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# The impact of MPA establishment on fish extraction in Indonesia

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**Abstract.** Open-access fisheries management is susceptible to overexploitation. Therefore, Marine Protected Areas (MPAs) have been increasingly seen as one of the most important tools for sustainable fisheries management. However, MPA still has a possibility to be overfished as MPA may attract fishermen to utilize the area excessively. This study focus on nine MPAs in Indonesia using secondary data collected from Ministry of Marine Affairs and Fisheries and Indonesia Statistic Center Agency from various years. This study used Schaefer and Fox model to measure the Maximum Sustainable Yield (MSY) as the basis to calculate overfishing index. Overfishing comparison analysis is done by mean difference t-test and panel data regression. The result revealed that MPA has lower fishing index compared to non-MPA. Also MPA establishment has negative and significant impact to overfishing index.

## 1. Introduction

Open-access fisheries management is susceptible to overexploitation and utilization of the resources is often disorganized [39]; [2]. It is difficult to determine the appropriate regulation concerning catch and capture which, inappropriate management usually, causes the fishing effort to be very high and reduce the profit [41]. Overfishing and optimal capture is closely related which [27] described overfishing causes the stock to collapse marked by a decline in economic viability (other than profit capture). If not accompanied by efforts to protect, conserve and sustainable use, global ocean resources will be exhausted in the next 40 years [44]. Thus, efforts are marked in the commitment of countries in Convention of Biological Diversity (CBD). It requires signatory country to conserve at least 10% of its total water territory to reduce the loss of marine biodiversity and realize sustainable use [50].

Marine protected areas (MPAs) have been increasingly seen as one of the most important tools for sustainable fisheries management, restoring depleted fisheries stocks [48], conserving and managing marine ecosystems [13]; [9]; [4]. The MPAs increase 5% annually covers a representative set of marine habitats that could contribute to the prevention of the collapse of fish stocks and reduce the species extinction [9]. Practically, MPA is established to protect from extractive and exhaustive activities, however majority of MPAs include a large variety of zoning and management schemes, ranging from single to multiple-zoning and from no-take to multiple-use areas [13]. Moreover, 94% of existing MPAs allow fishing activities therefore less protection of all aspects of biodiversity [13]; [14]. The other study revealed only 2% of MPAs are well-managed, and very limited conservation occurs within the MPA network in Southeast Asia [32].



The reviews of the extensive literatures concerning fish extraction within MPA are remarkably few. Most studies explored the impact of MPA establishment on marine reserve centered on spillover effect [38]; [1]; [40]; [48]; [10], yet it was found that only [9] discussed on fishing pressure within partially protected MPA in the San Miguel Island MPA, Tabaco City, Albay province, Philippines. The interviews were conducted in the fishing village of Sagurong, adjacent to the position of MPA to clarify differences in fishing pressure between the reserve zone (partially protected marine area) of the San Miguel Island MPA and the adjacent unprotected area. The study found that fishing pressures (fishing intensity and fish catch) were not different between the reserve and the adjacent unprotected area. In some cases, fishing effort becomes concentrated in partially protected areas relative to unprotected areas because of a perception among artisanal fishermen that MPAs are likely have more abundant or larger target size fishes due to fishing restrictions. This perception by fishermen consequently increases the fishing pressure in the reserve.

Therefore, this study hypothesized that MPA still has a possibility to be overfished as MPA may attract fishermen to utilize the area excessively. However, the overfishing problem might not too serious if compared to open-access ocean. To test this hypothesis, mean difference t-test was used to analyze the impact of MPA establishment on the fishing level index within MPA, Fisheries Management Area and non-MPA. Panel data regression was employed to identify factors influencing overfishing in Indonesia.

## 2. Material and Methods

### 2.1. Study areas

Indonesia has an area of 310 million hectares, 17,504 islands and about 95,186 km of coastline [24]. In 2014, Indonesia was regarded as the second largest country with capture fisheries in the world, placed after China, by producing 6 million tons of fishes and accounted for 7% of the world's total production [15]. In Indonesia, overexploitation usually coincides with destructive activities of Illegal, Unreported and Unregulated fishing (IUU fishing) causing it to suffer economic losses of up to 20 billion dollars per year [51].

Given the trend of fisheries resource in the world is increasing, Indonesia is committed to implement sustainable management of marine and fishery resources through the establishment of Marine Protected Area. The commitment is demonstrated by setting a target to establish MPA of 20 million hectares by 2020 and 30 million hectares by 2030, which currently Indonesia has approximately 17 million hectares of MPA. Beside the establishment of MPA, the National Long Term Development Plan for 2005-2025 also highlighted that marine economics will be developed in an integrated manner by optimizing the sustainable use of marine resources.

