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MANAGEMENT STRATEGIES OF CORAL REEFS FISHERIES IN BANGGAI LAUT ARCHIPELAGO, CENTRAL SULAWESI, INDONESIA

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Abstract

Banggai Laut archipelagoes hold a huge potential of coral reefs fisheries, yet sustainable fisheries management is not applied optimally prompted by several characteristics. Here we present the coral reefs and fisheries characteristics, diversity of fish and also the key aspect of reefs fisheries which are coral reefs. We also address the main issues and try to reformulate management strategies based on multidimensional perspectives. The study was conducted on several islands including Labobo Island, Bokan Islands, Banggai Island and Bangkurung Island of Banggai Laut archipelagoes. It was shown that not-environmentally friendly fishing methods are indeed affecting the coral reefs fisheries indicated by the coral reefs condition, fishing gear, trend production, and also the fish diversity and percent coverage of coral reefs. The overexploitation of coral reefs fisheries has directly pressured the conditions of the coral reefs and biotas. Strategic issues and general problems in actualizing the sustainable fisheries management in Banggai Laut including 1) fisheries management; 2) law enforcement, and 3) fisheries business actors. Hence, it is essential to reformulate management strategies based on ecological, social, institutional, and economic perspectives.

Keywords*: Sustainable fisheries; Multidimensional perspectives; Fish diversity, Coral reefs*

Introduction

Banggai Laut archipelagoes have a huge potential of coral reefs fisheries. These potentials include large pelagic fish, small pelagic fish, demersal fish, shrimp, crustaceans, mollusks, commercial natural seeds, corals, reef fish for consumption, ornamental reef fish, sea turtles, marine mammals, and seaweed which certainly strongly related to their supporting ecological habitats [1, 2]. But empirically, the utilization and management strategies of these massive resources is still not optimal in order to increase regional income and the welfare of coastal communities in Banggai Laut.

There are so many factors that need to be considered in utilizing and formulating sustainable management fisheries. The firsts are to addressing the main and strategic issue that occurs according to actual condition [3], seeing the increasing production on certain type of fish in the domestic market [4], and also the recording the fishing gear used by fisheries operators [5]. Another key assessment to give a better insight into the related issues is indicated by the

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coral reef's ecosystem [6, 7]. Coral reefs play a role as a shelter for a fish, a feeding sites for coral reef fishes, and coral reefs structures that affect the hydrological character of the sea [8]. This makes coral reefs as essential factors in developing management strategies for coral reefs fisheries [9, 10].

The utilization and management of coral reefs fisheries Banggai Laut archipelagoes really need big attention because of several issues including rapid population growth, illegal fishing, destructive fishing, and the absence of synergism of planning and comprehensive policies [9, 11]. Considering the importance of the management strategies for these resources. We aimed to identify the potential and characteristics of fish resources with their ecological aspects, to analyze the issues related to their management, and to formulate management strategies of coral reefs fish resources for the sustainable fisheries management in Banggai Laut archipelagoes.

Experimental

Times and study sites

Banggai Laut Regency administratively located in Central Sulawesi Province. This area is directly adjacent to Tomini Bay on the north side and Tolo Bay on the south side. While the Maluku Sea is located on the east side of the Banggai Laut Regency. On the west side of Banggai Laut Regency, there is the Peling Strait. The total area of the Banggai Laut Regency is 725.67km^2 which is divided into 342 islands [12]. The research was carried out in Banggai Laut Regency particularly on Labobo Island, Bangkurung Island, Bokan Island and Banggai Island (Fig. 1). The data collection carried out from 2014 to 2017.

