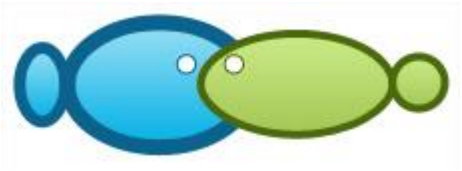

Do marine protected areas have lower overfishing level?

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Abstract. In Indonesia, overexploitation of marine resource, specifically on fisheries sector, is accompanied with destructive fishing behavior and Illegal, Unregulated and Unreported (IUU) fishing activities. These problems cause Indonesia to suffer loss amounting to around $20 million per year. Indonesia is committed to implement sustainable marine resource and fisheries management by establishing Marine Protected Areas (MPA) reaching to 30 hectares by the end of 2030. Yet, there is no recent empirical study concerning the impact of MPA establishment in Indonesia to the overfishing condition. This research is aimed to answer the question. We employ 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. Using mean difference t-test, we found that, overfishing index in MPA is lower compared to overfishing in level of regency and WPP. Panel data regression result also support our previous finding as MPA establishment has negative and significant impact to overfishing index. Other factors affecting overfishing level are the amount of total and sustainable effort. Our findings indicate that Indonesia is managing its MPA in the right way. Therefore, it is reasonable for government to expand MPA area in Indonesia in realizing the commitment of establishing 30 ha of MPA.

Key Words: overexploitation, IUU fishing, MSY, overfishing index, sustainable.

Introduction. Open-access fisheries management is a management that is often encountered in the world, including Indonesia. This type of management provides an opportunity to both household and firms to exploit the natural resources. Unfortunately, open-access fisheries management is terribly susceptible to overexploitation. Under this management, resources are not owned by anyone; therefore, no one can exclude other from consuming therefore. Consequently, utilization of the resources is often disorganized (Rosenberg et al 1993; Adrianto 2006). Overfishing and optimal capture is closely related. Li (2000) reported that overfishing causes stock collapse, marked by a decline in economic viability (other than profit capture). The fish stock becomes less and rarely encountered and the cost of capture becomes very high, preventing optimal capture in the future. Overfishing activities undeniably causes problems for the ecosystem. Reduced fish stock in the ecosystem needs a long period for the stock recovery, even after setting the area to be conservation area (Nao & Akihiko 2013).

Efforts of the world's countries toward protection, conservation and responsible utilization of the natural resources are marked by commitment shown in the Convention of Biological Diversity (CBD). The meeting, resulted an agreement which require signatory countries to have protected (conservatory) water area at least 10% of its total water territory in order to reduce the loss of marine biodiversity and to realize its sustainable use (UNEP 2004). Indonesia is committed to implement sustainable

management of marine and fishery resources through the establishment of MPA (MMA 2008).

MPA is considered to be country specific as MPA in one country may had different functions and objectives as well as implementation and management depending to its own considerations. Practically, MPA is established to protect some area from extractive and exhaustive activities, although some MPA areas still have zones to be utilized with limited quota. Essentially, MPA is aimed to protect and regulate a habitat and, hence, marine biodiversity (Kelleher & Kenchington 1991; Allison et al 1998); MPA is also established to regulate capture fisheries and fish stocks. With the MPA, the density of species in the conservation area will increase and it may spill over to the area surrounding the MPA. Given this, MPA can still be utilized by households or firms indirectly through its spillover effect. In the end, they are still able to manage their welfare or even improve it along with the effectiveness of MPA management (Sumaila et al 2000; Hanneson 2000; Sanchirico 2000). Besides recovery and spawning area, MPA also serves as a habitat for certain endemic species and for others classified as endangered species (Hilborn et al 2004).