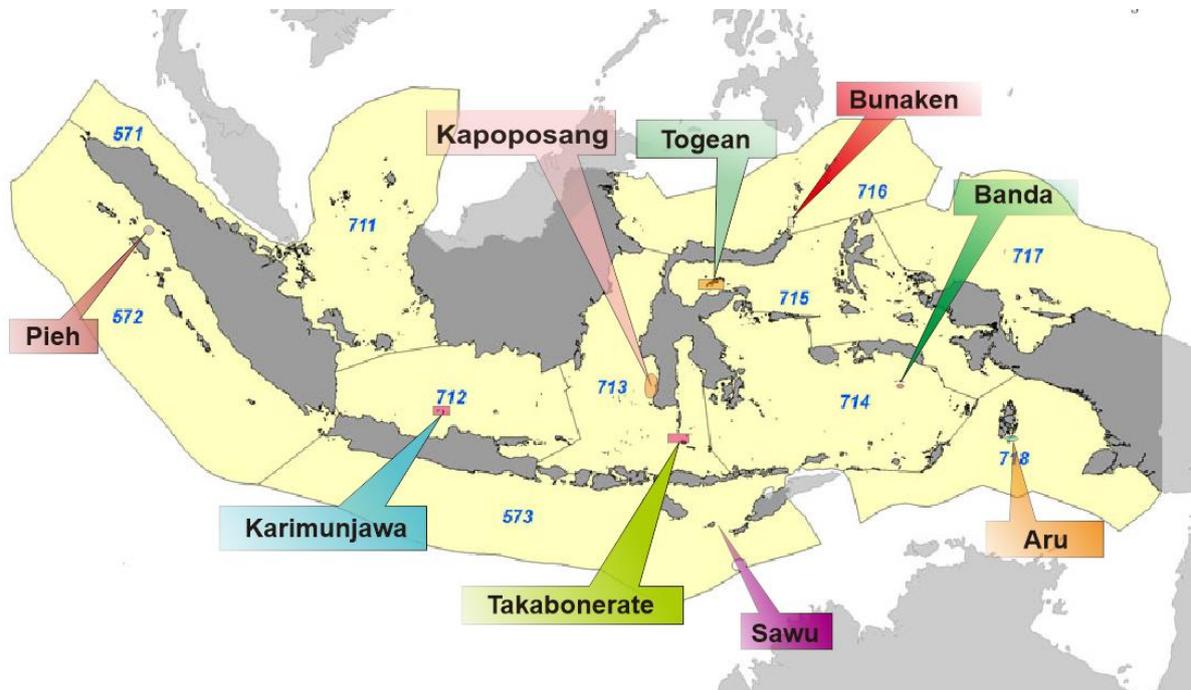
**Table 1.** Types of MPA in Indonesia.

| Name                 | Objective                                 | Management                     | Main focus                    | IUCN                                |    |
|----------------------|---|--------------------------------|-------------------------------|-------------------------------------|----|
| Marine National Park | Science, education, fisheries, recreation | research, sustainable tourism, | National                      | Biodiversity, tourism and fisheries | II |
| Marine Tourism Park  | Tourism and recreation                    | National/local                 | Tourism and biodiversity      | V                                   |    |
| Marine Reserve       | To protect biodiversity and ecosystems    | fisheries and its              | National/local                | Fish diversity and its ecosystem    | IV |
| Fisheries Reserve    | To protect certain species                | National/local                 | Protection of certain species | IV                                  |    |

Source: Suraji et.al. [47]

In Indonesia, MPA is within Fisheries Management Area which is protected, managed by the zonation system, for sustainable management of fisheries and environment. It comprises of core zone, utilization zone, traditional sustainable fisheries zone, general sustainable fishing zone and other zones. Core zone and utilization zone are not allowed for fishing (no-take zones), whereas traditional fishing zone and sustainable fisheries allow catching activities by using environmentally friendly fishing gear [31]. All MPAs should have core zone at least 2% of total area which core zone is designed to focus on biodiversity protection, while other zones are to support sustainable activities such as fisheries and marine ecotourism [47]. Within MPA, the use of unsustainable and non-environmentally fishing gear is restricted under Regulation No. 2 of 2015, Ministry of Marine Affairs and Fisheries.

Of all types of MP (Table 1), Marine national park is the only conservation area initiated and managed by national policy, while the others could be initiated and managed by national, local government or collaboration among them [47].



**Figure 1.** Fisheries management area and MPA in Indonesia.

**Table 2.** Data and year used in the analysis.

| Variable                | MPA                            | Fisheries Management Area | Non-MPA   |
|-------------------------|--------------------------------|---------------------------|-----------|
| Catch                   | 2001-2015                      | 2005-2014                 | 2001-2015 |
| Number of Ships         | 2001-2015                      | 2005-2014                 | 2001-2015 |
| MPA establishment year  | Various years of establishment | -                         | -         |
| Number of fishing gears | 2006-2016                      | -                         | 2010-2016 |
| Coremap                 | Various years                  | -                         | -         |

This study focuses on nine MPAs as listed in Table 2. The sampled MPA are managed by two ministries; Ministry of Marine Affairs and Fisheries and Ministry of Forestry and Environment. For instance Sawu, Kapoposang, Banda, Aru and Pieh are managed by Ministry of Marine Affairs and Fisheries, while the rest under Ministry of Forestry and Environment. It should be noted that sampled MPA were consisted of three types of MPA which are managed by the zonation system; the core zone,

utilization zone (non-extraction tourism), and fishing zone (traditional). However to analyze the extraction pattern of fish within MPA sampled sites, 11 Fisheries Management Area and 11 non-MPA were included for comparison.

### 2.2. Description of datasets

Secondary data were used at two different level; regency level and Fisheries Management Area as the unit of analysis (Table 3). Data were collected from Ministry of Marine Affairs and Fisheries as well as Indonesia Statistic Center Agency. However, due to unavailable data for trip, ships were applied to proxy the effort.