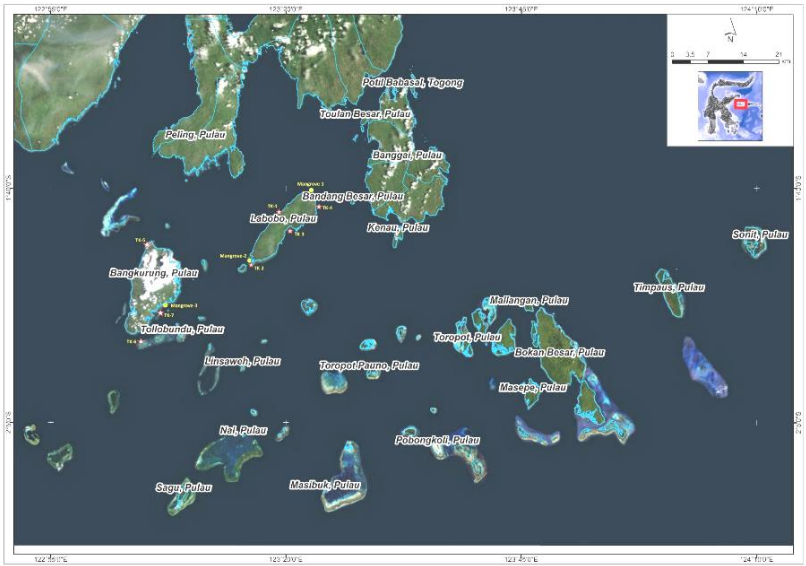

Fig. 1. Maps showing Banggai Laut Archipelagoes, study sites including Labobo Island, Bangkurung Island, Bokan Island, and Banggai Island [12]

Methods

Coral reefs condition and fisheries characteristics data

We describe the condition of coral reefs by categorizing it and explaining the actual conditions. To see the characteristics of fisheries in Banggai Laut, we also recorded the amount of fish production from 2014 to 2015 based on tons. We also note the fishing gear used by fisheries operator based on 2015, to represent the types that might damage resources.

Fish diversity and coral reefs coverage analysis

Observations and data collection are carried out using the Rapid Reef Assesment (RRA) method that can be used to determine coral cover, the level of damage and the causes of damage [13]. Coral species are collected, combined with a 50 meter Long Line Intercept Transect (LIT) method at the observation or research site [14]. Biota inventory refers to a field guide book.

The coral reef fishes species collection method is done by visual census which is usually done in conjunction with the line transect method for coral reefs. This method is carried out to determine the abundance, diversity, evenness, and dominance of coral reef fishes at each observation station.

To measure the percent coverage of coral reefs (lifeform) we used the equation:

$$Percent\ coverage = \frac{lifeform\ coverage\ length}{Total\ transect\ length} x100 \quad (1)$$

where percent coverage of coral reefs (lifeform) categorized as follows: 0,0 – 24,9 % = very bad; 25 – 49,9 % = bad; 50 –74,9 % = good; 75 – 100 % = excellence (KMNLH No. 4, 2001). To measure the diversity of coral reef fishes we used Shannon-Weaver index [15, 16] with an equation:

$$H' = \sum_{i=1}^{s} Pi \ln Pi \quad (2)$$

where diversity of coral reefs fishes categorized as follows: H'≤ 2 = low; 2 < H'≤ 3 = moderate; H' > 3 = high. Evenness index were used [15] with equation as follows:

$$E = H'/\ln S \quad (3)$$

where E is Evenness index value, H is a diversity index, and S is total species encountered. The dominance index was used based on 'Evenness Shannon' equation of Simpson [15] as follows:

$$C = (ni/N)^2 \quad (4)$$

where C is Simpson dominance value, ni is total individuals for each species, and N is total individuals of all species.

Formulating the management strategies

We address the main issues and several supporting factors based on the actual condition. Subsequently, we applied the multi-dimensional methods to formulate the management strategies [17] based on the potentiality of resources and actual conditions. The dimensions including ecological strategies, economical strategies, social strategies, and governmental strategies.

Results and discussion

The coral reefs condition and fisheries characteristics

The sea waters condition of the Banggai Laut Regency has uniformly general characteristics. The islands were surrounded by fringing reefs which are characterized by a relatively flat surface in the base profile with a depth of 2 - 10 meters with a width of 50 - 200 meters from the coastline. In the outer part of the islands, the coral reef has a fairly steep profile forming a reef slope zone to reach a depth of > 50 meters. The seawater current at this location is quite open and is strongly influenced by oceanographic conditions that occur along the monsoon season (East-Southeast monsoon and West-North monsoon season, as well as the transition season). In the transitional wind season, the waters are relatively calm and safe for

shipping and fishing activities. There are coral reefs ranging from a depth of 0.5 meters to a depth of 30 meters, whereas, in several sites, coral reefs will be exposed on the surface of the water at the lowest tide. The coral reef area in the study location is a fishing ground location by local communities or even fishermen from outside the area.

Based on the data we collected earlier, there are increasing trends in fisheries productivity in Banggai Laut, although reducing in certain types of fishes, gradually (Fig. 2). The composition of fish species produced in the Banggai Laut Regency includes commodities of large pelagic fish, small pelagic fish, demersal fish, reef fish and other fish (squid and octopus). The production of small pelagic fish commodities shows the greatest value, which is 58% of the total production which is dominated by types of flying fish and mackerel. The next biggest production is a demersal fish commodity at 14% of the production volume which is dominated by species of redfish and snapper. And then, large pelagic fish commodities such as tuna and mackerel which account for 13% of total production. While reef fish commodities such as grouper and baronang are 8% and squid species account for 7% of the volume of fish production in the Banggai Laut Regency.