However, the establishment of MPA needs to be implemented cautiously. Sanchirico (2000) argued that establishing MPA in some area can lead to changes in the behavior and management of capture fisheries industry. 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 Indonesia, MPA is an area within Fishery Management Area (Wilayah Pengelolaan Perikanan) which is protected, managed by the zonation system, for sustainable management of fisheries and environment. It comprises core zones, utilization zones, traditional sustainable fisheries zones, general sustainable fishing zones and other zones. Core zones and utilization zones are not allowed for fishing, whereas traditional fishing zones and sustainable fisheries allow catching activities which employ environmentally friendly fishing gear (KKP 2010). In MPA, the use of unsustainable and non-environmentally fishing gear is restricted which refer to Regulation of the Minister of Marine Affairs and Fisheries No. 2 of 2015 (MMA 2015).

Increasing the size of MPA affects its management. Pollnac & Seara (2011) stated that, in extending the size of MPA, government needs to consider the communities and fishermen population surrounding the area. This is mainly because fishing activities in MPA will be limited, thus, food security as well as income of surrounding population will be affected. Roberts & Hawkins (1997) suggested that smaller MPA would be more effective in protecting one or more species; while, in contrast, Bohnsack & Ault (1996) argued that small MPAs can increase the biomass of fish (of various species) more quickly.

Research concerning overfishing in the MPA in general is rarely implemented. Current, studies tend to discuss about catch optimization depending to catch stock, cost of catching and the revenue obtained and focus on particular species. In this research, we try to review the effectivity of MPA management in Indonesia by analyzing the overfishing level in the area. With limited data, we try to compare the overfishing level using two methods; mean difference hypothesis testing and panel data regression. Mean difference is employed between regency with MPA and without MPA and MPA with WPP. Panel data regression is employed to find the effect of MPA establishment in the level of overfishing in regency level area. This research is important for government of Indonesia as the result may be an input for policy makers in expanding future MPAs. Insignificant difference between regency with MPA and without MPA may indicate Indonesia is managing its MPA in wrong way. In this case, instead expanding the area, government should focus to improve the management.

Material and Method. Base area of analysis of the present research at the district level consisted with details of 22 MPA districts and 11 non-MPA districts. Data's from 11 areas of Fishery Management Area were used.

Our research is based on production surplus method introduced by Schaefer (1970) and Fox (1970). The models explain relationship of yield (Y) and effort, which

describes how much yield was obtained given to the level of effort. Basically, with this function, we can obtain the level of the Maximum Sustainable Yield (MSY) in each location. MSY denotes the maximum of fishing yield which can be routinely exploited without depleting the resources in the future. To obtain the maximum yield, we need to derive the model to obtain the level of effort which result on MSY, called as Maximum Sustainable Effort (MSE). Coefficient of a, b and c in the function is estimated using least square regression of Catch Per Unit Effort (CPUE) and effort.

Hilborn & Stokes (2010) argue that the optimum level of yield which result on sustainable fisheries should be not greater than 80% of MSY, otherwise the location is regarded to be overexploited. In line with this argument, Triyono (2013) also proposed that the optimum catch, or usually called as Total Allowable Catch (TAC), should be 80% of MSY. Using these two definitions, an area is categorized to be overfished if the total production is above 80% MSY, otherwise is not. We use fishing level index in the model. The index is obtained by dividing the level of production or yield to its MSY. Area having index above 80% of MSY, or TAC, means overfished.

We employ two methodologies in analyzing whether MPA has lower fishing level index than non-MPA or not. First, we apply mean difference testing between those two types of area. We use two different level of data, regency level and Fisheries Management Area (Wilayah Pengelolaan Perikanan/WPP). The mean difference is applied in comparing the fishing level index between regency with MPA with regency without MPA and regency with MPA with WPP. A significantly lower mean of fishing level index in regency with MPA indicates that Indonesia is managing its MPA appropriately. Secondly, we execute panel data regression to analyze what factor determining the fishing level index. We use pooled least square (PLS) in regency level data. We use two models as follow.

