most industrialized countries for several food productions [2,9]. Not only the Lutjanidae and Serranidae families are top priorities in fishing activities in the CT area, but several other artisanal reef fishes that are often caught by fishing also from the Carangidae (jacks), Lethrinidae (emperor), Siganidae (shale rabbitfish) families [2,4]. The reports from several locations in the CT area, excessive fishing activities of the Lutjanidae and Serranidae families cause low biomass for some of these fish species [10]. Several fish researchers suggested that predatory fish or carnivorous fish, especially Lutjanidae and Serranidae are attractive for fishing activities because they have economic value and become targets for fishers and cause the most detectable effects of fishing pressure in multi-species fisheries [11]. Another study from [10] states that the main threats to ecological resilience are overfishing and damage, including overfishing of Lutjanidae and Serranidae. The importance of sustainable fisheries protection and management to maintain economic important reef fish to recover, because the current conditions indicate the number of large-sized species from Lutjanidae and Serranidae is moderately low [12].

The increase in destructive fishing practice not mainly occurs in mainland areas with a high population. Several regions outside the mainland of Indonesia, especially on small outer islands, may even be more severe from destructive and over-exploitation fishing practices. The location in the remote area addresses the small outer islands more vulnerable. The lack of supervision and monitoring has led to the small outer islands being targeted by destructive fishing activities. The importance of providing the most up-to-date data for governments and authorities to take the proper policy and implement integrated and sustainable management to protect the local community's ecosystem and economy. In Indonesia, the study of small outer islands is a challenge because several small outer islands are far from the mainland and hard to transported to the research location. These oceanographic conditions make it impossible to long-term research because of the changing dynamic ocean waves, limited transportation, and accommodation. This study aims to provide the latest data related to the actual conditions associated with the status of important economic reef fish that are the main targets of fishing practice, specifically Lutjanidae and Serranidae, by studying at the differences from the two geographical regions in the small outer islands of Indonesia in the eastern part region (Liki) and Western part region (Natuna).

2. Research methodology
2.1. Study Sites Location
The determination of dynamics population from economically important reef fish was carried out at two Small Outer Island locations in Eastern Indonesia Region (Liki Island) and Western Indonesia Region (Natuna Island) (Figure 1). Both Liki and Natuna were sampled with six sites’ research
locations and evenly distributed in each island completely to represent the overall condition of each island.

Figure 1. Location of two small outer island - Natuna Island (western Indonesia region) and Liki Island (eastern Indonesia region) (Top). Distribution sites location in Natuna Island (bottom right) and distribution sites location in Liki Island (bottom left)

Liki and Natuna were inhabited islands, with higher population intensity and human activities (including fishing, tourism, and boat mooring) found on Natuna Island. In terms of area, Natuna has a larger area than Liki with high coastal activities. Both Liki and Natuna islands influenced by the
Pacific Ocean due to the position of these islands being the northernmost of Indonesia. Based on geographically and time zone, Liki is in the eastern part of Indonesia, and Natuna is in the western part of Indonesia, and, in terms of natural resource utilization, Liki and Natuna are known for their incredible marine resources and rich coral reef ecosystems.

2.2. Data collected
The important economic reef fish community data were collected using an underwater visual census (UVC) with modifications from (English et al., 1994) for the two small outer islands in the Indonesian region (Liki and Natuna). Belt transect UVC is the most common method for surveying the dynamics population of reef fishes with non-destructive for the environment [13,14]. The 70-meter belt transect placed on coral reefs to determine the number of species, fish abundance, and body length with an observation width of 5 meters [14] in diurnal times in each site's location [15]. The belt transects provide estimations communities structure of reef fishes, including total species, fish abundance, and length of body size data recorded during an underwater visual census [16]. Based on the frequency of use, UVC is the most commonly used technique in fish censuses [12,17–19]. The majority of researchers considering the dynamics population of coral reef fish using the UVC method due to the non-destructive for the environment and very appropriate to provide long-term monitoring for marine biota, especially in Marine Protected Areas [17,20]. The application of the UVC method in monitoring reef fish requires well trained and experienced researchers or surveyors to minimize bias and data errors. The data bias on the UVC method also increases if researchers are not familiar with changing underwater conditions, including dynamics of current or increased in turbidity, or even the presence of large populations of fish groups [17].