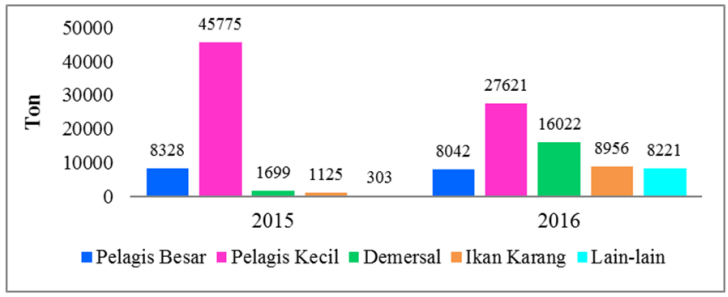

Fig. 2. Fisheries productivity rates of Banggai Laut Regency from 2015 to 2016

Data on fishing gear reflects the patterns and ways of fishermen in utilizing fish resources, fisherman knowledge, catches of fish, fisheries industrialization advancement, as well as the risk of the sustainability of fish resources. The types of fishing gear in the Banggai Laut Regency are quite varied. The most dominant gear used by fishermen in Banggai Laut Regency is pancing ulur (stretch fishing line) by 1,818 units, followed by rawai dasar (longline) 191 units, 173 units of bubu, 110 units of insang lingkar, 73 units of jaring insang lingkar, 44 units of arrows and spears, 37 units of purse seine, 16 units of lamp/giop, 11 units of pancing cumi (squid fishing line), 5 units of jala tebar (fishing net), and 2 units of sero (Fig. 3).

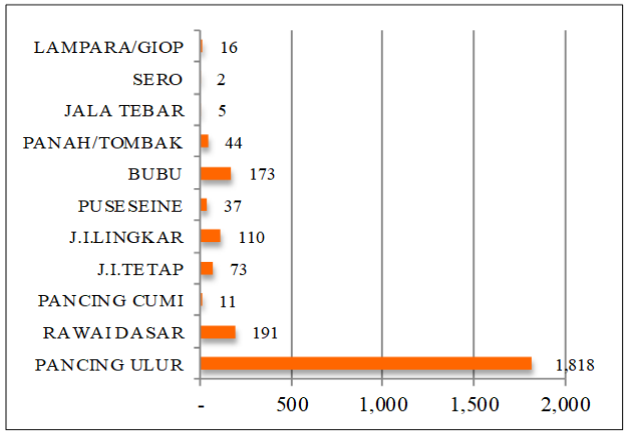

Fig. 3. The number and types of fishing gear and methods that used by fisheries operators in the Banggai Sea Laut

Previous analysis on gear-based fisheries management shows that there might be a great effect of using the fisheries closures, given that there was a species that have feeding characteristics, contributing to coral reef ecosystems recovery, and fisheries gears differed in species catches. However, the use of speargun and catching a high proportion fish may be the key to the recovery of coral reefs [5].

Coral Reefs Coverage and Coral Reefs Fish Species Diversity

The highest average of mortality index of coral reefs was in Labobo Island (43%) followed by Banggai Island (42%), Bangkurung Island (41%) and Bokan Island (32%) (Figure 3). The coral reef mortality index ranging from 0-1, which means the higher the value, the greater the damage to coral reefs, vice versa. Damage to coral reefs can occur due to human activities manifested by the not proper use of anchors and fishing gear (Smith et al., 2019).

Hard corals (lifeform) percent coverage with the highest average value was found in Bokan Islands (52.61%) followed by Labobo island (48.74%), Bangkurung island (48.5%), and Banggai island (41.84%) (Fig. 3). Bokan Islands has percent coverage with a good category where the remainders are categorized medium (KMNLH/No.4/2001). Generally, Bangkurung Island has the abiotic component that ranked as the second-highest percentage, which is dominated by dead corals (rubbles). Whereas in Bokan Islands, the dead coral component in benthic water formation is dominated by dead coral with algae, while the abiotic component is dominated by rubles. On Banggai Island, the dead coral component occupies the highest percentage, which is dominated by dead coral fragments. Several conditions of the corals can be seen below.