1. TkOF = *f* (dMPAyear, Fisherman, Prop.susteffort, Lncoremap, $Effort_{kpl}$)
2. TkOF = *f* (dMPAyear, Fisherman, Prop.susteffort, Lncoremap, $Effort_{kpl}$, dPB1, dPB2, dPB3, dPB4)

WhereTkOF is overfishing level; *d*MPAyear is MPA establishment (dummy: 1 if MPA is already established; otherwise 0); Fisherman is number of fisherman; Prop.susteffort is proportion of sustainable effort to total effort measured by catching tools; LnCoremap is coremap budget received by regency; Effort is effort measured by number of ships used; dPB1-4 is great island located MPA and non-MPA districts (1: Bali and Southeast Nusa; 2: Sulawesi; 3: Maluku; 4: Sulawesi; Base: Java).

We can conclude that Indonesia might be having proper management of MPA if the dMPAyear has significant and negative relationship with fishing level index.

However, we need to be cautious in estimating the CPUE. 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 example, would yield inconsistency data of effort, thus CPUE. To resolve this problem, catching effort needs to be standardized to obtain the reasonable amount of CPUE.

Result and Discussion. The results of the mean difference test between MPA and WPP regions and between MPA and non-MPA can be selected in the Table 1 as follows.

Table 1

Mean difference test result of MPA - WPP and MPA - non MPA

Location	*Mean*	*t*	*Information*
MPA	56.586	-5.779***	Overfishing level MPA < WPP
WPP	86.999		
MPA	56.586	-3.327**	Overfishing level MPA < Non MPA
Non-MPA	93.588		

Based on Table 1 we found that the mean of fishing level index of regency with MPA is lower compared to WPP and regency without MPA. The table shows that the mean of fishing level index is 56.58, 86.99 and 93.58 respectively. Statistically, there is a significant difference between regency with MPA compared to WPP and regency without MPA. Regency with MPA is significantly lower than WPP at 1%; meanwhile, regency with MPA is significantly lower than regency without MPA at 5%.

The most of regency with MPA has lower fishing level index compared to regency without MPA and MFA. Six regencies have maximum fishing level index under TAC, meaning that the areas are never overfished during the period of time. The distribution of fishing level index along the year is also concentrated around the mean. Yet, we found that regency with MPA still face overfishing problem. Out of nine regencies with MPA, there is only one regency having average index over the TAC, that is Karimun Jawa. But, Aru and Takabonerate has third quartile above the TAC. The three locations also have high variation of level fishing index. Furthermore, the maximum fishing level index in Aru almost reach 200%.

MFA has relatively high fishing level index. Out of 11 MFA in the analysis, there are seven MFA who have mean of fishing level index over the TAC. Four of them are even constantly overfished given the minimum fishing level index is above TAC. Nevertheless, we found that three WPPs; 573, 713 and 714, are not overexploited. Unlike regency level data, the dispersion of fishing level index in WPP is less sparse, indicating that the variation of fishing level index is relatively low.

Compared to regency with MPA and WPP, the condition of fishing level index in regency without MPA varies greatly. Based on the same graph, we found that the whisker of box plot is much longer compared to the others. Maximum fishing level index of TTU is even above 160%; while, Tulang Bawang's is the highest among all location in the analysis with approximately 200%. Out of 11 locations, there are 6 six regencies having mean of fishing level index over the TAC which three of them are constantly overfished during the span of time. Besides that, there are only two locations that are not overfished.

Based on the Figure 1, the MPA which has been consistently overfished in the last three years is the MPA Takabonerate in Selayar regency and MPA in Aru regency. Overfishing rate in Selayar regency is 70.91%, and 66.25% respectively from 2012 to 2014. Meanwhile, MPA in Aru Regency has the highest rate of overfishing in 2012 of 110.85% but decreased in 2013 and 2014 by about 6-8%. Both MPAs were established by Ministry of Forestry in 2001. MPA Takabonerate is established because of the uniqueness of the MPA, which is the home of atoll coral. In contrast to Takabonerate, MPA in Aru regency was handed over to the Ministry of Marine Affairs and Fisheries in 2009. In 2014, development of MPA Aru was planned using Management Plan set in 2014. Specificaly, MPA Aru was set up for turtle's protection. Figure 1 depicts fishing level index of regencies with MPA between 2012 and 2014. In Aru regency, there was a very high level of overfishing in 2012 which, then, dropped drastically the following year. It can be explained that in that year the proportion of the use of non-sustainable fishing gear is still higher than the use of sustainable fishing gears. In addition, after the handover of MPA from the Ministry of Forestry to the Ministry of Maritime Affairs and Fisheries is still in the early stage, especially the clarity concerning assets and boundaries which in the end hampers the management to run effectively. After 2012, the tasks and functions are already clear and the proportion of sustainable fishing gear increases so that the overfishing rate can be reduced. In addition, Aru Regency has been receiving Coremap budget from 2014.