2.3. Data analysis
Two main economically important reef fish families (Lutjanidae and Serranidae) were identified by the underwater visual census method. Each economically important reef fish are registered according to the lowest species of the taxon. The study concentrates on the economically important fish composition by analyzing diversity (the number of species), abundance (the number of individuals), and the biomass of economic important reef fishes per transect with calculated using a length-weight relationship [21,22] with the equation $W = a.LT^b$. Where $W$ is the reef fishes weight (g) each individual, LT is length of economic important reef fishes based on Total Length (cm) or Fork length (depend by specific reef fish species registered in Fishbase), a and b are specific coefficients for each species from the FishBase data (Froese and Pauly, 2003). The total of economic reef fishes biomass for the location of each site corresponds to the total weight of all fish per unit area (g/m²). The comparative Wilcoxon non-parametric test was chosen to determine differences important reef fishes composition (the number of species, abundance, and biomass) between families at each location to provide a more reliable insight into differences distribution of each economically important fish family (Lutjanidae and Serranidae) between the eastern region (Liki) and the Western region (Natuna). The contribution of economically important reef fish density based on size population in each reef fishes family was analysis using a biplot frequency-size distribution where the axis variable (x) is estimated the total length (l) of each economically important fish family and ordinate (y) is the frequency of distribution.

3. Result
3.1. Species ranking of economic important reef fishes in Natuna and Liki
A total of 12 recorded species in 3 genus Lutjanidae families found in the Liki Island. The most dominant species of the Lutjanidae family in Liki Island was *Macolor macularis*, followed by *Lutjanus fulvus, Lutjanus kasmira, Macolor niger, Lutjanus decussatus, Lutjanus semicinctus, Lutjanus monostigma, Lutjanus fulviflamma, Lutjanus bohar, Lutjanus rivulatus, Aphareus*
furca, and *Aprion virescens*. The different Lutjanidae composition conditions are shown in Natuna Island, with seven recorded species in 2 genera Lutjanidae. The most dominant species of the Lutjanidae family in Natuna Island was *Lutjanus decussatus*, followed by *Lutjanus fulviflamma*, *Lutjanus russeli*, *Lutjanus quinquelineatus*, *Lutjanus monostigma*, *Lutjanus carponotatus*, *Lutjanus argenticulatus*, and *Symphorichthys spilurus*.

![Figure 2. The composition of Lutjanidae Family (snapper) in Liki Island (eastern region) and Natuna Island (western region)](image1)

A total of 19 recorded species in 3 genus Serranidae families found in the Liki Island. The most dominant species of Serranidae family in Liki Island was *Aethaloperca rogaa*, followed by *Cephalopholis spiloparaea*, *Cephalopholis leopardus*, *Epinephelus fasciatus*, *Cephalopholis cyanostigma*, *Variola louti*, *Cephalopholis urodeta*, *Cephalopholis semicinctus*, *Cephalopholis argus*, *Epinephelus merra*, *Plectropomus maculatus*, *Cephalopholis micropion*, *Anyprerodon leucogrammicus*, *Cephalopholis miniata*, *Epinephelus macrospilos*, *Epinephelus fuscoguttatus*,

![Figure 3. The composition of Serranidae Family (groupers) in Liki Island (eastern region) and Natuna Island (western region)](image2)
Epinephelus quoyanus, Epinephelus coeruleopunctatus, and Gracila albomarginata. The different Serranidae composition conditions were shown in Natuna Island with a total of 7 recorded species in 3 genera Serranidae. The most dominant species of Serranidae family in Natuna Island was Plectropomus maculatus, followed by Cephaloplos argus, Cephalopholis cyanostigma, Diploprion bifasciatum, Cephalopolis boenak, Cephalopolis micropion, and Plectropomus laevis.