**Table 3.** MPA study sites, fisheries management area and non-MPA.

| <b>MPA</b>                       | <b>Types</b>   |
|----------------------------------|--|
| 1. Sawu                          | Marine National Park   |
| 2. Kapoposang                    | Marine Tourism Park  |
| 3. Takabonerate                  | Marine National Park   |
| 4. Bunaken                       | Marine National Park   |
| 5. Togean                        | Marine National Park   |
| 6. Banda                         | Marine Tourism Park  |
| 7. Aru                           | Marine Nature Reserve  |
| 8. Karimunjawa                   | Marine National Park   |
| 9. Pieh                          | Marine Tourism Park  |
| <b>Fisheries Management Area</b> | <b>Location</b>  |
| 1. 573                           | Covering Indian Ocean to the south of Java to the south of Nusa Tenggara, Sawu Sea, and the West Timor Sea |
| 2. 713                           | Covering Makassar Strait, Bone Bay, Flores Sea, and Bali Sea   |
| 3. 716                           | Covering Celebes Sea and north of Halmahera Island   |
| 4. 715                           | Covering Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea and Berau Bay                                    |
| 5. 714                           | Covering Tolo Bay and Banda Sea  |
| 6. 718                           | Covering Aru Sea, Arafuru Sea, and East Timor Sea  |
| 7. 712                           | Covering Java Sea  |
| 8. 572                           | Covering Indian Ocean to the west of Sumatra and the Sunda Strait  |
| 9. 571                           | Covering the Straits of Malacca and the Andaman Sea  |
| 10. 711                          | Covering Karimata Strait, Natuna Sea, and South China Sea  |
| 11. 717                          | Covering the waters of Cenderawasih Bay and the Pacific Ocean  |
| <b>Non-MPA</b>                   | <b>Location</b>  |
| 1. Timor Tengah Utara            | East Nusa Tenggara   |
| 2. Pinrang                       | South Sulawesi   |
| 3. Kepulauan Talaud              | North Sulawesi   |
| 4. Cilacap                       | Central Java   |
| 5. Pesisir Selatan               | West Sumatera  |
| 6. Lampung Barat                 | Lampung  |
| 7. Lampung Selatan               | Lampung  |
| 8. Tulang Bawang                 | Lampung  |
| 9. Bengkulu Selatan              | Bengkulu   |
| 10. Kaur                         | Bengkulu   |
| 11. Muko-muko                    | Bengkulu   |

### 2.3. Standardization of Effort

Estimating the CPUE should be extra cautious. Different gear may have different effectiveness in catching fishes, hence same amount of gear may result on different yield or catches under the same conditions. For example, ships with a machine of a certain size will differ in term of catches compared to non-engined vessels or vessels with smaller engines. Therefore, using number of ships directly to measure effort, for instance, would yield inconsistency of data for effort, thus CPUE. To resolve this problem, catching effort was standardized to obtain the reasonable amount of CPUE using the formula by Sparre and Venema [45] using the equation as follows:

$$CPUE\ i\ (y) = \frac{Yi\ (y)}{Ei\ (y)} \quad (1)$$

CPUE is measured by dividing yield with effort for each gear  $i$  and year of  $y$ . After obtaining CPUE for each gear and year, then relative CPUE is estimated.

$$Ri\ (y) = \frac{CPUE\ i\ (y)}{average\ CPUE\ i\ (y1,y2)} \quad (2)$$

Relative CPUE per year and gear is obtained by dividing the CPUE gear  $i$  and year  $y$  with average of CPUE for gear  $i$  between  $y1$  (first year) and  $y2$  (latest year). To obtain relative total CPUE, catch for each gear in one year is summed. With data of  $Ri(y)$ ,  $Yi(y)$  and  $Ys(y)$ , relative total CPUE ( $R(y)$ ) is:

$$YS\ (y) = \sum_{i=1}^n Yi\ (y) \quad (3)$$

$$R\ (y) = \sum_{i=1}^n (Ri\ (y) \times \frac{Yi\ (y)}{YS\ (y)}) \quad (4)$$

To obtain normalized relative effort, formula used is

$$E\ (y) = \frac{\frac{YT\ (y)}{R\ (y)}}{average\ \frac{YT}{R}} \quad (5)$$

Where  $YT(y)$  is total catch including number of catch from unknown gear,  $R(y)$  relative total CPUE and average of ratio between  $YT$  and  $R$  during  $y1$  and  $y2$ .

### 2.4. Production surplus method

This study is based on production surplus method introduced by Schaefer [42]; [43] and Fox [16]; [17]. The models explain relationship of Yield ( $Y$ ) and Effort, which describes yield given level of effort:

$$Y = f\ (Effort) \quad (6)$$

Schaeffer and Fox explained that the relationship between Yield and Effort is quadratic, meaning that the impact of increasing effort is diminishing. In one point, increasing effort will result in decreasing yield, instead of increasing.

$$Y = a + bE - cE^2 \quad (7)$$

This function can obtain Maximum of Sustainable Yield (MSY) in each location. MSY denotes the maximum of fishing yield which can be routinely exploited without depleting the resource in the future. To obtain the maximum yield, Maximum Sustainable Effort (MSE) should be derived as follows:

$$\frac{\partial Y}{\partial E} = 0 = b - 2cE \quad (8)$$

Coefficient of  $a$ ,  $b$  and  $c$  in the function is estimated using least square regression of Catch Per Unit Effort (CPUE) and effort as follow:

$$CPUE = \frac{Y}{E} = b - c.E \quad (9)$$

### 2.5. Equilibrium fishing

Fisheries management in the world is mostly based on theory first made by the Swedish fishery biologist, Hjort, in 1930, widely known as “Equilibrium Fishing” which suggests that number of fish caught should equal to amount of fish recovered through reproduction. The maximum amount of fish stock caught is when the fish population decreases to half of the natural biomass condition. When it happens, the number of fishing gear must be kept constant. In addition, government can no longer issue new permit to catch fish [53].