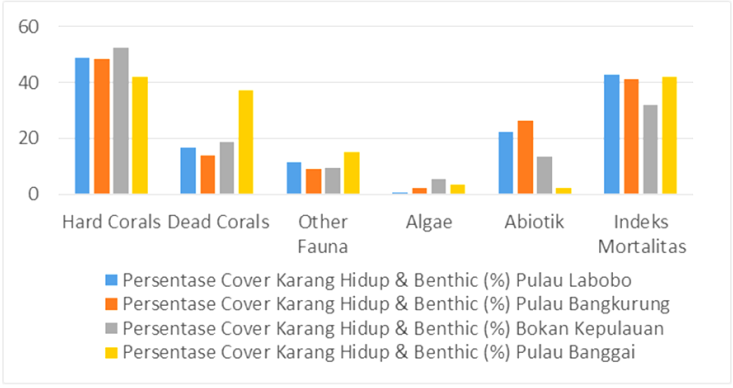

Fig. 4. Percent coverage of coral reefs (lifeform) and benthic from each observed sites.

The high exploitation of coral reefs in the study sites by the various fisheries activities has directly pressured the conditions of the coral reefs. The practice of 'non-environmentally friendy' fishing is common, especially around the Bangkurung Island. This common practice (destructive fishing) is mainly due to the lack of supervision in this area. This lack of supervision has given a negative excess to the condition of the marine environment, especially to coral reefs. Most coral reefs in the reef flat zone have suffered severe damage, indicated by the small number of hard coral (lifeform) cover. In the reef flat zone, benthic is dominated by a dead coral cover that has been covered by macroalgae, coral fragments, and coarse sand. Another Indicator of severe damage is the discovery of fine fractures (small size approximately <10 cm) of dead coral at several points in the study location with an average radius between 3 - 10 meters.

Based on the observation of the coral reef's ecosystem, there were several benthic biotas that are common to be encountered and symbiote with the coral reefs. Those several biotas including (1) Kima/Tridacnidae (*Tridana Tridacna squamosa* and *Tridacna crocea*); (2) Bintang Laut (*Linckia laevigata* and *Acanthaster panci*); (3) Ascidian (*Didemnum molle*,

Rhopalaea crassa, *Polycarpa aurata*, *Pycnoclavella* sp.); (5) Sponge (*Gelliodes* sp., *Callyspongia* sp., *Callyspongia muricina*, *Haliclona fascigera*, *Clathria basilana*, *Clathria reinwasdti*, *Spirastella vagabunda*); (6) Comasteridae (*Stephanometra* sp., *Camaster multifidus*, *Petasometra clarae*, *Comanthina audax*, *Oxycomanthus bennetti*); (7) Hydrozoans (*Aglaophenia cupressina*, *Plumularia* sp., *Lytocarpus philippinus*, *Aglaophenia* sp.); (8) Sea Shells (*Dendropoma maxima*, *Tetrus niloticus*, *Dendropoma maxima*); (9) Soft Coral (*Lobophyton* sp., *Sinularia* sp. *Sarcophyton* sp., *Nepthea* sp., *Xenia* sp.); (10) Bambu Laut (*Isis hippuris*); (11) Akar Bahar (*Subergorgia mollis*, *Alertigorgia* sp., *Plumigorgia schuboti*, and *Hicksonella* sp.). The heterogenous reef environmental is determining the composition of the benthic biota by the microhabitat conditions and complex biotic interaction [18].

Fig. 5. The coral reefs condition in Banggai Laut archipelagoes; A) Coral reefs in Banggai island in general; B) Dead coral assimilated with algae in Bokan Islands; C) Dead Corals in Bangkurung island; D) Coral reefs in Labobo Island in general

Fig. 6. Several Benthic biotas that symbiotes with coral reefs ecosystem

The diversity index results show the highest value is found in Bangkurung island (4.24), followed by Labobo island (4.05), Bokan Islands (2.63) and Banggai island (1.88) (Table 1). The higher diversity index is indicated by several factors including environmental factors such as climate and the presence of nutrients for reef fish [19]. Climatic factors affecting reef fish diversity include currents and waves [20]. Nutritional factors such as phytoplankton and zooplankton may also contribute to fish diversity [21].

The Evenness index results show the highest value was found in Bangkurung island (0.87), followed by Labobo Island (0.85), Bokan Islands (0.67) and Banggai island (0.49) (Table 1). These index values describe the presence or absence of a species by a very large number [22]. Bangkurung Island and Labobo Island have an Evenness index of more than 0.80 which can occur if the environmental conditions are adequate for many species of reef fish.