3.2. Species richness of economic important reef fishes in Natuna and Liki

The comparison species richness (SR) of economically important reef fishes families based on location for each reef fishes family (Lutjanidae and Serranidae) shown in Figure 4. There was a highly significant difference in the species richness economical important reef fish of Lutjanidae family (snapper) in the Liki Islands ($\mu_{SR} = 9.83$ species) when comparing from Natuna Islands ($\mu_{SR} = 4.00$ species) with Wilcoxon rank test ($p$-value = 0.0046), where the mean species richness of Lutjanidae family (snapper) in Liki Island higher than Natuna Island. A comparison of the species richness economical important reef fish for Serranidae family (grouper) between Liki Island ($\mu_{SR} = 8.50$ species) and Natuna Island ($\mu_{SR} = 1.83$ species) also shows a highly significant difference in the number species richness (SR) with Wilcoxon rank test ($p$-value = 0.0048), where the mean species richness of the Serranidae family in Liki Island also shown significant higher than Natuna Island.

![Figure 4](image.png)

**Figure 4.** The comparison Species Richness (SR) of Lutjanidae Family (snapper) and Serranidae family (grouper) in Liki Island (eastern region) and Natuna Island (Western Region) with Wilcoxon test. Each location had six sites transect location.
3.3. The abundance of economically important reef fishes in Natuna and Liki
The comparison of economically important reef fishes families based on abundance for each family (Lutjanidae and Serranidae) shown in Figure 5. There was a significant difference in abundance economical important reef fish of Lutjanidae family in the Liki Islands (μ_{abund.} = 71.83 individuals/350 m²) when comparing from Natuna Islands (μ_{abund.} = 17.83 individuals/350 m²) with Wilcoxon rank test (p-value = 0.0043), where the mean abundance of Lutjanidae family in Liki Island higher than Natuna Island. The mean abundance of the Serranidae family (grouper) in Liki Island also shown higher value than Natuna Island with a comparison of the abundance Serranidae family (groupers) between Liki Island (μ_{abund.} = 34.67 individuals/350 m²) and Natuna Island (μ_{abund.} = 2.33 individuals/350 m²). The abundance analysis of Serranidae (groupers) between Liki and Natuna also shown a significant difference in abundance with the Wilcoxon rank test (p-value = 0.005).

![Figure 5](image)

**Figure 5.** The comparison Abundance of Lutjanidae Family (snapper) and Serranidae family (grouper) in Liki Island (eastern region) and Natuna Island (Western Region) with Wilcoxon test. the area of research is 350 m² (70-meter x 5 meter)

3.4. Biomass of economically important reef fishes in Natuna and Liki
The comparison Biomass of economically important fishes families based on location for each reef fishes family (Lutjanidae and Serranidae) shown in Figure 6. There was a highly significant difference in the biomass economical important reef fish of Lutjanidae family (snapper) in the Liki Islands (μ₉ = 24657.29 gr/350m²) when comparing from Natuna Islands (μ₉ = 1477.11 gr/350m²) with Wilcoxon rank test (p-value = 0.0022), where the mean biomass of Lutjanidae family (snapper) in Liki Island
higher than Natuna Island. A comparison of the biomass economically important reef fish for Serranidae family (grouper) between Liki Island ($\mu_L = 13117.31$ gr/350m$^2$) and Natuna Island ($\mu_N = 403.30$ gr/350m$^2$) also shows a highly significant difference in the number species richness (SR) with Wilcoxon rank test ($p_{\text{value}} = 0.005$), where the mean biomass of the Serranidae family in Liki Island also shown significant higher than Natuna Island.

![Figure 6](image_url)

**Figure 6.** The comparison Biomass (gr/area) of Lutjanidae Family (snapper) and Serranidae family (grouper) in Liki Island (eastern region) and Natuna Island (Western Region) with Wilcoxon test. The area of research is 350 m$^2$ (70-meter x 5 meter).