Fish Biology model is determined based on reproduction behavior of fish. Changes in fish population in the ocean depend on its growth and breeding pace. Growth of fish means condition when it gains weight and changes in size and volume; while, breeding means condition when fish reproduce through reproduction system, which called as natural growth of fish [29]. The process of biological fish growth as below:

$$G_t = S_{t+1} - S_t ; G = G(S) \quad (10)$$

Growth at  $t + 1$  depends on stock at time  $t$ , suggesting that growth is a function of stock as follows:

$$G(S) = g \left( 1 - \frac{S}{S_{Max}} \right) S \quad (11)$$

The maximum growth rate of fish is achieved at the stock level of MSY. When the fish stock is low ( $< S_{MSY}$ ) and the amount of food is large, the growth of fish populations will be high and, vice versa. The level of catch should be observed so that fish stock is in a stationary condition. Describes growth as a function of stock so that the catch rate (H) depends on growth rate (G) [34].

$$G = G(S) ; H = G(S) \quad (12)$$

The fishing activity depends on production function of  $H = H(E,S)$  with the specific form  $H = eES$ . Based on the function, catch (H) depends on stock (S), effort (E) and the constant catch coefficient (e). In this case, Catch Per Unit Effort (CPUE) is equal to the stock.

$$\frac{H}{E} = eS \quad (13)$$

The net stock of fish depends on growth and catch, illustrated by the equation as follows:

$$S = G(S) - H ; \frac{dS}{dt} = g \left( 1 - \frac{S}{S_{Max}} \right) S - H \quad (14)$$

Analysis of surplus model of fishery production was developed to estimate production function and determine Maximum Sustainable Yield (MSY). According to Schaefer [42]; [43] and Fox [16]; [17] in [36], production surplus model is as follows:

$$Y = 0 + a.E - b.E^2 \quad (15)$$

$$Y = 0 + c.E \cdot \exp(d.E) \quad (16)$$

Where: E = Effort  
Y = Yield  
a,b,c,d = Coefficient/parameter of production function

To obtain the MSY, those functions need to be differentiated in respect to E to obtain value of E and resulted to maximum Y:

$$\frac{\partial Y}{\partial E} = a - 2b.E \quad (17)$$

$$\frac{\partial Y}{\partial E} = c.\exp(d.E) \quad (18)$$

CPUE is obtained by dividing catch with effort as follows:

$$CPUE = \frac{Y}{E} = a - b.E = c.\exp(d.E) \quad (19)$$

### 2.6. Fishing level index

Two methodologies were employed in analyzing the hypothesis whether MPA has lower fishing level index than non-MPA. Firstly the hypothesis was tested using mean difference; a significant lower mean of fishing level index indicates that the area is being managed sustainably. The optimum level of yield for sustainable fisheries should not greater than 80% of MSY [21]; [49], otherwise the location is regarded to be overfished. In addition, the optimum catch or Total Allowable Catch (TAC) should be 80% of MSY [49]. These concepts were used to determine the overfishing level in this study. Thus, area having index above 80% of MSY, or TAC, will be categorized as overfished.

### 2.7. Panel data regression

Secondly, to analyze the factors influencing overfishing, the study used pooled least square (PLS) with regency level data. The model is proposed as follows:

$$OF = \alpha_i + d\beta_0MPA + \beta_1Prop.susteffort + \beta_2LnCoremap + \beta_3Effort + \mu_{it} \quad (20)$$