Table 1. The Index summary of Diversity, Evenness, and Dominance from each observed island

	Labobo Island	**Bangkurung Island**	**Bokan Islands**	**Banggai Island**
Total individual	3128.00	3196.67	610.25	1330.33
Total Family	29.00	29.33	14.13	17.33
Total Species	129.50	146.00	51.13	47.00
Diversity Index (H')	4.05	4.24	2.63	1.88
Eveness Index (E)	0.85	0.87	0.67	0.49
Dominance Index (D)	0.03	0.02	0.17	0.39

The results of the dominance index show the highest value was found on Banggai island (0.39), followed by Bokan Islands (0.17), Labobo island (0.03) and Bangkurung island (0.02) (Table 1). The dominance index value illustrates the existence of a species that dominates in a population [23]. Banggai Island has the highest dominance index because it has the lowest hard coral (lifeform) cover than other locations.

Reef fishes are an integral part of the coral reef's living system. The recovery of previously damaged coral reefs is a long-term process, thus, the first indicator that can be used to assess changes over time in the population level is fish and coral reefs [23]. Almost all good and healthy coral reefs have a high diversity of reef fish [18, 24]. The reef fish is not just a community of biota that has an important role in the coral reef ecosystem but also for the fisheries and tourism sector [25]. The maintenance of coral reefs is essentials for the purpose of sustainable management fisheries in Banggai Laut.

Main Issues of Management Strategies and Several supporting factors

Strategic issues and general problems which are the main obstacles in actualizing the sustainable fisheries management including 1) fisheries management; 2) law enforcement, and 3) fisheries business actors. The weakness of the fisheries management system in Banggai Laut has been indicated by the irregular utilization of fish resources. For example, in coastal waters in several groups of islands, it has shown an indication of overfishing. However, the level of utilization of fish resources in offshore waters is still not optimal (under fishing). Destructive fishing practices and conflicts between fishermen are still relatively high so that local governments need to immediately organize by strengthening policies. However, the condition of law enforcement in the fisheries sector is also relatively weak, both in quantity and quality. This resulting in the losses on the regional level, both economically and conservation, which may lead to the collapse of fish resources. This was indicated by the common activities of IUU fishing. Another issue is that most fisheries business operators still don't have sufficient knowledge about sustainable management fisheries. Still, there are many unsustainable fisheries business practices, even the overuse of hazardous materials for fishing activities. Exaggerated by economic businesses scale that not feasible, pressurize the fisheries operators to pursue the quantity of production disregarding the ecosystem carrying capacity.

There are seven issues along with problems and potential impacts that occur to actualize the sustainable fisheries management in Banggai Laut archipelagoes, including the rise of Illegal Unreported Unregulated (IUU) fishing, crowded fishing in coastal waters, underdeveloped domestic markets, limited access to business capital, low-quality fishermen, and uneffective data collection systems.

Multidimensional perspectives for Management Strategies

Basically, every problem that occurs is related to another. The main causes of all the problems can be classified into 4 dimensions which are ecological, economic, social, and institutional. In the ecological dimension, to eradicate IUU fishing, it is necessary to increase and oversee through the MCS (monitoring, controlling and surveillance) system and build an effective and transparent management system. To improve the effectiveness of aquatic ecosystem-based management, it is necessary to determine the optimal allocation of the number of fishing vessels and maintain the availability of fish resources through implementation such as ecosystem-based fisheries management, implementation of local wisdom, and a moratorium for areas that indicated as overfishing. In the economic dimension, to improve product competitiveness, it is necessary to develop an integrated fisheries industrial area, increase safety and product quality assurance, product optimization, and reduce the level of losses in handling practices in fisheries. To create a quality marketing and distribution system for domestic fishery products, it is necessary to increase fishermen's knowledge and understanding of the fisheries code of ethics (CCRF) and increase product branding through attractive promotions. To improve fisheries efficiency for small scale fishermen, it is necessary to provide easy access to the financial body, and activities to improve management capabilities. In the social dimension, to improve the quality and welfare of fishermen or any workers, it is necessary to improve the employment system, increase the participation of fishing communities in resource management and fish conservation, and improve the social security system through the development of an index-based insurance system. In the Institutional dimension, to improve an integrated data collection system, it is necessary to increase the quality and quantity of data, development of good human resources. Subsequently the improvement of facilities and infrastructure for data management and capture fisheries information.

Conclusions

The overexploitation of coral reefs fisheries has directly pressured the conditions of the coral reefs and biotas based on diversity, evenness, and dominance analysis, and it was proven that reef fishes are an integral part of the coral reef's ecosystem. The fisheries activities in Banggai Laut archipelagoes are not successfully applying sustainable fisheries management. By its main issues an ‘open access’ fisheries, the activities of illegal fishing are common. Thus, addressing the main issues, reformulating the management strategies from different perspectives, and also actualize the solution is urgent in order to achieve sustainable fisheries management.

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