3.5. Size-frequency distribution economic important reef fishes in Natuna dan Liki

The standard length-frequency distributions of these individuals were summarized in Figure 7. The total Lutjanidae fishes counted was 431 individuals in Liki Island (Eastern Indonesia), and 107 individuals in Natuna Island (Western Indonesia). Lutjanidae fishes in Liki Islands ranged to 52.0 cm, with a mean, standard length of 25.4 cm, while in the Natuna Islands family, Lutjanidae ranged to 38 cm, with a mean, standard length of 15.3 cm. There was a clear trend in economically important reef fishes population in small outer islands for Lutjanidae families had bigger body size in Liki island compare Natuna Islands.
The standard length-frequency distributions of these individuals for the Serranidae family were summarized in Figure 8. The total Serranidae fishes counted was 208 individuals in Liki Island (Eastern Indonesia), and 14 individuals in Natuna Island (Western Indonesia). Lutjanidae fishes in Liki Islands ranged to 52.0 cm, with a mean, standard length of 24.8 cm, while in the Natuna Islands family, Serranidae ranged to 38 cm, with a mean, standard length of 19.4 cm. There was a clear trend in economically important reef fishes population in small outer islands for Serranidae families had bigger body size in Liki island compared to Natuna Islands.

Figure 7. Size-frequency distributions of nominally several Lutjanidae families at Eastern Indonesia - Liki Island and Western Indonesia - Natuna Island

Figure 8. Size-frequency distributions of nominally several Serranidae families at Eastern Indonesia - Liki Island and Western Indonesia - Natuna Island
3.6. Ecological indices

Figure 9. The ecological indices of economic coral reef fishes (Lutjanidae and Serranidae) in Liki Island and Natuna Island

Economical important coral reef fish in small outer Islands location (Liki, and Natuna) showed low to medium categories in biodiversity indices (Shannon-Wiener) with the $H'$ value between 0.00 – 2.08. Liki Islands were generally more diverse than Natuna, for each economically important reef fishes families (Lutjanidae and Serranidae) with the Kruskal-Wallis test for Shannon-Wiener diversity indices (Kruskal-Wallis, p-value = 0.00052). The mean of diversity index Shannon-Wiener in Liki ($H'$) for Lutjanidae was (1.776 ± 0.056 se; n = 6), and Natuna was ($H'$) (0.760 ± 0.201 se; n = 6). The diversity of Shannon Index ($H'$) for Serranidae family also a similar pattern with Lutjanidae with the mean of diversity index Shannon-Wiener in Liki ($H'$) for Serranidae was (1.858 ± 0.0084 se; n = 6) and Natuna island diversity index Shannon for Serranidae was (0.544 ± 0.264 se; n = 6). In terms of equitability, there was no significant difference between Lutjanidae and Serranidae in each location (Liki and Bepondi) (Kruskal-Wallis, p-value = 0.17). Based on Simpson dominance ($D$) index analysis, each site and economically important reef fishes family categories (Lutjanidae and Serranidae) showed the Simpson dominance value also shown non-significance different with (Kruskal-Wallis, p = 0.19). Based on true diversities analysis with an Effective Number of Species (ENS), Lutjanidae in Liki Islands had a similar mean diversity as a community of 7 equally-common species and Serranidae 7 equally-common species. In comparison, the Natuna Islands for Lutjanidae and Serranidae had each mean ENS values were two equally common species, respectively.

4. Discussion

The composition of Lutjanidae and Serranidae fish in coral reefs is particularly important because it contributes greatly to fish biomass[22]. Our results show that the number of species, density, and biomass of economically important reef fish in the West Indonesia region (Natuna) was significantly smaller than in the Eastern Indonesia region (Liki). The low composition of economically important reef fishes shows in Natuna endured a completely high degradation. Our results also showed that the body size of economically important reef fishes at Natuna was much smaller than Liki Island. The study also shows the important economically large fish in Natuna was much smaller than Liki Island. The presence of large, economically important reef fish in high groups is a concern in
the recovery of important economical fish due to the degradation. Several economically important reef fish compositions were difficult to find near the coastline area caused by several Lutjanidae, and Serranidae fish species may settle in nearshore habitats and move deeper coral ecosystem habitat in line with the magnitude of pressure in coastal areas, increasing in age and maturity of reef fish [23]. Other studies have proved there were several species of fish Serranidae, and Lutjanidae with large body size had lacked in coastal locations due to annihilation [24,25]. Consequently, of the low composition of fish from Lutjanidae and large Serranidae is difficult to perform or assess the recovery conditions of economically important fish conditions [12], especially in small outer island areas.