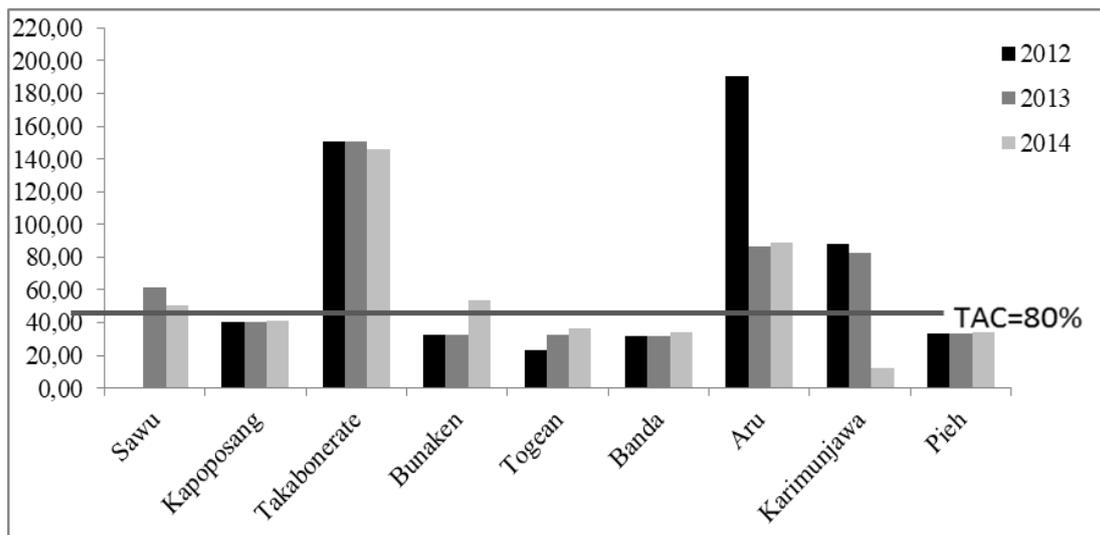
Where,

|                           |   |
|---------------------------|---|
| OF                        | : overfishing level   |
| $\alpha_i$                | : constant coefficient  |
| $\beta_0, \dots, \beta_6$ | : slope coefficient   |
| $i$                       | : i-th regency  |
| $t$                       | : period of time (2006-2016)  |
| $\mu_{it}$                | : error term  |
| $dMPA$                    | : MPA establishment (dummy: 1 if MPA is already established; otherwise 0)     |
| Prop.susteffort           | : proportion of sustainable effort to total effort measured by catching tools |
| LnCoremap                 | : COREMAP budget received by regency  |
| Effort                    | : effort measured by number of ships  |

## 3. Result and Discussion

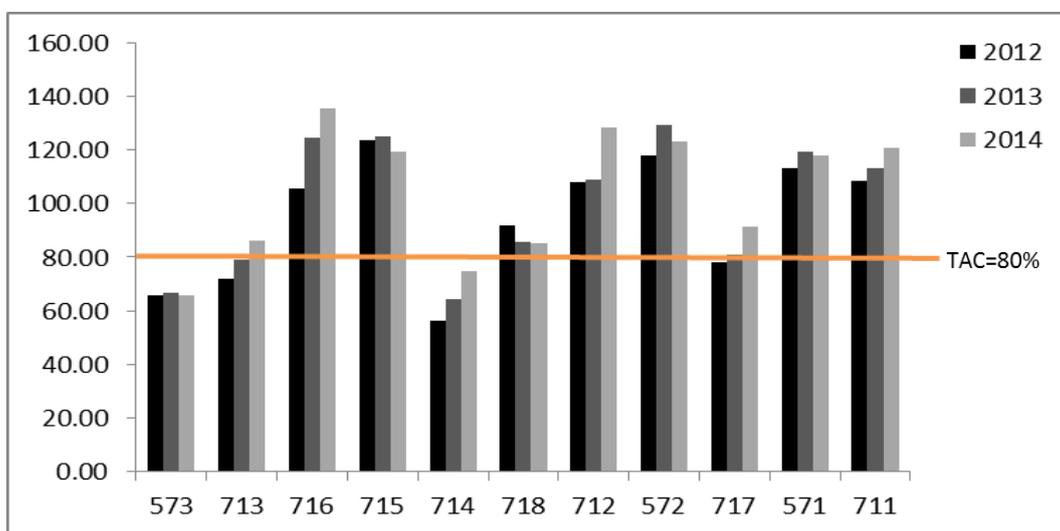
### 3.1. MSE, MSY, TAC and fishing level index

MSE, MSY and TAC were calculated for each study site (see Appendix Table A1). It was found Sawu has the largest MSE within MPA, while Pieh has the lowest value. For MPA Sawu, it can be explained as it has the widest area compared to others. Despite the lowest MSE of Pieh, it reveals a higher MSY value among others. This is possible if the restriction of fishing activity in the area has resulted into higher recovery rate compared to other regency. Conversely, non-MPA showed relatively lower MSY compared to MPA and Fisheries Management Area. Of non-MPA, South Lampung has the greatest fisheries potential indicated by highest MSY. Among all study sites, Fisheries Management Area has the highest MSY due to its size as it comprises of ocean from several districts.



**Figure 2.** Fishing level index of MPA between 2012 and 2014.

The calculated MSY value then used to measure fishing level index. Index above 80% indicates that the area is overfished. Of all study sites, MPA has lower fishing level index compared to Fisheries Management Area and non-MPA (Figure 2). Six MPAs have maximum fishing level index under TAC, meaning that the areas were never overfished during the period of analysis. The distribution of fishing level index along the year was also concentrated around the mean. However, some MPAs still facing overfishing problem, for instance, MPA Takabonerate and Aru were in the third quartile above the TAC. Yet, Karimun Jawa was also having average index over the TAC. These three locations have showed high variation of fishing level index which Aru almost reach 200%.