According to Christie et al (2002), overfishing in MPA areas may occur depending on MPA management. 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 to the above, it is necessary to review the proportion of sustainable fishing gear to support the continuity of sustainable fishing, implementation of Coral Reef Management and Rehabilitation (Coremap) program as well as community empowerment programs around the conservation area.

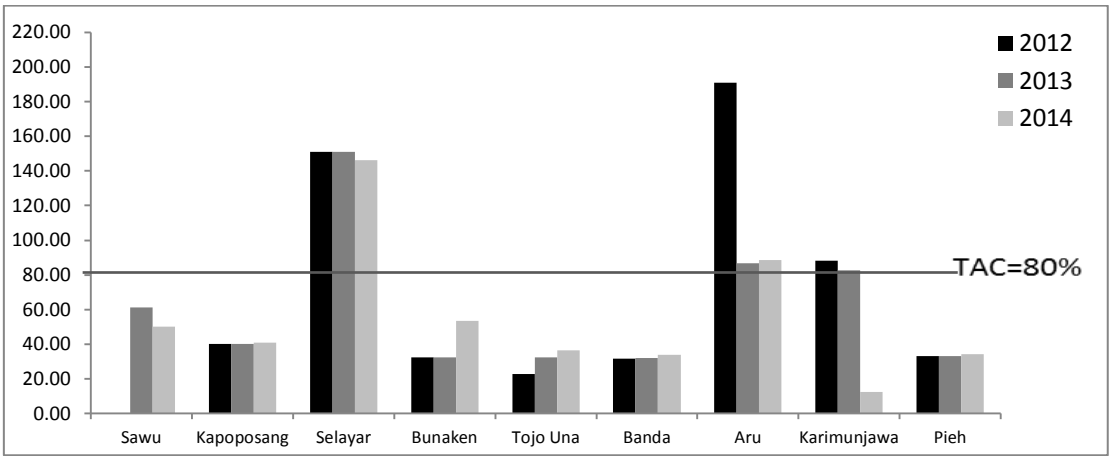

Figure 1. Fishing Level Index of Regencies with MPA in 2012 – 2014.

In Selayar regency, the fishing gear tends to not develop, as, dominantly, fishing gears used are still nets, fishing line, set net and trap, although, these tools are still classified as sustainable fishing gear (Ngadi 2013). However, according to Bandiyono et al (2008) destructive fishing activity is still rampant in Selayar regency, often employing bomb and poison activity done by neighboring regency fishermen such as Bulukumba, Sinjai, Bantaeng and Jeneponto. This resulted in a high level of overfishing. The following comparison of the proportion of sustainable fishing gear use in some regencies with MPA.

The Coremap program in Selayar District has been implemented since 1999 Coremap's activities focus on coral reef rehabilitation where 30% of the 2000 ha of coral reefs have been damaged and improvement of income-generating activities around the conservation area (Bandiyono et al 2008).

Table 2

Regression result of fishing level index determinants

Independent variables	*Model 1*	*Model 2*
d MPAyear	-26.295**	-24.211**
	(11.157)	(8.663)
Fisherman	0.00068	0.00089
	(0.00075)	(0.00059)
Prop_susteffort	-1.663***	-1.653***
	(0.424)	(0.428)
LnCoremap	0.797**	0.811*
	(0.388)	(0.431)
$Effort_{kpl}$	0.002**	0.002**
	(0.0009)	(0.0009)
*d*PB1	-	-21.548
		(21.039)
*d*PB2	-	-25.139*
		(13.809)
*d*PB3	-	-46.769**
		(15.026)
*d*PB4	-	-10.789
		(15.174)
Constant	143.706***	161.11***
	(21.811)	(30.794)