From the results of our study, we found that the number of compositions of economically important fish species in the Liki region in the high category (species richness, abundance, and biomass). The sampling sites in the Liki region discovered high abundant (schooling) for Macolor macularis species, which indicates the location may be considered a fish spawning location. Several species of Lutjanidae and Serranidae fish have large home ranges [26] and have massive spawning aggregation behavior [27]. The characteristics habit of spawning several species from Lutjanidae and Serranidae shown the great travel distances with a high population [26]. The distribution of a high population in certain coral reef ecosystems from Lutjanidae and Serranidae that emphasized reef location supports the economically important fish spawning process [28]. The low fish composition is economically important both from population abundance and biomass, which shows pressure on biota and ecosystems. [29] reported a fourfold increase in the total abundance of species studied, including those from Lutjanidae and Serranidae and up to 11 times the increase in Lutjanidae density in protected areas compared to catchment areas [30].

Geographical conditions influence the composition of marine biota. Liki is located in Eastern Indonesia and closer to the center of world marine diversity, causing the economically important fish composition at Liki to be higher. The eastern Indonesia region additionally recognized for highly diverse coral reef ecosystems, which affects the number of reef fish species associated with these ecosystems. Some economically important fish species from Lutjanidae and Serranidae have specific habitats, especially large species that require the appropriate habitat for spawning. Several studies have shown that Lutjanidae is found mainly in large coral sites, such as Acropora foliose [31]. In addition [32], a mixture of live coral and sand habitat was found as the preferred habitat for the recruitment of Serranidae and Lutjanidae, especially Plectropomus maculatus, Epinephelus quoyanus, and Lutjanus carponotatus. [33] also provides information that lives corals on loose substrates (e.g., Corymbose and arborescent Acropora) offer optimal habitat and prey protection to recruit predatory fish.

The suitable ecosystem habitat has a significant influence on the growth of Lutjanidae and Serranidae fish to grow optimally [34] and lives [35,36]. Several species of Lutjanidae and Serranidae are recognized as predatory invertebrates, and fish in large groups [37,38], even research from [10] affirms that Lutjanidae is one of the main Predators in coral reef ecosystems. Another interesting ability of Lutjanidae and Serranidae is the relatively high swimming ability that can last longer in a period of sustained swimming [2,39] cause a wide distribution of the population. Based on research from [40], the distribution of Serranidae and Lutjanidae fish range nearly 20 km.

Our results found low spawning habitat for economically important fish Lutjanidae and Serranidae in the Natuna Islands. Due to destructive fishing, the damaged coral reef ecosystems have caused small and lack of appropriate locations to provide economically important fish spawning grounds. Our research also supports that the aggregation of Serranidae and Lutjanidae is very vulnerable to annihilation [41]. The damaged coral reef ecosystems also cause low diversity and population and economically important fish. As affirmed by [42], several species on protected sites area are characterized by the presence of Serranidae, Lutjanidae, Lethrinidae, Chaetodontidae, Labridae, Scaridae and Acanthuridae [42], consequently the absence of some of these families signifying with great pressure on the coral reef ecosystem. Based on research from [9], Serranidae and Lutjanidae are important economic fish that are sought in high volumes and traded and of high value [9,43].
5. Conclusion
Several of Indonesia's outer regions, especially on the small outer islands, may even be worse in destructive fishing practices and over-exploitation, including in Natuna Island. Our study found that the economic reef fish composition from Lutjanidae and Serranidae family on Natuna Island was significantly lower compared to Liki Island (number of species, abundance, and biomass). Another important information regarding several small outer islands location, especially in the Papua region, had the protection of the natural resources system by local communities called Sasi. The need requirement for regular and continuous research on the small outer islands as a foundation for creating integrated policies in managing the outer regions and borders of Indonesia.

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