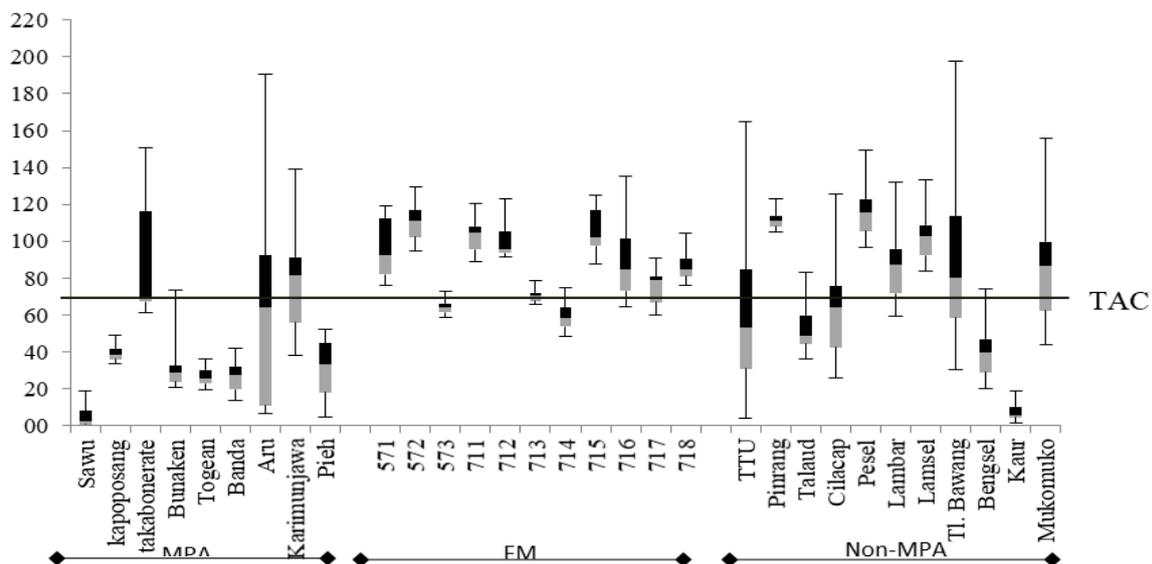
**Figure 3.** Fishing level index in fisheries management area from 2012 to 2014.

MPA Takabonerate (in Selayar regency) and Aru were found to be consistently overfishing. Both MPAs were established by Ministry of Forestry in 2001. MPA Takabonerate was established due to its uniqueness, which is home for atoll coral, while MPA Aru was set up for turtle protection. However MPA Aru was handed over to the Ministry of Marine Affairs and Fisheries in 2009. MPA Aru has the highest overfishing rate in 2012 (110.85%), but decreased in 2013 and 2014 by 6-8%. The highest overfishing rate was attributed by the greater use of non-sustainable fishing gear like bottom trawl, trawl,

mini purse seine and purse seine. At the early stage after the handover of MPA from the Ministry of Forestry to the Ministry of Marine Affairs and Fisheries, the clarity concerning assets and boundaries had hampered the management to run effectively. However the dispute was cleared after 2012, and found the increasing use of sustainable fishing gear and COREMAP budget received from 2014 able to reduce overfishing in the area.

Besides, it was found that destructive fishing activity is still rampant in Selayar regency, with bomb and poison activity done by neighboring regency fishermen such as Bulukumba, Sinjai, Bantaeng and Jeneponto [7].

Out of 11 Fisheries Management Area, seven found to have mean fishing level index over the TAC which four of them showed constantly overfished (Figure 3). Unlike MPA data, the dispersion of fishing level index in Fisheries Management Area was less sparse, indicating that the variation of fishing level index was relatively low. Most of the Fisheries Management Area was being overfished at least once, except two areas (573 and 714). Seven areas faced constant overfishing problem during the period. Three of them (716, 712 and 711) have an increasing trend of fishing level index, meaning that the area needs extra monitoring to avoid another increase, while one area (718) faces a decreasing trend, and the rest fluctuates across years.



**Figure 4.** Boxplot of fishing level index in MPA, Fisheries Management Area and non-MPA

3.2. Mean difference T-test of fishing level index

Compared to MPA and Fisheries Management Area, the condition of fishing level index in non-MPA varies greatly. The whisker box plot was much longer compared to the others (Figure 4). For instance, maximum fishing level index of TTU was above 160%, while Tl. Bawang was approximately 200%, the highest among all. Out of 11 locations, six regencies having mean of fishing level index over the TAC which three of them are constantly overfished during the time. Only two locations identified were not overfished.

**Table 4.** Mean difference of MPA-Fisheries Management Area and MPA-non MPA.

| Location                         | Mean   | t         | Information  |
|----------------------------------|--------|-----------|--|
| <b>MPA</b>                       | 56.586 |           |  |
| <b>Fisheries Management Area</b> | 86.999 | -5.779*** | Overfishing level in MPA < Fisheries Management Area |
| <b>MPA</b>                       | 56.586 |           |  |
| <b>Non-MPA</b>                   | 93.588 | -3.327**  | Overfishing level in MPA < Non MPA                   |

The mean difference of fishing level index was tested to confirm the hypothesis that MPA having lower fishing index compared to Fisheries Management Area and non-MPA. The result showed that fishing level index in MPA is significantly lower than Fisheries Management Area at 1% and 5% in non-MPA (Table 4). It is concluded that overfishing level in MPA was much lower if compared to non-MPA.

### 3.3. Determinants of overfishing

This study used four determinants to analyze factors influencing overfishing such as MPA establishment (dummy:1 if MPA is already established; otherwise 0), proportion of sustainable fishing effort using catch tool, receiving COREMAP budget, and effort (the standardization of effort was done based on Sparre & Venema [45]). Of four factors, the study found that proportion of sustainable fishing effort ( $p < 0.01$ ) was the most significant factors in determining the fishing level index (Table 5). This means that widely use of sustainable fishing effort will be able to reduce fishing level index and otherwise.