There are two models presented in Table 2 (multiple linear model and non linear model). Based on the table, we can see that MPAyear variables, Lncoremap and effort have significant effect to the fishing level among all the models. MPAyear and effort are

significant at 5%; meanwhile, the proportion of sustainable fishing (prop_susteffort) is significant at level 1%. By interpretation, the determination of MPA will reduce the overfishing rate of each model of 24.21-26.29 points. A 1% increase in effort led to an increase in the overfishing rate of 0.002 point and the increase of coremap funding increased the overfishing rate by 0.79-0.81 points. An increase in the use of environmentally friendly fishing gear at 1% will reduce the overfishing rate by 1.65-1.66 points. Based on Table 2, the overfishing rate of Sulawesi Island and Maluku is lower than of Java Island. The overfishing rate in Sulawesi Island is lower with a value of 25.14 points (10% significance) and in Maluku is also lower with a value of 46.77 points (5% significance). While the the overfishing rate in island of Bali Nusra and Sumatra is not significant.

Establishment of MPA reduces the rate of the fishing index; this is supported by Sumaila et al (2000) which argue that MPA reduces overexploitation and mitigates the deterioration of the aquatic environment. Increasing fishing effort will increase the level of overfishing because at a certain point increasing that effort will decrease the stock. Hence, more increasing of fishing effort causes overfishing. Open-access policies do not limit effort which provide a higher opportunity for overfishing as open-access fisheries indicate almost limitless utilization of exploitation of fishery resources using any number of vessels or fishing gears. If this is continued, it will result in damage to the resources or even economic problems. Adrianto (2007) explains that if there is no control over the number of vessels operating, but only control over the number of catches, it will result in overexploitation and overfishing. Each vessel will compete to fulfill the catch quota which, if it is assumed that every ship tries to reach the target, may cause overfishing. Therefore, it is necessary to restrict the operated vessels which until now have not been done in the territorial waters in Indonesia.

Coremap funds should be able to suppress the level of overfishing, but, instead, we found a contrasting result as it increases the level of overfishing. We assume it to happen as the funds are not properly targeted. Coremap funds focus on coral reef recovery which is the main objective of coremap activities in conducting the program. However, there are other things to be considered by government. For example, government needs to focus to raise awareness of all stakeholders, especially fisheries household and firms, to not do damage during the fishing activities. Migrant fishermen should be monitored carefully, as they sometimes do excessive and even destructive activities in MPA.

MPA and sustainable fishing gear are related. An area designed to be an MPA promotes the use of sustainable fishing gears, which is highly dependent on the supervision and monitoring effectiveness in the MPA. In this research, we found that both MPA and sustainable fishing gears are successful in suppressing overfishing in Indonesia. It is expected that the use of sustainable fishing gears will increase in open-access areas so that fishing activities can be more sustainable.

Conclusions. Although aimed to reduce overfishing, MPA cannot still be separated from overfishing problems besides Unregulated and Unreported (IUU) fishing. It becomes problematic in Indonesia as the target MPA in 2020 and 2030 would be severely useless if overfishing problems still occur in the MPA region. This study examines the extent of overfishing occurring in the MPA. From the analysis, we found that the regency with MPA has generally lower level of overfishing compared to regency without MPA and WPP. Referring to the panel data regression, a regency having MPA would also have lower fishing level index by 24-26 points. In addition, raising 1% of sustainable effort can reduce the overfishing rate by 1.65-1.66 points; meanwhile, the addition of effort (fleet of boats) increases the overfishing rate of 0.002 point. The islands of Sulawesi and Maluku are still experiencing lower levels of overfishing making it possible for the development of sustainable fisheries. Our research concludes that MPA manage to eliminate overfishing or suppress higher levels of overfishing. Given the success of MPA to suppress higher levels of overfishing, it is appropriate for the government to expand the area. Nevertheless, effective management still needs to be considered in expanding the area.

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