**Table 5.** Regression result of determinant for overfishing.

| <b>Independent Variable</b>                  |                        |
|--|------------------------|
| <i>d</i> MPAyear                             | -26.491**<br>(11.041)  |
| Prop_susteffort                              | -1.706***<br>(0.441)   |
| LnCoremap                                    | 0.860**<br>(0.400)     |
| Effort                                       | 0.003**<br>(0.0008)    |
| Constant                                     | 148.543***<br>(21.663) |
| N  | 264                    |
| Prob > F                                     | 0.0000                 |
| R <sup>2</sup>                               | 0.0567                 |
| Standard Error in parentheses                |                        |
| *** $p < 0.01$ ; ** $p < 0.05$ ; * $p < 0.1$ |                        |

MPA establishment also had a negative effect on fishing level index ( $p < 0.05$ ). The establishment of MPA is seen able to reduce fishing level index in the study area. For effort, the result was as expected. Increasing fishing effort will increase the level of overfishing because at a certain point it will decrease the stock.

COREMAP funds should be able to suppress the level of overfishing; instead, this study showed a contrasting result as it increases the level of overfishing. However, the result should be carefully interpreted as different MPAs received COREMAP funds in different years. For instance Takabonerate received the funds since COREMAP phase I (1999-2003), while others just received the fund between 2015 and 2016. It is assumed the effect of fund was not uniform across the MPAs and not properly targeted.

### 3.4. Overfishing, total allowable catch and fishing effort

Overfishing undeniably causing problems for the ecosystem and resulted into longer period for stock recovery, even after setting the area to be conservation areas [33]. Overfishing activity is characterized by high level of exploitation and lower levels of stock [21]. However overfishing may occur not because of high rate of capture but due to failure in reproduction, thereby reducing the stock or even succumb to its predators (*Depensation phenomenon*) [28]. Therefore, to maintain aquatic resources, it is important to regulate the rate of captures.

There is a standard, although differ across region, to categorize overfishing problem by referring to Total Allowable Catch (TAC). TAC is the number of marine biological natural resources that can be

captured by considering technical, biological, economic and social aspects, with the aim to achieve sustainable fisheries [49]. In Indonesia, the level of TAC is between 80% to 90% MSY. Overfishing conditions occurs when the exploitation level is over the standard of 83.99% [21]. TAC itself can be used as a policy to control fishing level by quota. Quota through TAC can be implemented by dividing the catch shares to fishery households or firms [23]. Besides imposing quota through TAC, there are several ways to control fishing activities, such as by limiting the number of fishing permits and effort [11]. However, policy makers should consider to implement both quota and effort limitation policy [23]. If there is no control over the number of vessels operating, but only control over the number of catches, it still cause overexploitation and overfishing [3]. Therefore, it is necessary to restrict the operated vessels which until now have not been done in the territorial waters in Indonesia.

In addition to quota and TAC policies, Indonesia also controls its fishing activities by establishing Fisheries Management Area, a territorial fisheries management legalized through the Ministerial Decree number PER.01/MEN/2009 and updated with Candidate KP No. 18/ PERMEN-KP/2014 which divides all Indonesian waters territorial to 11 region. This policy is enacted to regulate fishing activities and to improve the fisheries sector through conservation, research and development. All area in Indonesia's ocean is regulated through this decree, including deep waters, archipelagic waters, territorial waters, additional zones and the Exclusive Economic Zone (ZEE). Fisheries Management Area is one of tools to achieve optimal and sustainable utilization of fisheries sector as well as marine ecosystem.

Furthermore, Marine Protected Area (MPA) is also established to control fishing activities comprehensively by combining several policies.

### *3.5. Establishment of MPA as a tool for sustainable fisheries*

In response to the coastal and marine resources degradation, Government of Indonesia collaborates with other institutions to safeguard its coral reef and associate ecosystems through establishing MPA, as it is believed as the best tool to manage fisheries resources in sustainable way [47]. Essentially, MPA is aimed to protect and regulate habitat, fish stock and hence marine biodiversity [5]; [26], and also to provide more benefit through education, tourism and research. MPA also serves as a habitat for certain endemic species and other species classified as endangered species [22].

Based on the new policies, approach in the planning and management of MPA in Indonesia is shifted from centralized to the decentralised in line with local autonomy [47]. Local government in the provincial, district and village levels has been encouraged to develop and manage their own MPAs. Focus of conservation program now is not only to protect marine biodiversity rather multipurpose MPA while empowering local community [47].

MPA establishment found to have positive impact on fish stock management and better fishing conditions in both Maximum Economic Yield regimes and open-access fisheries [6]. The density of species in the conservation area increased and spill over to the area surrounding the MPA. MPA thus, seen as a main tool for sustainable fisheries and a way to tackle overexploitation [20].

However, the decision to establish and increase the size of MPA needs to be implemented cautiously; it may affects its management and caused overfishing [12]. Establishing MPA in some area can lead to changes in the behavior and management of capture fisheries industry [41]. In worst case, there will be a migration of destructive activities from one area to another if it is not accompanied by strong monitoring activities in other area. In extending the size of MPA, government needs to consider the communities and fishermen population surrounding the area [35]. This is mainly due to limited fishing activities in MPA, thus, food security as well as income of surrounding population will be affected. To operate the MPA, a management authority is absolutely required to arrange fishing strategies while providing incentives for fishermen to improve fisheries management [8]. In fact, the authority needs to enforce rules which are based on optimization model [19], which most MPAs are about fishery management not conservation [14]. However, if MPAs are managed unsuitably, their creation may have little effect on the recovery of depleted stocks or may even make the existing condition worse [48]. On the other hand, [37] suggested that smaller MPA would be more effective at protecting one or more species, and able to increase the biomass of fish (of various species) more quickly.

However, factors such as good education programs for the local community, legal enforcement support from local and national officials, and scientific and recreational interests in the MPA contributed

to the success and effectiveness of MPA [25]. Besides, well executed MPA and the local community benefited from the tourism making them less reliant on fishing for livelihood. The design of MPA should be based on good scientific and management studies. Some argue that the implementation of MPA policies in developing countries has a high probability of failures because, most of the time, it does not consider socio-political aspects and environmental context appropriately [12]. Moreover, the management of MPA faces many hindrance and problem. For instance, most of society does not have sufficient information of MPA. Even, some of them do not acknowledge the existence of MPA. To some extent, fishermen living far away from the area may still exploit the area as they do not realize the existence of MPA.

### 3.6. Coral reef rehabilitation and management program (COREMAP)

To protect, rehabilitate and manage the sustainable use of coral reefs, since 1998, the World Bank and Asian Development Bank (ADB) has provided financial support for the project initiated by the Indonesian government called COREMAP (Coral Reef Rehabilitation and Management Program). COREMAP covered selected ecological hotspots within the declared MPAs which include 336,651 hectares of coral reef, 7,383 hectares of seagrass and 9,493 hectares of mangroves [52]. COREMAP phase I as initiation step started in 1999-2003, COREMAP phase II as acceleration step is designed to establish a management system for coral reef resources in priority areas started since 2004 and ended by 2011 [47]. The COREMAP II is implemented through Ministry of Marine Affairs and Fisheries and funded by the Asian Development Bank for the western part of Indonesia and by the World Bank for eastern part of Indonesia. The program covers eight provinces and 15 districts [47].

Of the three components under COREMAP, community-based and co-management component provides significant input to the success of the program. It focused on community empowerment, community-based coral reef management, local MPA management, supports the Marine National Park development, alternative livelihoods development, and local infrastructures [47]. In fact, the COREMAP's contributions in the establishment of MPAs are significant for MPAs' national objectives. COREMAP explicitly aims to facilitate an active community role in MPA management [18]. Community facilitator and village motivator worked together with community in developing village-based MPA (well-known as marine sanctuary) and formalized through village regulation [47].

However, among the challenges faced by COREMAP were lack of understanding of marine conservation issues by the local government and community leaders, and difficulties in reaching agreements among communities due to different perception levels of conservation concepts and issues [47]. Even if community-managed reserves would achieve 10% coverage of COREMAP [33], they would generally be too small to protect mid- and large-size commercial fishes such as groupers and snappers from over-exploitation. It was found that COREMAP funds to support local capacitation and livelihood mainly provided benefits to an influential minority while resource access and decision-making influence were outside the reach of the majority of villagers [18]. For instance, the Village Grant was not used according to the priorities voiced by the majority of residents. Much of it was privately appropriated rather than employed for more generally recognized community welfare [18]. Another study [18] discussed on the management of *Spermonde Archipelago* and found that the participation of locals in decision making is very low and they are restricted in accessing the resources. Locals were consulted during the establishment of no-take areas but then it only involves a few locals [25]. The COREMAP programs support a lot of other activities including providing loans for start-up business for alternative livelihood, grants to build infrastructure and facilities, conservation/mitigation measures, or capacity building. However, many of these facilities were found to be misused. In addition, there are issues of time and resource constraints to participatory implementation, and the law and rules are not widely known or enforced on regular basis [25].

## 4. Conclusion

This study examined the impact of MPA establishment on the fish extraction in Indonesia. The study found that overfishing level in MPA was generally lower compared to non-MPA and Fisheries Management Area, though two sites (MPA Takabonerate and Aru) experienced overfishing problem. In

addition, from regression analysis both MPA and sustainable fishing gear evidence to be successful in controlling overfishing in Indonesia.

That establishment of MPA reduces overexploitation and mitigates the deterioration of the aquatic environment [46]. The equilibrium population size of a depleted stock tends to recover and able to enhance ecological resilience with the introduction of MPA [48]. However, the positive impact of MPA depends heavily on the migration characteristics of the target species, fishing policies and fishing goals [48].

MPA management should take into account socio-economic and environmental aspects. If those aspects are not satisfied in the management process, there will be a possibility of failure in MPA establishment. In addition, it is necessary to review the proportion of sustainable fishing gear to support the continuity of sustainable fishing. Though an area designed to be an MPA that promotes the use of sustainable fishing gear, yet, it is highly dependent on the supervision and monitoring effectiveness in the MPA. However, keeping per area fishing efforts constant after introducing MPAs may be difficult because, in most of cases, many fishers are economically or socially dependent on that species [48]. This difficulty might be overcome by, for instance, a fisheries management with feedback control, which redirects fishing effort towards more abundant species in response to changes in populations, rather than reducing the total fishing effort [48]; [30].

This study suggests that MPA manage to control overfishing in Indonesia. Given the success of MPA to suppress fishing level index, it gives a positive signal for the government to expand the area. In fact, the MPA strategy is currently considered to be the best approach by many governments, and Southeast Asia countries are seen to be keen to adopt the strategy [25]. However, achieving sustainable fisheries management is not only about hectares, efficient zoning plans, and political will. It is also about local availability of human resources for management [33]. In this respect, it involves professionals, government officials, villagers and pool of expertise from diverse background to effectively manage MPAs. It should be noted that MPA is considered to be a country specific as MPA in one country may have different functions and objectives as well as implementation and management depending on its own considerations.

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